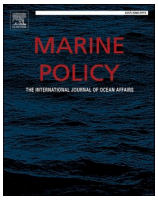
Marine Policy 127 (2021) 104449

Contents lists available at ScienceDirect

Marine Policy

journal homepage: http://www.elsevier.com/locate/marpol



Fish quality and market performance: The case of the coastal fishery for Atlantic cod in Norway

Geir Sogn-Grundvåg [a,*], Dengjun Zhang [a,b], Edgar Henriksen [a], Sjurdur Joensen [a], Bjørn-Inge Bendiksen [a], Øystein Hermansen [a]

[a] Norwegian Institute of Food, Fisheries and Aquaculture Research, Tromsø, Norway
[b] Business School, University of Stavanger, Stavanger, Norway

ARTICLE INFO

Keywords:
Fish quality
Hedonic price
Imperfect competition
Fishing methods
Atlantic cod

ABSTRACT

This study focuses on fish quality and resource utilization at the ex-vessel level of the value chain. Substantial waste in the form of reduced fish quality is revealed for Atlantic cod landed by the coastal fleet in Norway, with approximately 30% of the sampled cod from 399 catches downgraded, implying reduced value of products in onshore processing. By using an objective quality index for individual catches in hedonic price modeling, we obtain new insights regarding the important role markets may play in sustainable utilization of marine resources. The econometric results indicate that the quality index had a rather modest effect on prices and that fishing methods is more important in price formation. These findings are attributed to a poorly performing ex-vessel market where asymmetric information regarding fish quality and the bargaining power of fishers distort the relationship between quality and price, with the result that fishers are not incentivized to deliver fish of good quality.

1. Introduction

In 2013, the Food and Agriculture Organization (FAO) of the United Nations [1] assessed that 89.5% of all marine fish stocks were fully fished (58.1%) or overfished (31.4%), and thus urged states to manage fisheries in a biologically sustainable way. In addition, the FAO [2] encouraged states to utilize fish stocks to contribute to the nutritional, social and economic value of fish, where preserving its quality is paramount. Fish of high quality provide consumers with safe and healthy meals with high nutritional value, as well as enjoyable eating experiences, positively influencing their satisfaction and willingness to pay. This may in turn lead to increased value added and greater profits for the various actors along the value chain. However, fresh fish is highly perishable and spoils more rapidly than almost any other food. Thus, appropriate harvest and post-harvest handling and subsequent preservation are crucial to "locking-in" the quality and nutritional attributes of fish, as well as reducing waste. Importantly, a decline in quality during harvest can never be regained in later stages of the value chain [3], implying that fishers play a crucial role in sustainable use of limited marine resources.

Well-functioning ex-vessel markets play an important role in incentivizing fishers to land fish of high quality because in competitive markets prices should reflect the quality (and quantity) of landed fish. In addition, the most competitive buyers will be the ones that, over time, are the most capable of adding value to the fish they purchase and of gaining the highest returns from their customers and markets. Past research has shown that ex-vessel prices are affected by quality attributes such as fish size [4–8], freshness [5] and overall quality grades [7,8]. It should be noted that in the case of direct sales, quality grades are usually self-reported [7,8] and they may be used deliberately to influence prices [9]. In some markets, quality grades may also be rather coarse grained as is the case for groundfish in Norway where fish quality is graded as just regular or downgraded [7].

Insights into the effect of quality on price have also been provided by a number of studies finding that fishing methods influence ex-vessel prices [5,7,10–12]. For example, Sogn-Grundvåg et al. [12], studying the ex-vessel market for frozen groundfish in Norway, found that cod and haddock caught with longlines gained 15% and 13.3% higher prices than fish caught with bottom trawling, respectively. Because fishing methods have been found to affect fish quality [13,14], it seems reasonable to assume that fishing methods represents useful quality signals to buyers. However, quality differences between vessels within

* Corresponding author.
E-mail address: geir.sogn-grundvag@nofima.no (G. Sogn-Grundvåg).

https://doi.org/10.1016/j.marpol.2021.104449
Received 22 September 2020; Received in revised form 21 December 2020; Accepted 14 February 2021
Available online 22 February 2021

groups of vessels fishing with the same gear may be substantial due to variations in fishing tactics such as soaking time for gillnets and longlines [14–16] and the size of hauls when fishing with Danish seines and trawls [17–20]. Thus, fishing methods may conceal important variations in fish quality and prices gained between vessels fishing with the same gear.

This study contributes to the literature by providing fine-grained insights into the relationships between fishing methods, fish quality and price at the ex-vessel level of the supply chain. More specifically, primary data were collected over a five-year period (2014–2018) by conducting on-site objective quality assessment of 399 catches of Atlantic cod landed by the coastal fleet in Norway using the catch damage index developed by Esaiassen et al. [21]. A second dataset was drawn from a database provided by the Norwegian Directorate of Fisheries containing details about the same catches such as prices, the size of fish, and the weight of the catch. By examining the effect of the objective fish quality in individual catches on prices it was possible to determine to what extent buyers had adopted quality-based pricing in this market. In this way, insights into the functioning of the marketplace and its role in incentivizing fishers to deliver high-quality fish through quality-based pricing is addressed.

2. Methods

2.1. Fish quality

It is well-known that the quality of fish is influenced by the way in which they were caught and handled onboard the fishing vessel. Fishing methods such as trawling, gillnets, traps, Danish seines, trolling, longlines and handlines have all been found to affect fish quality, but to a variable degree [14,19,22]. The quality of landed fish may also vary between vessels fishing with the same gear, depending on variations in fishing tactics such as soaking time for gillnets and longlines [14,15,23], and onboard handling practices such as how fast the fish are bled [19]. Accordingly, econometric studies of factors affecting ex-vessel prices usually find that fishing methods influence prices, most likely reflecting quality differences [5,7,10,11].

The quality of the raw fish influences the share of high-value products that can be made from a catch [21,22,24–26]. Typical high-value products are “shiny” cod, fresh loins and primeira saltfish. However, when a catch contains fish of low quality, the share of high-value products is reduced, diminishing the value of the product mix as a whole. Depending on prices gained, this may have a negative influence on processors’ costs, revenues and profits. Thus, when considerable quantities of fish of low quality are landed, as observed here, there may be negative economic and social consequences for local communities, many of which are strongly dependent on fisheries.

The Norwegian Food Safety Authority enforces technical regulations regarding the catching and handling of fish on board the vessels. Importantly, it is explicitly stated that the fish’s blood should be drained. Further, fish that were dead when being taken onboard should be stored separately. However, compliance with these regulations is low during the peak season [27]. Regarding sustainable fishing, the northeast Atlantic cod has been certified by the Marine Stewardship Council since 2010.

2.2. The coastal groundfish fishery and ex-vessel market

The Norwegian fishery for Atlantic cod is the most valuable fishery in Norway. In 2018, the coastal fleet landed about 193,000 tons of cod at an ex-vessel value of NOK 3.3 billion (EUR 344 million). The fishing fleet involved is diverse, ranging from small and medium-sized to large vessels fishing with handlines, gillnets, longlines and Danish seines, delivering fresh catches to local fish buyers daily. The coastal groundfish fishery was open access until 1989, when it was closed due to the dire state of the Northeast-Atlantic cod stock. Individual vessel quotas were awarded based on previous fishing activity. Since 1990, the system has developed into one characterized by bounded transferability of fishing quotas [28] and many vessels now hold relatively large quota portfolios, often combining different groundfish species such as Atlantic cod, haddock and pollock with pelagic fish such as herring and mackerel. In order to catch all the different species with sometimes overlapping seasons, incentives for intense and swift fishing tactics are created, where fish quality may be compromised by the quantity of fish landed [29].

The ex-vessel sale of wild-caught fish in Norway is organized by sales organizations, owned by fishers. According to the Raw Fish Act, these have the exclusive right to coordinate sales and set minimum prices to secure the fishers a price that reflects the market prices and to avoid powerful buyers using their bargaining power to set prices that are too low for small independent fishers. Under the Raw Fish Act, buyers may downgrade fish based on its quality and reduce the price up to 40% compared with the minimum price.

Fishers are free to choose where to land the fish. However, vessels reach varies in terms of how far they can, within reasonable costs and time, travel to land their daily catches. Smaller local vessels typically land their catches in their home community, where a small number of buyers are usually present. However, during the peak season some smaller vessels chooses a port of call close to the fishing grounds, which may be far away from their home port. Larger coastal vessels have wider reach and may shop around for the best prices but may also be loyal to specific buyers based on informal agreements and relationships. Fish buyers compete for fish by offering competitive prices but also by creating relationships and commitment by minority ownership in vessels, loans, and various other services [30].

The catches are landed directly to fish buyers’ processing plants, where the fish are gutted, weighed and processed into a wide variety of products. Fish processing plants can broadly be categorized based on their main type of end products, that is, the production of fillets (fresh or frozen), fresh whole gutted fish, salted fish and dry-salted fish (clipfish), and stockfish. Most specialize in one type of production, but often combine with packing fresh whole fish. Fish buyers may also buy cod from oceangoing trawlers and longliners, but they mainly freeze their catches as headed and gutted onboard in order to make longer trips (typically around 3–4 weeks) to utilize their fishing and storage capacity to the max [12]. Frozen headed and gutted cod may be used in onshore processing, but mainly for salted products. It should be noted that the frozen cod is a commodity sold in the global market and is generally more expensive than the fresh cod from the coastal fleet [31].

The organization of the ex-vessel market with direct sales has implications for the bargaining power of fishers and fish buyers, potentially affecting prices [9,32,33]. This can be explained by the open systems perspective, which implies that fishers and fish buyers are mutually dependent on each other to stay in business. Fishers depend on someone to purchase their catches so that they can pay for fuel, fishing gear, wages and other input factors. At the same time, fish buyers depend on fish, skilled workers and other input factors for their production. This influences the power balance between fishers and fish buyers, because dependence is inversely proportional to power [34]. For example, a fish buyer highly dependent on fish supplies has, in principle, little power over the fisher.

Important here is the fact that buyers’ investments in production capacity are influenced by changes in yearly quotas and are adapted to manage a high throughput in the peak season (February to April). Figs. 1 and 2 shows how cod landings from the coastal fleet vary across years and months, respectively.

As Fig. 1 demonstrates, yearly cod catches fluctuate substantially with variations in the cod stock. Moreover, Fig. 2 shows how cod landings vary during the year and illustrates that production capacity is adapted to the peak landings early in the year. Investments in production capacity are usually made in periods with rising cod quotas, resulting in overcapacity in periods when quotas are in decline [35].

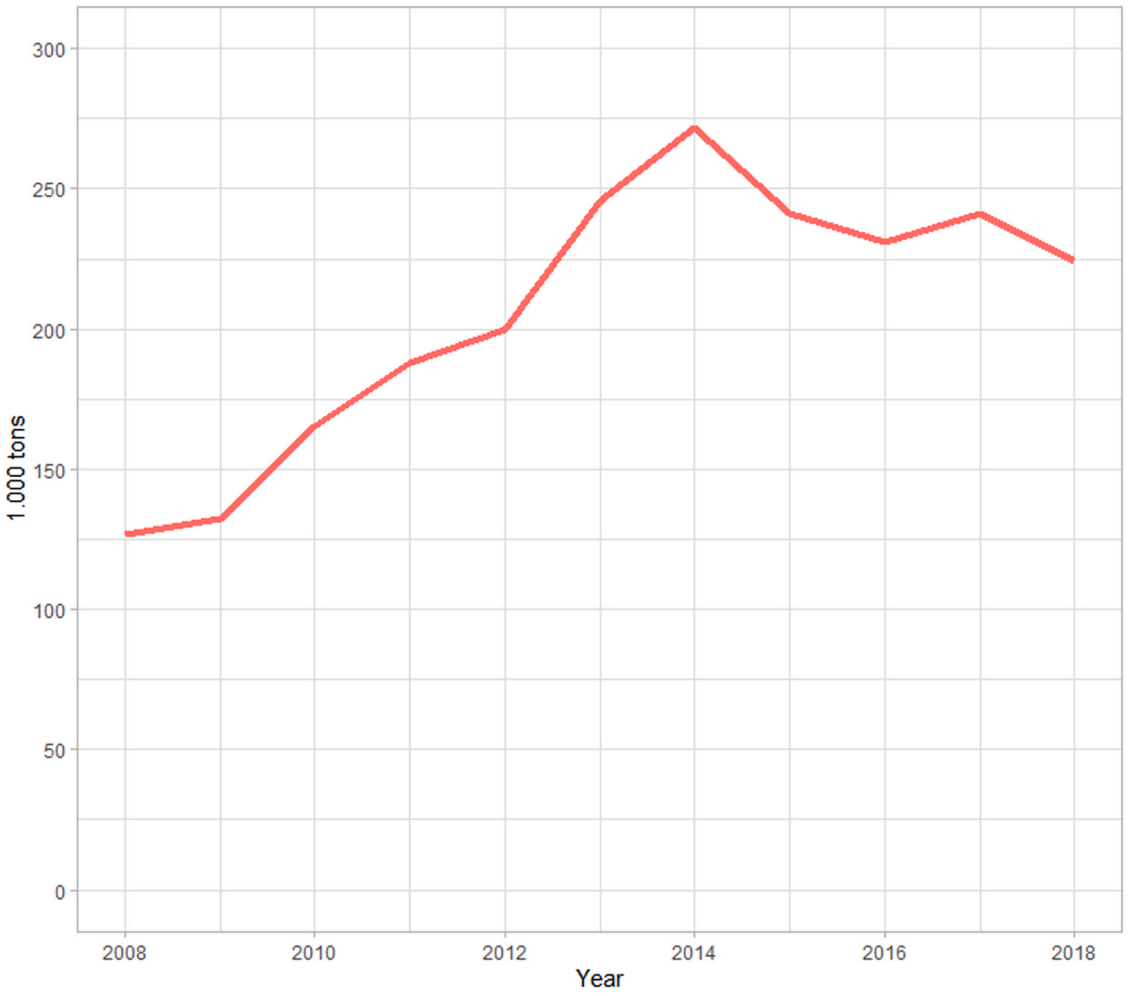


Fig. 1. Cod landings by the coastal fleet for the period 2008–2018.
Source: Elaborated from Directorate of Fisheries (2020).

This tendency to invest in excess capacity is well described by MacDonald and Mazany [36], who studied the Canadian Atlantic fishing industry, where investments in capacity were driven by *anticipated* future profits based on actual profits, caused by increases in landings and high market prices. Nevertheless, as common wisdom states, "nothing grows into heaven," and this includes fish landings and prices.

Thus, most of the time, the onshore processing sector has substantial excess capacity, implying strong dependency on supplies. By contrast, and as noted above, previous overcapacity in the fishing fleet has been substantially reduced through policy interventions. Fish buyers' strong dependency on supplies means that fishers have substantial bargaining power. This can be illustrated by comparing the operating margin of the coastal fleet and the onshore processing sector, presented in Fig. 3. Fig. 3 shows that the average profitability of the coastal fleet was substantially higher than for the processing sector, in particular for the last three years covered by the graph. For six of the 11 years covered, the average profitability for the onshore processing sector was negative.

Interestingly, in 2009, when the effects of the financial crisis hit important seafood markets with falling demand and prices, bargaining power shifted from fishers to fish buyers. As described by Sogn-Grundvåg and Henriksen [9], inspectors from the Norwegian Directorate of Fisheries revealed that fish buyers applied quality downgrading without objective reasons [37], indicating that quality downgrading was used to reduce prices. This is also indicated by the narrow gap in profitability between fishers and processors in 2010 as shown in Fig. 3.

2.3. The quality assessment

The catch-damage-index (CDI) was developed by Esaiassen et al. [21] as a tool for processing plants to determine the quality of catches based on the expected value of their end products. However, to the best of our knowledge, the CDI has not been applied by fish buyers. But the index has been used for research and development purposes such as comparing quality variations caused by variations in fishing tactics; see e.g., [15,17].

Between 2014 and 2018, quality assessment was conducted on 399 catches delivered by 169 different coastal vessels to four different processing plants in Northern Norway. The assessment was conducted in February and March, which are the peak months in the coastal cod fishery in Norway. Two assessors from a research institute visited one processing plant at a time and worked from about 8AM until midnight, or as long as there were vessels coming in to land their catches. When one catch had been assessed, the next one in line was chosen, but catches with less than 50 fish were not assessed. In addition, because the majority of vessels fished with gillnets, vessels fishing with handlines, longlines or Danish seines would be chosen over gillnetters when they arrived at the same time as gillnetters.

The assessment was performed on individual fish picked from the process line after the fish had been gutted. The fish coming through the process line were mixed in terms of quality and size because it is not conventional for fishers to sort fish by size or quality onboard the vessel. Thus, in order to ensure that fish of different sizes and qualities were

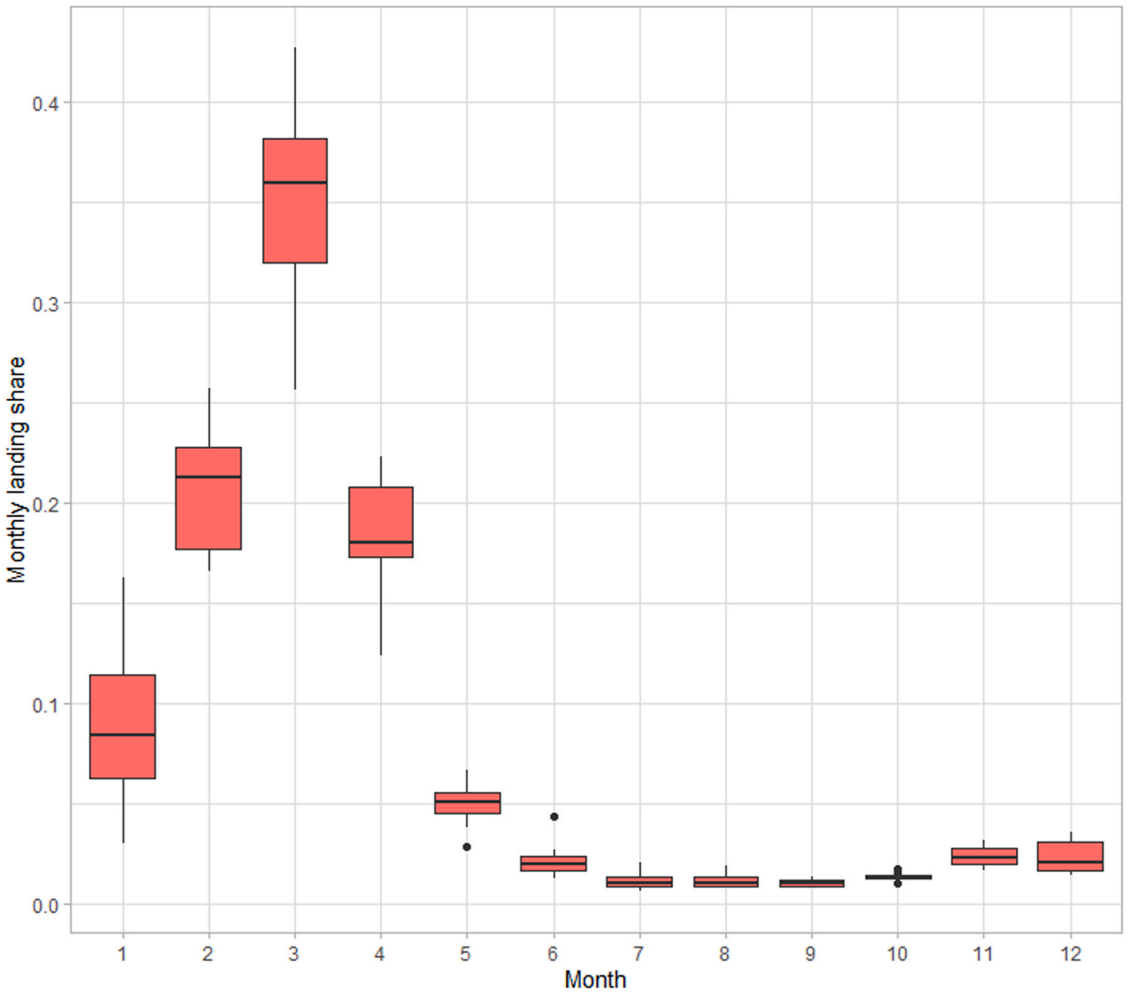


Fig. 2. Average monthly cod landings by the coastal fleet for 2008–2018.
Source: Elaborated from Directorate of Fisheries (2020).

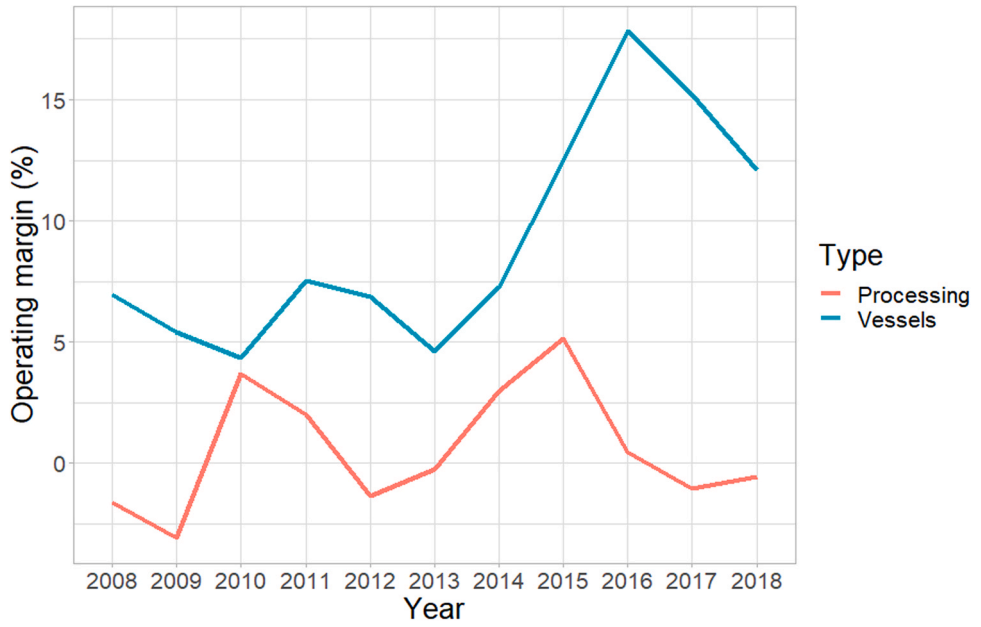


Fig. 3. Average earnings before interests and tax (EBIT)/total revenues for the coastal fleet and the onshore processing sector from 2008 to 2018.
Source: Vessel profitability elaborated from Directorate of Fisheries (2020); processors' profitability elaborated from own data.

randomly picked the following selection rule was followed: when the first fish had been assessed, the second fish was the next fish passing by on the process line, and so on. The quality assessment was a time-consuming exercise, the two assessors needing about 1–2 h to assess 50 cod.

Between 25 and 184 (53 on average) fish were picked from each catch and assessed using the CDI (For other applications of the CDI, see e.g., [13,15,17]). All visible damage to fish was registered in accordance with the predefined categories in the CDI,[1] that is: "dead in gear", "gear-related damage", "bruises", "gaffing damage", "poorly bled", "skin abrasion" and "pressure injuries". The registered damage was scored as "0" (flawless), "1" (moderate) and "2" (serious) for every category except "dead in gear", which was regarded as a form of serious damage (2). If the damage reduced the quality of the final product but did not compromise the value of the end product, a moderate flaw (1) was registered. If the damage was severe and solely responsible for down-grading, a serious flaw (2) was registered. Downgrading affect the value of the output mix in onshore processing negatively in that the share of high-value products such as fresh loins or primeira saltfish is reduced [21].

The average size of catches by fishing methods varied substantially, with catches from Danish seines averaging 6789 kg, almost 20 times more than the average for handlines (351 kg), illustrating considerable differences in catching capacity between vessel groups.

2.4. Model and econometric analysis

To examine the influence of fish quality on the price of fresh Atlantic cod, we followed the hedonic price modeling literature [6,11,38,39]. Hedonic price modeling relies on characteristics theory, which assumes that consumers derive utility directly from the quality attributes inherent in a good [40,41]. Thus, the actual price of a good can be considered as the sum of the implicit prices of those attributes [41]. This indicates that the price of cod depends on its characteristics, such as its quality and fish size [4,5,7,42]. Fish prices may, however, also be influenced by factors such as the size of the catch and the size of a vessel's quota, implying bargaining power as indicated above. Past research has found that the quality of cod is influenced by fishing methods [13,14,43]. Thus, to avoid multicollinearity and over-specification, the quality index and dummies for fishing methods are not included in the same models.

In previous research, hedonic price modeling has used either the linear price or the logarithmic price as the dependent variable. Our test results, based on Vuong's non-nested likelihood ratio test [44], revealed that the model with the logarithmic price as the dependent variable fitted the data better than the model with linear price formulation. Accordingly, the two models, one including the quality index (Model A) and the other including dummies for fishing methods (Model B), are expressed as follows:

$$\begin{aligned}\log(Price_i) =& a_0 + a_1 Quality_i + b_1 \log(Transaction\_Quantity_i) \\ &+ b_2 \log(Yearly\_Catch\_Quantity_i) + c_1 Fish\_Size1_i \\ &+ c_2 Fish\_Size2_i + d_1 Whole_i + d_2 H\&G_i + \sum_{u=1}^{3} f_u Buyer_{u,i} \\ &+ \sum_{o=1}^{4} w_o Year_{o,i} + m_1 March_i + Residual_i\end{aligned} \quad \text{(Model A)}$$

$$\begin{aligned}\log(Price_i) =& a_0 + a_1 Handline_i + a_2 Longline_i + a_3 Danish\_Seine_i \\ &+ b_1 \log(Transaction\_Quantity_i) \\ &+ b_2 \log(Yearly\_Catch\_Quantity_i) + c_1 Fish\_Size1_i \\ &+ c_2 Fish\_Size2_i + d_1 Whole_i + d_2 H\&G_i + \sum_{u=1}^{3} f_u Buyer_{u,i} \\ &+ \sum_{o=1}^{4} w_o Year_{o,i} + m_1 March_i + Residual_i\end{aligned} \quad \text{(Model B)}$$

where *i* indexes transactions and log is the natural logarithmic function; The error term *Residual* captures any other unobserved factors that may affect prices; the dependent variable, *Price, is* the price of cod per kilogram. In Model A, *Quality* is the share of downgraded fish in each catch. In Model B, the three fishing methods, *Handline*, *Longline* and *Danish Seine,* are dummies, with gillnet as the base. The same control variables are incorporated in the two models, that is: *Transaction-Quantity* representing the volume of each transaction in kilograms; *Yearly-Catch-Quantity* for the total yearly catch of cod for each vessel; the product form dummies, *H&G* and *Whole*, for cod landed as headed and gutted and whole fish, respectively, with gutted cod with head on as the base. The *Year* dummies were included in the model to control for any yearly variations in prices with 2014 as the base year. The monthly dummy, *March*, controls for price differences between February and March. We set *Buyer* dummies with *Buyer*-4 (the largest one) as the base.

As the dependent variable is expressed in logarithmic form, the estimated coefficient for *Quality* is interpreted as a_1 percent changes in price as a result of a 0.01-unit (one percentage point) change in *Quality*. The quantity variables are in the logarithmic form and their coefficients are interpreted as elasticities. For example, a 1% change in *Transaction–Quantity* led to a b_1% change in price. For the dummy variables,

Table 1
Descriptive statistics of the variables included in the econometric models.

Variable	Description	Mean	SD
Price	NOK per kilogram	12.55	2.789
Transaction-Quantity	Kilogram	2512	4678
Yearly-Catch-Quantity	Kilogram	247,020	287,013
log (Price)		2.502	0.247
Quality		0.332	0.191
log (Transaction-Quantity)		6.880	1.427
log (Yearly-Catch-Quantity)		11.82	1.162
Fish size 1	2.5–6 kg	0.480	
Fish size 2	More than 6 kg	0.361	
Fish-Size 3 (base)	Less than 2.5 kg	0.159	
Gillnets (base)		0.579	
Handlines		0.093	
Longlines		0.120	
Danish seiners		0.207	
Gutted with head (base)		0.130	
H&G	Gutted without head	0.136	
Whole	Whole fish	0.734	
Buyer 1		0.143	
Buyer 2		0.325	
Buyer 3		0.239	
Buyer 4 (base)		0.293	
2014 (base)		0.120	
2015		0.195	
2016		0.259	
2017		0.307	
2018		0.120	
February (base)		0.579	
March		0.421	

[1] The category of "biting injuries" from the original CDI was not included because such damage hardly occurred in our samples. It should also be noted that the CDI does not include flaws such as soft flesh and fillet gaping, because these are rarely visible until several days after a fish has been landed. Soft flesh and gaping may have a negative effect on the quality of fresh fillets and whole fresh fish targeted for restaurants and fish counters in supermarkets. In addition, the CDI does not include the condition factor of the fish, which may vary depending on the fishing method used. For example, cod caught by gillnets are usually larger and in better condition than cod caught by longlines [14,49,50]. Large and well-conditioned cod are usually preferred for the production of saltfish and clipfish.

the estimated parameters are percentage changes in prices when the dummy variables change from zero to one.

2.5. Descriptive statistics

Table 1 presents the descriptive statistics for the variables included in the econometric models.

Table 1 shows that the average size of catches across all vessels was 2512 kg, and that the average yearly landing by individual vessels was 247,020 kg. Table 1 also shows the variable *Quality*, with an average share of downgraded fish of 33.2%.[2] The reported means of each dummy variable are the number of observations (transactions) within each category as a proportion of the total number of observations for the category. For example, handlines accounted for 9.3% of the total number of catches for all fishing methods during the sample period. The mean of the buyer dummies shows that *Buyer-4*, the largest buyer, accounted for 29.3% of all transactions in the sample.[3]

3. Results

Table 2 presents the econometric results for Models A and B. The adjusted R^2 value is 0.88 for Model A and 0.89 for Model B, indicating that most of the variations in prices are explained by the explanatory variables. For each model, the robust clustered standard errors are applied to correct for heteroskedasticity and serial correlation in the error terms and clustering for different buyers. To assess whether multicollinearity is a problem in the models, the variance inflation factor (VIF) was computed for each variable. The values of the VIF are well below the recommended threshold of 10 [45], indicating that multicollinearity does not affect the validity of the regression models.

Table 2
Econometric results from estimating the hedonic price models.

	Model A			Model B		
Variable	Estimate	SE		Estimate	SE	
Intercept	1.8072	0.0976	***	1.8019	0.0488	***
Quality	−0.1240	0.0531	**			
Handline				0.0688	0.0156	***
Longline				0.0763	0.0132	***
Danish seine				0.0880	0.0201	***
log (Transaction-Quantity)	0.0162	0.0124		0.0100	0.0115	
log (Yearly-Catch-Quantity)	0.0113	0.0121		0.0049	0.0109	
Fish size 1	-0.0041	0.0207		0.0128	0.0192	
Fish size 2	0.0530	0.0280	**	0.0658	0.0276	**
Buyer 1	0.0126	0.0166		0.0442	0.0208	**
Buyer 2	0.0234	0.0235		0.0576	0.0283	**
Buyer 3	0.0167	0.0053	***	0.0251	0.0068	***
Whole	−0.0001	0.0363		-0.0046	0.0231	
H&G	−0.0125	0.025		-0.0067	0.0102	
2015	0.2808	0.0228	***	0.2864	0.0221	***
2016	0.4742	0.0287	***	0.4872	0.0338	***
2017	0.6174	0.0151	***	0.6331	0.0210	***
2018	0.7290	0.0339	***	0.7408	0.0378	***
March	0.0374	0.0199	*	0.0450	0.0219	
Adj.R^2	0.8823			0.8904		

Notes: ***, **, and * indicate significance at the 0.01, 0.05 and 0.10 level, respectively. SE denotes the clustered robust standard error.

Model A in Table 2 shows that the coefficient of *Quality* is significant and negative, indicating that an increase in the quality index, which means a reduction in quality, leads to lower prices, indicating that quality-based pricing is present. However, the effect of quality on price is rather modest. A 0.01-unit (one percentage point) change in the quality index leads to 1.24% change in price. Taking the mean of the quality index (0.332, see Table 1) into account, a 0.01-unit change means a 3.3% increase in the quality index. In other words, if the share of downgraded cod for a catch increases by 3.3%, it leads to a 1.24% reduction in price.

The estimates for the size of catches (*Transaction–Quantity*) and yearly catches by individual vessels (*Yearly–Catch–Quantity*) are not significant, indicating that the buyers were unwilling to pay more to attract vessels with large catches and quotas. The largest fish size (larger than 6 kg) gained a 5.3% price premium compared to fish smaller than 2.5 kg (the base). The estimate for cod in the medium-sized category (2.5–6 kg), was not significantly different from small cod. For the buyer dummies, only the estimate for *Buyer–3*, the second largest buyer, is significant and positive, indicating that buyer 3 paid higher prices than the largest buyer, *Buyer–4* (the base), holding other factors constant. Model A also indicates that whole fish and cod gutted without head did not gain higher prices than other product forms. The year dummies were all significant and positive, reflecting that price has increased over time. The dummy for March is significant and positive compared to the base (February).

Model B in Table 2 show that the estimates for the dummies for fishing methods were all significant and positive. Compared to cod caught by gillnet, the buyers paid 6.88% more for cod caught by handline, 7.63% more for cod caught by longline, and 8.8% more for cod caught by Danish seine.

For the other variables, Model B provides similar estimation results as in Model A, with the exception of buyer dummies. In Model B, all the three buyer dummies are significant and positive. Compared to the largest buyer (the base), the three smaller buyers are willing to pay between 2.5% and 5.7% more for cod, holding other variables such as fish size and fishing methods constant.

Overall, Model B fits the data better than Model A. The R^2 is slightly higher for Model B, and fishing methods in Model B seems to better capture the influence of fish quality on prices than does the quality index in Model A. In addition, all the estimates for the buyer dummies are significant in Model B, whereas only one of the buyer dummies is significant in Model A.

4. Discussion

The results of the quality assessments indicated that a high share (30%) of the Atlantic cod in the assessed catches was downgraded, representing a substantial waste of quality compromising the value of the final products in onshore processing. Despite of this, the econometric results showed that the quality index had a rather modest effect on prices. The results indicate that fishing method, an important indicator of fish quality, is more important for price formation. This is interesting because fishing method is a general characteristic of groups of catches and because the quality of fish may vary substantially between catches landed with the same fishing method. At the same time, the results also show that fish caught by Danish seines gained better prices than catches from vessels fishing with handlines, and almost the same price as fish caught by longline despite the substantially better quality of fish using the latter two methods. Why do not buyers penalize fishers by lowering prices for individual catches with low-quality fish and vice versa?

First, the rather modest influence of the quality index on prices may be related to buyers' lack of information of the quality of fish in individual catches. Typically, the quality of cod is not assessed by buyers

[2] This percentage differs slightly from the 30% downgraded fish reported from the quality assessment. This is due to the discrepant number of lines in the landing notes for different catches (each line represents one size category, which may differ between catches).

[3] In order to prevent the four buyers from becoming identifiable, we refrain from providing further details about them.

during unloading.[4] This may be explained by the fact that this process is time-consuming making it costly to conduct reliable and trustworthy quality assessments of individual catches following the CDI protocol. It also requires trained assessors, who should be independent to ensure that assessments are trustworthy, which is also costly. It should also be noted that during the peak season, the logistics of unloading vessels is put under considerable pressure. Assessing all catches would add to this pressure and delay onshore gutting and processing. Simpler quality checks with a small number of fish or focusing on just a few important criteria such as whether the fish were properly bled take less time, but are less reliable, and thus with substantial potential for disagreements between fishers and buyers. Thus, with insufficient information about the quality of individual catches, buyers seem to use fishing methods as a proxy for quality in their pricing, at least for catches from vessels fishing with gillnets, handlines and longlines.

Second, the ex-vessel market for fresh cod is organized with direct sales, implying that prices are a result of negotiations and bargaining between buyers and sellers. Here, buyers' strong dependency on fishers for supplies implies that fishers enjoy a strong bargaining position. In fear of losing supplies, buyers may be reluctant to reduce prices for poor-quality fish in individual catches. That fish buyers are hesitant to penalize fishers by lowering prices for low-quality fish has been observed in other fisheries [36,46]. As long as buyers pay similar prices for fish of high and low quality, there are no economic incentives for fishers to increase the quality of their catches. In fact, for fishers, economic incentives work in the opposite direction, that is, to reduce fishing costs by for example longer soaking time for gillnets, and larger hauls for Danish seine, lowering the quality of the landed fish, but increasing catch size and thus profits.

This situation may be described as a "social dilemma," that is, one where seemingly rational individual behaviors lead to circumstances where everyone is worse off than they otherwise would have been [47]. When a fisher uses his or her bargaining power to gain high prices for poor-quality fish, there are lower opportunity costs related to reduced quality and revenues associated with swift and intense fishing tactics. Thus, incentives to reduce costs may prevail, which is rational because it enhances profitability. It is also rational for fish buyers to compete fiercely to secure supplies, and in such a way compensate for low margins with a higher quantity. The results of these individually rational behaviors are that Norwegian processors suffer from a poor reputation, lower prices and lost customers in high-end markets. This in turn jeopardize the economic performance of onshore processors, undermining their ability to pay good prices for good-quality cod and also affecting fishers' future economic performance negatively.

Given that fishers can influence the quality of their catches through changes in fishing tactics such as soaking time and haul size [14–16], price incentives may lead to improved fish quality. Auction markets with many sellers and buyers imply efficient markets and have the advantage that bargaining power carry no weight [48]. In addition, display auctions where fish are weighed, graded by size and quality by a neutral auction house should minimize information asymmetry. However, display auctions may also have unwanted consequences as they may lead to centralization of fish sales, which may disfavor small and less mobile fishing vessels and fish buyers located far from the nearest auction.

CRediT authorship contribution statement

Geir Sogn-Grundvåg: Conceptualization, Writing - original draft preparation, Writing - review & Editing. **Dengjun Zhang:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Edgar Henriksen:** Conceptualization, Writing - review & editing, Project administration, Funding acquisition. **Sjurdur Joensen:** Conceptualization, Investigation, Writing - review & editing. **Bjørn-Inge Bendiksen:** Conceptualization, Investigation, Writing - review & editing. **Øystein Hermansen:** Writing - review & editing.

[4] Personal communication, Jonette Braathen, Quality Controller at the Norwegian Fishermen's Sales Organization, April 2020.

Acknowledgment

The authors acknowledge funding provided by FHF – Norwegian Seafood Research Fund, grant no. 901585.

References

[1] Food and Agriculture Organization of the United Nations. The State of World Fisheries and Aquaculture 2016. Contributing to Food Security and Nutrition for All, FAO, Rome, 2016. ⟨http://www.fao.org/3/a-i5555e.pdf⟩.
[2] The State of World Fisheries and Aquaculture 2018. Meeting the Sustainable Development Goals, FAO, Rome, 2018. ⟨http://www.fao.org/3/I9540EN/i9540en.pdf⟩.
[3] J. Østli, M. Esaiassen, L. Garitta, B. Nøstvold, G. Hough, How fresh is fresh? Perceptions and experience when buying and consuming fresh cod fillets, Food Qual. Prefer. 47 (2013) 26–34, https://doi.org/10.1016/j.foodqual.2012.05.008.
[4] E. Sjoberg, Pricing on the fish market-does size matter? Mar. Resour. Econ. 30 (2015) 277–296, https://doi.org/10.1086/680445.
[5] M.Y. Lee, Hedonic pricing of Atlantic cod: effects of size, freshness, and gear, Mar. Resour. Econ. 29 (2014) 259–277, https://doi.org/10.1086/677769.
[6] D. Kristofersson, K. Rickertsen, Efficient estimation of hedonic inverse input demand systems, Am. J. Agric. Econ. 86 (2004) 1127–1137, https://doi.org/10.1111/j.0002-9092.2004.00658.x.
[7] F. Asche, Y. Chen, M.D. Smith, Economic incentives to target species and fish size: prices and fine-scale product attributes in Norwegian fisheries, ICES J. Mar. Sci. 72 (2015) 733–740, https://doi.org/10.1093/icesjms/fsu208.
[8] C. Hammarlund, The big, the bad, and the average: hedonic prices and inverse demand for Baltic cod, Mar. Resour. Econ. 30 (2015) 157–177, https://doi.org/10.1086/679972.
[9] G. Sogn-Grundvåg, E. Henriksen, The influence of human rationality and behaviour on fish quality, Ocean Coast. Manag. 87 (2014) 68–74, https://doi.org/10.1016/j.ocecoaman.2013.10.016.
[10] J. Martínez-Garmendia, J.L. Anderson, M.T. Carroll, Effect of harvesting alternatives on the quality of U.S. North Atlantic Bluefin Tuna, North Am. J. Fish. Manag. 20 (2000) 908–922, https://doi.org/10.1577/1548-8675(2000)020<0908:eohaot>2.0.co;2.
[11] K.E. McConnell, I.E. Strand, Hedonic prices for fish: tuna prices in Hawaii, Am. J. Agric. Econ. 82 (2000) 133–144, https://doi.org/10.1111/0002-9092.00011.
[12] G. Sogn-Grundvåg, D. Zhang, B. Dreyer, Fishing methods for Atlantic cod and haddock: quality and price versus costs, Fish. Res. 230 (2020), 105672, https://doi.org/10.1016/j.fishres.2020.105672.
[13] B.T. Rotabakk, D. Skipnes, L. Akse, S. Birkeland, Quality assessment of Atlantic cod (Gadus morhua) caught by longlining and trawling at the same time and location, Fish. Res. 112 (2011) 44–51, https://doi.org/10.1016/j.fishres.2011.08.009.
[14] M. Esaiassen, H. Nilsen, S. Joensen, T. Skjerdal, M. Carlehög, G. Eilertsen, B. Gundersen, E. Elvevoll, Effects of catching methods on quality changes during storage of cod (Gadus morhua), LWT – Food Sci. Technol. 37 (2004) 643–648, https://doi.org/10.1016/j.lwt.2004.02.002.
[15] E. Savina, J.D. Karlsen, R.P. Frandsen, L.A. Krag, K. Kristensen, N. Madsen, Testing the effect of soak time on catch damage in a coastal gillnetter and the consequences on processed fish quality, Food Control 70 (2016) 310–317, https://doi.org/10.1016/j.foodcont.2016.05.044.
[16] S. Løkkeborg, T. Pina, Effects of setting time, setting direction and soak time on longline catch rates, Fish. Res. 32 (1997) 213–222, https://doi.org/10.1016/S0165-7836(97)00070-2.
[17] J. Brinkhof, S.H. Olsen, O.A. Ingolfsson, B. Herrmann, R.B. Larsen, Sequential codend improves quality of trawlcaught cod, PLoS One 13 (2018), e0204328, https://doi.org/10.1371/journal.pone.0204328.
[18] S.H. Olsen, T. Tobiassen, L. Akse, T.H. Evensen, K.T. Midling, Capture induced stress and live storage of Atlantic cod (Gadus morhua) caught by trawl: Consequences for the flesh quality, Fish. Res. 147 (2013) 446–453, https://doi.org/10.1016/j.fishres.2013.03.009.
[19] S.H. Olsen, S. Joensen, T. Tobiassen, K. Heia, L. Akse, H. Nilsen, Quality consequences of bleeding fish after capture, Fish. Res. 153 (2014) 103–107, https://doi.org/10.1016/j.fishres.2014.01.011.
[20] R.A. Svalheim, Ø. Aas-Hansen, K. Heia, A. Karlsson-Drangsholt, S.H. Olsen, H. K. Johnsen, Simulated trawling: exhaustive swimming followed by extreme crowding as contributing reasons to variable fillet quality in trawl-caught Atlantic cod (Gadus morhua), PLoS One 15 (2020), e0234059, https://doi.org/10.1371/journal.pone.0234059.
[21] M. Esaiassen, L. Akse, S. Joensen, Development of a Catch-damage-index to assess the quality of cod at landing, Food Control 29 (2013) 231–235, https://doi.org/10.1016/j.foodcont.2012.05.065.
[22] S. Margeirsson, B. Hrafnkelsson, G.R. Jónsson, P. Jensson, S. Arason, Decision making in the cod industry based on recording and analysis of value chain data, J. Food Eng. 99 (2010) 151–158, https://doi.org/10.1016/j.jfoodeng.2010.02.012.

[23] A.S. Christensen, J. Raakjær, Fishermen's tactical and strategic decisions. A case study of Danish demersal fisheries, Fish. Res. 81 (2006) 258–267, https://doi.org/10.1016/j.fishres.2006.06.018.
[24] S. Margeirsson, G.R. Jonsson, S. Arason, G. Thorkelsson, Influencing factors on yield, gaping, bruises and nematodes in cod (Gadus morhua) fillets, J. Food Eng. 80 (2007) 503–508, https://doi.org/10.1016/j.jfoodeng.2006.05.032.
[25] S. Margeirsson, A.A. Nielsen, G.R. Jonsson, S. Arason, Quality seafood: effect of catch location, season and quality defects on value of Icelandic cod (Gadus morhua) products, in: Seaf. Res. from Fish to Dish Qual. Saf. Process, Wild Farmed Seaf., 2006, https://doi.org/10.3920/978-90-8686-581-9.
[26] L. Mazany, N. Roy, W.E. Schrank, Multi-product allocation under imperfect raw material supply conditions: the case of fish products, Appl. Econ. 28 (1996) 387–396, https://doi.org/10.1080/000368496328768.
[27] Norwegian Fishermen's Sales Organization, Report from the quality supervision 2015–2017 (in Norwegian), Tromsø, 2017.
[28] S. Johnsen, J.P. Jentoft, Transferable quotas in Norwegian fisheries, in: M. WinderG (Ed.), Fish. Quota Manag. Quota Transf. Ration. through Bio-Economics., MARE Publi, Springer International Publishing AG, 2018, pp. 121–139.
[29] B.A. Bertheussen, B.M. Dreyer, Is the Norwegian cod industry locked into a value-destructive volume logic? Mar. Policy 103 (2019) 113–120, https://doi.org/10.1016/j.marpol.2019.02.023.
[30] G.G. Ottesen, K. Grønhaug, Primary uncertainty in the seafood industry: an exploratory study of how processing firms cope, Mar. Resour. Econ. 18 (2003) 363–371, https://doi.org/10.1086/mre.18.4.42629408.
[31] I.K. Pettersen, E.H. Brækkan, Ø. Myrland, Are Norwegian fishermen selling in the same market? J. Commod. Mark. 12 (2018) 9–18, https://doi.org/10.1016/j.jcomm.2017.12.008.
[32] J. Blomquist, C. Hammarlund, S. Waldo, Time for fishing: bargaining power in the Swedish baltic cod fishery, Mar. Resour. Econ. 30 (2015) 315–329, https://doi.org/10.1086/680729.
[33] D.M. McEvoy, S. Brandt, N. Lavoie, S. Anders, The effects of ITQ management on fishermen's welfare when the processing sector is imperfectly competitive, Land Econ. 85 (2009) 470–484, https://doi.org/10.3368/le.85.3.470.
[34] R.M. Emerson, Power-dependence relations, Am. Sociol. Rev. 27 (1962) 31–41, https://doi.org/10.2307/2089716.
[35] B.I. Bendiksen, B. Dreyer, Technological changes – the impact on the raw material flow and production, Eur. J. Oper. Res. 144 (2003) 237–246, https://doi.org/10.1016/S0377-2217(02)00390-9.
[36] J.D. MacDonald, R.L. Mazany, Quality improvement: Panacea for the Atlantic fishing industry? Can. Public Policy /Anal. Polit. 10 (1984) 278–286, https://doi.org/10.2307/3550321.
[37] Directorate of Fisheries, Profitability survey of the Norwegian fishing fleet, 2020.
[38] D. Kristofersson, K. Rickertsen, Hedonic price models for dynamic markets, Oxf. Bull. Econ. Stat. 69 (2007) 387–412, https://doi.org/10.1111/j.1468-0084.2006.00441.x.
[39] L. Gobillon, F.C. Wolff, P. Guillotreau, The effect of buyers and sellers on fish market prices, Eur. Rev. Agric. Econ. 44 (2017) 149–176, https://doi.org/10.1093/erae/jbw006.
[40] K.J. Lancaster, A new approach to consumer theory, J. Polit. Econ. 74 (1966) 132–157, https://doi.org/10.1086/259131.
[41] S. Rosen, Hedonic prices and implicit markets: product differentiation in pure competition, Tetrahedron Lett. 82 (1974) 34–55, https://doi.org/10.1016/S0040-4039(00)85403-9.
[42] F. Zimmermann, M. Heino, Is size-dependent pricing prevalent in fisheries? The case of Norwegian demersal and pelagic fisheries, ICES J. Mar. Sci. 70 (2013) 1389–1395, https://doi.org/10.1093/icesjms/fst121.
[43] J.R. Botta, G. Bonnell, B.E. Squires, Effect of method of catching and time of season on sensory quality of fresh raw Atlantic cod (Gadus morhua), J. Food Sci. 52 (1987) 928–931, https://doi.org/10.1111/j.1365-2621.1987.tb14245.x.
[44] Q.H. Vuong, Likelihood ratio tests for model selection and non-nested hypotheses, Econometrica 57 (1989) 307–333, https://doi.org/10.2307/1912557.
[45] R.M. O'Brien, A caution regarding rules of thumb for variance inflation factors, Qual. Quant. 41 (2007) 673–690, https://doi.org/10.1007/s11135-006-9018-6.
[46] J.A. Wilson, Adaptation to uncertainty and small numbers exchange: the new England fresh fish market, Bell J. Econ. 11 (1980) 491–504, https://doi.org/10.2307/3003375.
[47] P. Kollock, Social dilemmas: the anatomy of cooperation, Annu. Rev. Sociol. 24 (1998) 183–214, https://doi.org/10.1146/annurev.soc.24.1.183.
[48] J. Bulow, P. Klemperer, Auctions versus negotiations, Am. Econ. Rev. 86 (1996) 180–194, https://doi.org/10.2307/2118262.
[49] I. Huse, S. Løkkeborg, A.V. Soldal, Relative selectivity in trawl, longline and gillnet fisheries for cod and haddock, ICES J. Mar. Sci. 57 (2000) 1271–1282, https://doi.org/10.1006/jmsc.2000.0813.
[50] M. Ovegård, K. Berndt, S.G. Lunneryd, Condition indices of Atlantic cod (Gadus morhua) biased by capturing method, ICES J. Mar. Sci. 69 (2012) 1781–1788, https://doi.org/10.1093/icesjms/fss145.