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# Auction versus direct sale: the effect of buyers and sellers on prices

**Geir Sogn-Grundvåg**[†,*] **and Dengjun Zhang**[†,‡]
[†]*Norwegian Institute of Food, Fisheries and Aquaculture Research, Norway;* [‡]*Business School, University of Stavanger, Norway*

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## Abstract

This study examines the question of selling agricultural commodities by auction or directly. Hedonic price analysis using transaction data from the sale of frozen cod in Norway shows that buyer–seller matches explain 32.4 and 13.6 per cent of the price variation in direct sales and auctions, respectively, indicating that direct sales are more informationally efficient than auctions. Meanwhile, auctions gain a price premium of 2.6 per cent over direct sales, holding other variables constant. However, a substantial increase in the use of direct sales indicates that their information efficiency is more important to sellers than the small price premium provided by auctions.

**Keywords:** auction, direct sales, unobserved quality, commodity price, asymmetric information

**JEL classification:** L11, Q22

## 1. Introduction

The point of departure for this study is that in the main market for frozen Atlantic cod in Norway, where sellers are free to choose between auction and direct sales, the share of auction sales decreased from 52 per cent in 2009 to 31 per cent in 2017. Based on relevant literature, the low and declining share of auctions is surprising for several reasons. First, a study of the same market found that frozen cod of similar sizes obtained higher prices when sold by auction than when sold directly (Helstad *et al.*, 2005). Second, the costs of selling by auction and directly are the same, favouring the auction for its higher prices (Bulow and Klemperer, 1996, 2009; Leffler, Rucker and Munn, 2007). Third, frozen cod is defined as a commodity with well-known and standardised specifications traded in an integrated global market (Pettersen and Myrland, 2016), again favouring the auction for its higher prices (Leffler, Rucker and Munn, 2007; Bajari, McMillan and Tadelis, 2008).

*Corresponding author: E-mail: geir.sogn-grundvag@nofima.no

Why then do many sellers in this market prefer direct sales over auctions?[1] This is an important question because in many agricultural and seafood markets, sellers may choose between different sales mechanisms, giving rise to a decision problem that is more complex than optimisation within a given mechanism (Arnold and Lippman, 1993). It is therefore surprising that, despite large bodies of research devoted to the optimal design of specific sales mechanisms, this decision problem has received comparatively little attention in the literature (Leffler, Rucker and Munn, 2007; Bajari, McMillan and Tadelis, 2008). However, some empirical studies have been conducted. These have focussed on the procurement of complex building contracts in the private (Bajari, McMillan and Tadelis, 2008) and public sectors (Chong, Staropoli and Yvrande-Billon, 2014), as well as selling mechanisms for timber (Leffler, Rucker and Munn, 2007; Roberts and Sweeting, 2013), livestock (Arnold and Lippman, 1993; Hobbs, 1997) and real estate (Chow, Hafalir and Yavas, 2015).

These studies can be divided into studies regressing the choice of sales mechanism against factors such as project complexity, the number of available contractors/buyers, transaction costs, entry costs, and seller and buyer characteristics (Hobbs, 1997; Bajari, McMillan and Tadelis, 2008; Leffler, Rucker and Munn, 2007; Chong, Staropoli and Yvrande-Billon, 2014) and studies comparing prices between auction and negotiation (Arnold and Lippman, 1993; Roberts and Sweeting, 2013; Chow, Hafalir and Yavas, 2015; Helstad *et al.*, 2005). The study closest to ours is the one by Helstad *et al.* (2005) mentioned above. Whereas their finding regarding price differences between auction and direct sales is interesting, they explicitly assumed fishers and fish buyers to be independent. This may seem a strong assumption, given that several sellers and buyers in this market are vertically integrated or have developed long-term business relationships in direct sales, which, as indicated by Gobillon, Wolff and Guillotreau (2017), may improve information efficiency and influence prices in direct sales. In addition, Helstad and colleagues did not control for quality attributes such as fishing methods and downgrading, which are known to influence cod prices (Sogn-Grundvåg, Zhang and Dreyer, 2020; Sogn-Grundvåg *et al.*, 2021).

A key insight that can be drawn from the above-mentioned studies is that complex items may benefit from the more informationally efficient direct sales mechanism (Leffler, Rucker and Munn, 2007; Bajari, McMillan and Tadelis, 2008). This is relevant here because, despite being defined as a commodity in the literature (Pettersen and Myrland, 2016), frozen cod is a biological product that will naturally vary in quality (Anderson and Anderson, 1991). Thus, some quality attributes may not be observable and may vary among

1 That sellers may prefer direct sales has been observed elsewhere. For example, in the Boulogne fish market—the largest fish market in France—about 60 per cent of all transactions are conducted outside the auction (Mignot, Tedeschi and Vignes, 2012). About 50 per cent of slaughtered cattle in the UK are sold through an auction system, and the remainder are sold directly (Hobbs, 1997). The same distribution between auction and direct sale was also observed in the selling of cattle in British Columbia (Allen, 1993).

commodities with the same observable attributes (Gobillon, Wolff and Guillotreau, 2017). For example, fishing method, which is an important observable quality signal that influences prices in capture-based fisheries (e.g. McConnell and Strand, 2000; Lee, 2014; Sogn-Grundvåg, Zhang and Dreyer, 2020; Sogn-Grundvåg *et al.*, 2021), may conceal quality variation between catches landed with the same fishing method. This variation may be caused by variations in the size of hauls, on-board processing facilities and routines among vessels fishing with the same gear (Rotabakk *et al.*, 2011; Olsen *et al.*, 2014).

This implies that some unobserved quality may not be accounted for by the quality attributes posted in the auction.[2] Thus, some sellers may choose market mechanisms depending on the degree to which observable product quality attributes correspond with the actual or true product quality. For instance, if unobservable quality will affect the overall product quality negatively, sellers may prefer direct sales. In that way, they can provide additional information about the true quality of the product and, despite lower prices, maintain their reputation and avoid costly complaints (Akerlof, 1970; Shapiro, 1983). Conversely, some sellers may choose direct sales if the unobservable product quality means that the overall product quality is higher than would be expected based on the attributes posted at auctions. In direct sales, this information asymmetry may be resolved and lead to a higher price than in an auction.

Depending on the extent of unobservable quality, buyers' preferences for market mechanisms may also be influenced. For example, to avoid buying 'lemons' in a market with information asymmetry regarding product quality, some buyers may prefer direct sales over auctions. However, information about unobservable quality may be known only by some buyers through their interaction with some sellers, indicating that some commodities may be sold at different prices by sellers with different willingness to sell or bought by buyers with different willingness to pay (Gobillon, Wolff and Guillotreau, 2017).

This discussion suggests that when unobservable quality influences the true value of the product, direct sales will be a more informationally efficient market than the auction. But it also posits that this relates closely to buyers' and sellers' ability to obtain and utilise this information, which in turn may lead to a preference for direct sales over auctions among some buyers and sellers. To examine this proposition, we present a stepwise procedure with hedonic models to examine price setting in auctions and direct sales and to what extent this is influenced by buyer and seller heterogeneity. More specifically, we propose that unobserved quality would be reflected in the extent to which seller and buyer heterogeneity explains variation in prices—and that this effect would be stronger in direct sales, where information asymmetry has better prospects to be resolved. Thus, seller and buyer dummies are added to the basic hedonic model while controlling for observed product attributes and other control

2 In display auctions, experienced buyers may assess the quality of the fish by physical inspection (Kirman and Vriend, 2001). But when auctions are conducted online, such as for the frozen cod studied here, physical inspection prior to bidding is not possible (Sogn-Grundvåg, Zhang and Iversen, 2019).

variables. Next, we add dummies for buyer–seller matches to examine whether and to what extent these contribute to explaining price variation—and whether this may vary between auction and direct sales. We apply the hedonic price models and provide a detailed empirical study of auctions and direct sales and the role of seller, buyer and seller–buyer heterogeneity in the main market for frozen cod in Norway. To the best of our knowledge, this approach has not been applied to examine price variation within and between auctions and direct sales for the same commodity.

The remainder of the article is organised as follows. In the next section, we provide a background to our study by describing the auction and direct sales markets for frozen cod, as well as the data. Section 3 outlines the hedonic models and econometric approach, and Section 4 presents the results. Section 5 concludes.

## 2. Background and data

### 2.1. The auction and direct sales markets

The frozen cod included in this study is sold through the Norwegian Fishermen's Sales Organization (NFSO), which has exclusive rights to all ex-vessel sales of cod and other groundfish landed along the Norwegian coast from Nordmøre in the southwest to Finnmark in the northeast. To allow longer trips, the fish is frozen on board large oceangoing trawlers, longliners and Danish seiners (Sogn-Grundvåg, Zhang and Dreyer, 2020). Catches are landed at one of 14 independent cold storage plants spread along the coastline, from which buyers ship the lots by cargo vessels to processing plants in Norway or abroad (Bendiksen and Dreyer, 2002). The fisher pays a weekly storage fee, but the fish can be stored for several months if the fisher for instance anticipates future price increases. However, longer storage time will reduce the quality of the cod (Badii and Howel, 2002). The fisher is free to choose between auction and direct sales. The NFSO charges a service fee of 0.69 per cent of the sales value of frozen headed and gutted cod, which is the focus here, independent of sales mode.

The auction is conducted online on the NFSO's auction website, implying that physical inspection of the fish is not possible at the time of bidding. The auction is an English type of auction where the bidder with the highest bid at the closing time wins. The auction website is open for registered buyers and sellers, and entry is easy (Sogn-Grundvåg, Zhang and Dreyer, 2021). On the auction website, all participants can see details of the lot, including the name of the vessel, the fishing method used, the time and location of landing, if the fish was downgraded or not, the product form, as well as the starting price. The number of bidders and their identity are not revealed in the auction. The seller may provide a reserve price for the lot in NOK per kilogram, but this is not binding, as about one-third of the auction transactions included in this study were sold at a price below sellers' reserve prices.

Some of the quality attributes posted in the auction may conceal quality variations. Most notably, fishing methods may hide substantial quality variation between vessels fishing with the same gear. This may be related to variations in the skills of the skippers and crews and their available technology, such as onboard processing facilities and equipment. For instance, variations in fishing tactics such as long soaking time for longlines and large hauls when fishing with Danish seiners and trawlers may increase fishing efficiency but compromise fish quality (Sogn-Grundvåg, Zhang and Dreyer, 2020).

Interestingly, skippers may downgrade a catch or parts of it. According to the auctioneer, this is mainly done to avoid complaints. This is interesting because it indicates that downgrading is a way of signalling unobserved quality, which is not captured by observable quality attributes or signals such as fishing method, fish size or storage time. Avoiding complaints is important because they may be costly but also because they may affect a seller's reputation negatively. Downgrading can be done for several reasons, for example, if a haul is too large, causing poor bleeding (Rotabakk *et al.*, 2011). Fish may also have soft flesh due to their feed content or faulty cuts during gutting. A haul with cod may also include some redfish, which due to their harsh skin may cause skin damage to the cod during the catch operation. The different faults leading fishers to downgrade a lot may be more or less important to different buyers, depending on what plans they have for the lot. Also, the share of fish with faults in a downgraded lot may vary. About 5.8 per cent of the lots (transactions) included in our data were downgraded, but the reasons for downgrading were only provided for about 3 per cent of these lots. It should be noted that it is possible to hire an independent quality assessor to evaluate the quality of a sample from a lot. However, in only 121 out of the 28,746 transactions in the data (0.42 per cent) such quality assessment was available upon request.

Table 1 provides some information on the structure of the auction and direct sales markets. The table shows that the number of transactions, the total value and transaction size are substantially higher for direct sales than for auctions. Furthermore, the number of sellers is higher than the number of buyers in both markets, and most sellers and buyers seem to have traded in both markets. Interestingly, the average number of buyers per seller is significantly lower in the direct sales market than in the auction. A similar pattern is shown by the average number of sellers per buyer, which is lower in direct sales than in the auction. It is also interesting that the average number of transactions for buyer–seller pairs is substantially higher in the direct sales market. These characteristics of the two markets indicate a focus on relationships in the direct sales market. In addition to helping to resolve information asymmetries regarding fish quality, buyer–seller relationships in direct sales may also reduce transaction costs related to negotiations, complaints and payments and improve adjustments of product specifications.

There are also some vertically integrated companies that include both fishing and onshore processing. These have different sales strategies, with some

**Table 1.** Descriptive statistics of the two market modes (2009–2017)

| | Auction | Direct sale |
|---|---|---|
| Total number of transactions | 11,248 | 17,498 |
| Total sales (in million NOK) | 3,426 | 7,829 |
| Average value per transaction (NOK) (SD)[a] | 304,588 (540,345) | 416,564 (735,736) |
| Number of sellers | 180 | 182 |
| Number of buyers | 132 | 140 |
| Average number of buyers per seller (SD)[a] | 20.2 (26.3) | 14.2 (19.6) |
| Average number of sellers per buyer (SD)[a] | 14.8 (12.3) | 10.9 (10.5) |
| Number of buyer–seller matches[b] | 2,676 | 1,990 |
| Average number of transactions per match (SD)[a] | 4.2 (5.5) | 8.8 (25.0) |

[a]Results from t-test show that the mean differences are statistically different.

[b]A buyer–seller match is defined as a buyer–seller pair involved in at least one transaction (Gobillon, Wolff and Guillotreau, 2017).

using only direct sales and some using both market mechanisms.[3] Figures 1 and 2 show the share of cod bought at auction for the 20 largest buyers and sellers, respectively.[4] The figures show that the use of the two market mechanisms varies among both sellers and buyers, but more so for buyers. For example, Figure 1 shows that 2 of the 20 largest buyers hardly use the auction but also that 3 of the other buyers mainly use the auction.

Figure 3 shows that the share of cod sold at the auction during the period covered by this study dropped from 52 per cent in 2009 to 31 per cent in 2017. This may indicate that prices in the auction were reduced over time. However, a study of the same auction using data from 2010 to 2018 showed that with the exception of 2010 and 2011, when the average number of bidders in each auction was 3.66 and 3.25, respectively, the average number of bidders remained stable between 2.12 (2016) and 2.63 bidders in each auction (2014) in the period between 2012 and 2018 (Sogn-Grundvåg, Zhang and Dreyer, 2021).[5] This indicates that, despite the reduced share of auction sales compared to direct sales over time, competition in the auction has been relatively

3 It should be noted that the share remuneration payment system, whereby the crew receives a fixed share of the revenues rather than a fixed wage (McConnell and Price, 2006), and the strong position of the Norwegian Seafarers' Union make it difficult for vertically integrated companies to buy the fish directly from their own vessels at low prices.

4 Figures A1 and A2 illustrate the share of cod bought at auction against volume shares for the largest buyers and sellers, respectively. While the relationship between volume shares and the share of auctions is more volatile for the largest buyers, this relationship has a lower level of fluctuations for the largest sellers.

5 The same study showed that the number of bidders participating in each auction influences prices, with price premiums of 4.51, 6.47 and 7.18 per cent for auctions with two, three and four bidders, respectively, compared to auctions with one bidder only (Sogn-Grundvåg, Zhang and Dreyer, 2021).

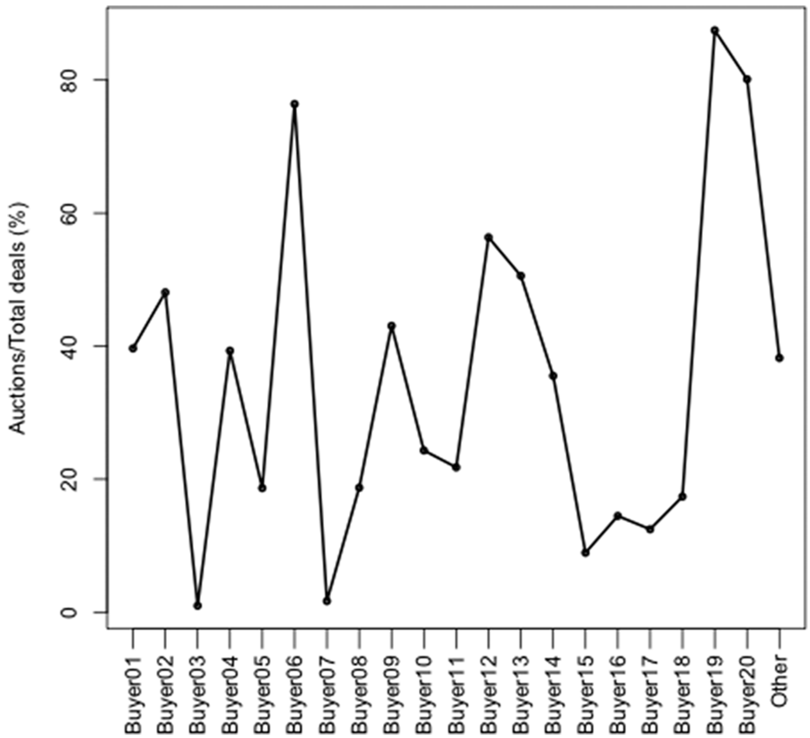


**Fig. 1.** The share of cod bought at auction out of the total number of transactions for the 20 largest buyers (2009–2017).

stable over time. Figure 4 compares average prices for cod sold by auction and direct sales. Auction prices were higher than those in direct sales in 2010 and 2011, and price differences were small during 2009 and 2012–2017. The drop in prices from 2011 to 2013 was probably caused by a substantial increase in cod landings. From 2011 to 2013, the total cod landings rose from 340,000 tons to 471,000 tons. Landings remained high averaging 428,000 tons during the period 2013–2017. An important reason for the increasing prices after 2013 was a weakening of the NOK against key currencies such as USD and GBP (Nyrud, Bendiksen and Dreyer, 2016).

## 2.2. Data and variables

The data include details of 28,746 transactions of frozen headed and gutted Atlantic cod during the period January 2009–December 2017, totally 506,100 tonnes of Atlantic cod with a value of NOK 10,715 million (EUR 1,147 million). For each transaction (lot), the data include the weight of the lot in kilograms, the fishing gear (bottom trawl, longline, Danish seine or other

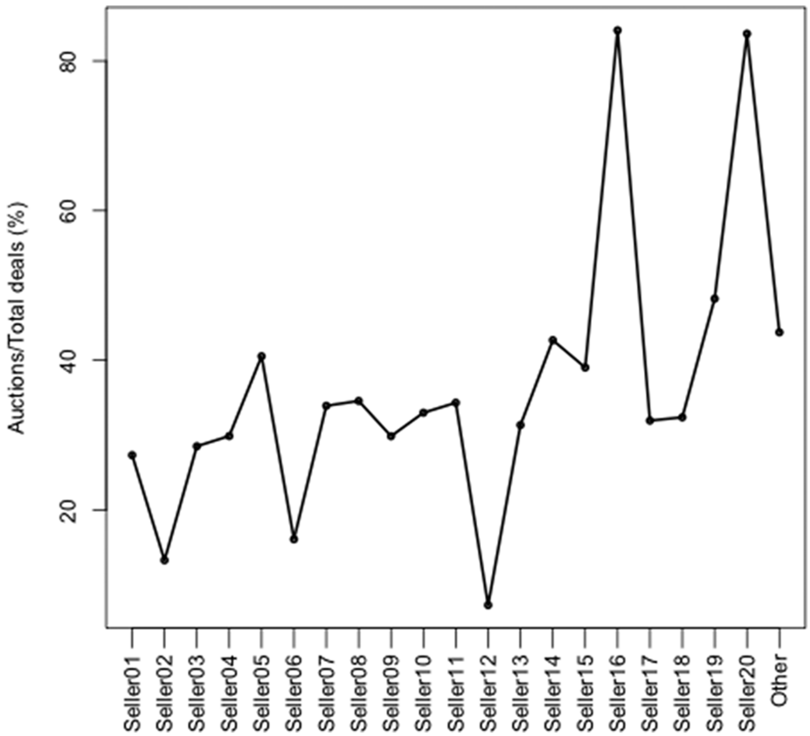


**Fig. 2.** The share of cod sold at auction out of the total number of transactions for the 20 largest sellers (2009–2017).

gears), the average size of the fish in kilograms, its quality (regular or downgraded), the name of the vessel and buyer, and the sales mode (auction or direct sale).

Table 2 presents the descriptive statistics for the control variables included in the econometric models. Under the dummy-coding technique, the reported mean for each dummy variable is the number of observations (transactions) within each category as a proportion of the total number of observations. For example, bottom trawling of cod accounted for 63.5 per cent of all transactions during the sample period. Table 2 also shows a dummy variable for regular quality, with downgraded fish as the base, and dummies for the three main fishing methods, with other fishing methods[6] as the base. Table 3 shows the mean differences between the control variables for the two sales mechanisms. The means are different ($p < 0.001$) for all control variables, indicating the necessity to control for these attributes when examining price differences between auctions and direct sales.

6 Several other fishing methods were used, such as traps and pots. These are treated as one group and used as a base category for comparisons with bottom trawl, longline and Danish seine.

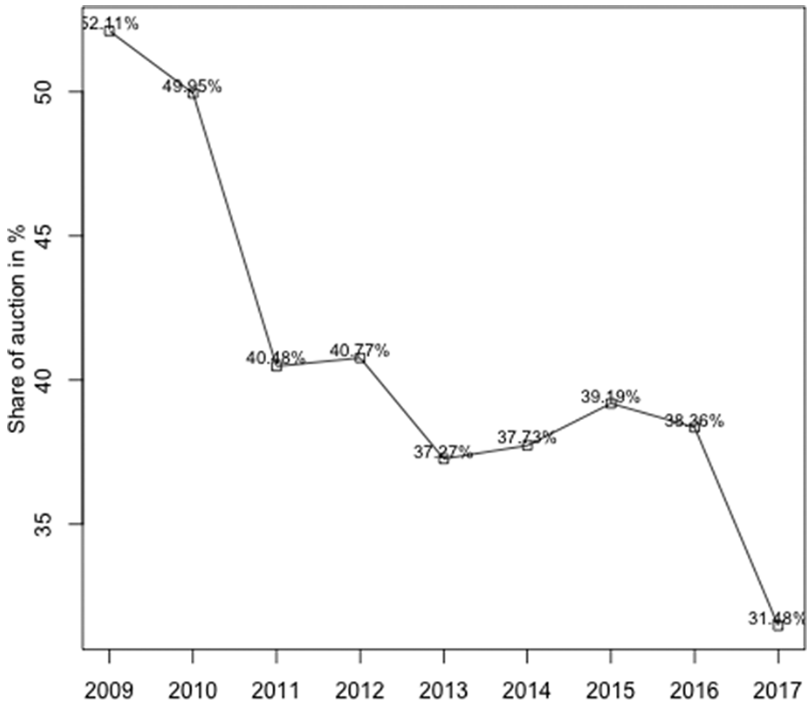


**Fig. 3.** The share of cod as a percentage of transactions sold in the auction, 2009–2017.

## 3. Model and econometric analysis

To examine price differences between auctions and direct sales, we present a stepwise procedure with a basic hedonic model controlling for observable product attributes and other control variables and then adding fixed effects for the heterogeneity of sellers, buyers and seller–buyer matches in subsequent models. In doing so, we follow Gobillon, Wolff and Guillotreau (2017) and Sogn-Grundvåg, Zhang and Dreyer (2020, 2021). The baseline model (Model A) specification is[7]

$$\log(p_i) = a_0 + b_1 Auction_i + \sum_{n=1}^{7} c_n X_{n,i} + \sum_{o=2}^{12} k_o Month_{o,i} + \sum_{o=2}^{9} j_o Year_{o.i} + +Residual_i \quad (1)$$

where $i$ represents the number of transactions, and log is the logarithm function. *Auction* is a dummy, which equals 1 for deals in the auction market and 0 for direct sales. The error term, *Residual*, captures any other unobserved

7 For each model, the test results of Vuong's non-nested likelihood ratio test (Vuong, 1989) indicate that the specification with the logarithmic price as the dependent variable fits the data better than the specification with linear price formulation.

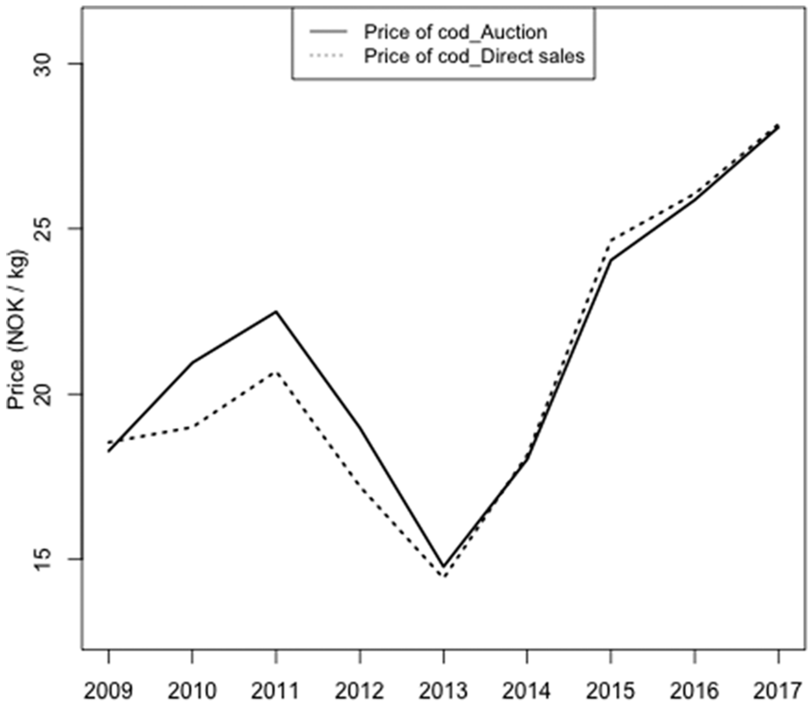


**Fig. 4.** The average prices for cod at auction and in direct sales, 2009–2017.

factors that might influence the price. *X* represents a vector of control variables. The year and month dummies are included in the model to control for any seasonality in prices. The prices can be considered hedonic prices, and thus, the primary price determinants are the average size of the cod *(Fish-Size)*, the storage time (*Storage-Time*), the quality (regular or not, *Quality*) and fishing method (*Bottom-Trawl, Longline* or *Danish-Seine*), which is an important quality signal (Sogn-Grundvåg, Zhang and Dreyer, 2020). Fish prices may also be influenced by factors such as transaction quantity (*Transaction-Quantity*) (Kirman and Vriend, 2001; Guillioni and Bucciarelli, 2011; Fluvià *et al.*, 2012; Gobillon, Wolff and Guillotreau, 2017; Sogn-Grundvåg, Zhang and Iversen, 2019). Table 2 shows a list of control variables.

To examine the effects of heterogeneity of sellers, buyers and seller–buyer pairs, we modified the baseline model by including dummies for the 50 largest buyers, the 50 largest sellers and the 199 largest buyer–seller pairs.[8] This gives Model B with the dummies for the largest buyers and sellers and Model C with

8 The share out of total transaction quantity is 93.1 per cent for the top 50 buyers, 76.6 per cent for the top 50 sellers and 51.5 per cent for the top 199 buyer–seller pairs. We did not include dummies for the followers in order to avoid multicollinearity.

**Table 2.** Descriptive statistics of control variables for the whole sample

| Variable | Definition | Mean | SD |
|---|---|---|---|
| Auction | Dummy (=1 for auction and 0 otherwise). | 0.391 | 0.488 |
| Fish-Size | Fish size (kg) in logarithmic scale (log). | 0.428 | 1.190 |
| Transaction-Quantity | Quantity of lots (kg) in logarithmic scale (log). | 8.339 | 2.024 |
| Storage-Time | Storage time (days) in logarithmic scale (log). | 2.214 | 0.990 |
| Bottom-Trawl | Dummy (=1 for bottom trawl and 0 otherwise) | 0.635 | 0.481 |
| Longline | Dummy (=1 for longline and 0 otherwise) | 0.240 | 0.427 |
| Danish-Seine | Dummy (=1 for Danish seine and 0 otherwise) | 0.095 | 0.294 |
| Quality | Dummy (=1 for fish with regular quality and 0 otherwise) | 0.942 | 0.233 |

further the largest buyer–seller pairs:

$$\log(p_i) = a_0 + b_1 Auction_i + \sum_{n=1}^{7} c_n X_{n,i} + \sum_{n=1}^{50} e_n Buyer_{n,i} + \sum_{n=1}^{50} f_n Seller_{n,i} + + \sum_{o=2}^{12} k_o Month_{o,i} + \sum_{o=2}^{9} j_o Year_{o,i} + Residual_i \quad (2)$$

$$\log(p_i) = a_0 + b_1 Auction_i + \sum_{n=1}^{7} c_n X_{n,i} + \sum_{n=1}^{50} e_n Buyer_{n,i} + \sum_{n=1}^{50} f_n Seller_{n,i} + \sum_{n=1}^{199} g_n Pair_{n,i} + \sum_{o=2}^{12} k_o Month_{o,i} + \sum_{o=2}^{9} j_o Year_{o,i} + Residual_i \quad (3)$$

To compare price differences for the various product attributes between the auction and direct sales, we also estimated Models A, B and C (without the variable *Auction*) for auctions and direct sales separately.

Finally, it is worth pointing out some econometric issues. First, although the data used in this study provide detailed information about the transactions and our model specifications follow previous studies, some unobserved (omitted) variables, which are probably related to fish quality, as discussed above, may influence prices. Second, the error terms in Models A and B are probably correlated, and thus, ignoring these correlations may lead to low efficiency of the regressions. Since Model B and Model C use different subsamples of the dataset, the seemingly unrelated regression approach is not an appropriate tool. Third, the estimation results may be subject to selection bias given that some unobservable factors may affect the choice of sale channels and prices. However, since this study focuses on the comparison of the goodness of fit of models, these econometric issues may not affect the comparison results.

**Table 3.** Mean differences for the control variables for auction and direct sales

| Variable | Auctions | Direct sales | Difference | *p*-Value |
|---|---|---|---|---|
| Fish-Size (log) | 0.469 | 0.401 | 0.068 | <0.001 |
| Transaction-Quantity (log) | 8.202 | 8.427 | –0.225 | <0.001 |
| Storage-Time (log) | 2.144 | 2.259 | –0.116 | <0.001 |
| Bottom-Trawl | 0.555 | 0.687 | –0.132 | <0.001 |
| Longline | 0.268 | 0.222 | 0.046 | <0.001 |
| Danish-Seine | 0.138 | 0.068 | 0.070 | <0.001 |
| Quality | 0.921 | 0.956 | –0.036 | <0.001 |

## 4. Empirical results

### 4.1. Estimation results for the whole sample

The results of the hedonic price regressions for the whole sample, including both auction and direct sales, are presented in Table 4.[9] The adjusted $R^2$ value for Model A is 0.7389, indicating the model's goodness of fit to the data. In Model B, buyer and seller dummies are introduced. This leads to an increase in the adjusted $R^2$ value from 0.7389 to 0.7735 (+4.6 per cent), implying that Model B has a better fit to the data than Model A. The introduction of buyer and seller fixed effects has a quite substantial effect on the coefficient for the auction dummy, which drops from 0.0355 to 0.0272 (–23.4 per cent). In Model C, we introduce buyer–seller dummies. This leads to an increase in the adjusted $R^2$ value from 0.7735 to 0.7852 (+1.5 per cent). The coefficient for auction further drops to 0.0258 (–5.8 per cent) in Model C, indicating that the price of cod in the auction is 2.6 per cent higher than the price of cod in direct sales, holding other variables constant.

The increase in the adjusted $R^2$ value when buyer–seller matches are introduced is only 1.5 per cent, which may seem modest. However, the contribution of buyer–seller match effects to explaining variation in prices accounts for 25.3 per cent of the overall contribution of the unobserved heterogeneity terms.[10] In Section 1, we argued that buyer–seller relationships may be more informationally efficient in direct sales than in the auction. To examine this, separate regressions for Models A, B and C for the two markets are estimated in the next section, where we also examine whether observed quality variables are priced differently in the two markets.

We now consider the effects of observable quality variables on prices, while controlling for other variables. F-test results for the three models indicate that

9 The robust clustered standard errors are applied to correct for heteroscedasticity and serial correlation in the error terms and clustering for buyers. The value of the variance inflation factor for each variable in each model is well below the threshold of 10 (O'Brien, 2007), indicating that multicollinearity does not affect the validity of the regression models.

10 This percentage is calculated as follows: (R2 of Model C – R2 of Model B)/(R2 of Model C – R2 of Model A) × 100.

**Table 4.** Estimation results of Models A, B and C for the whole sample

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Intercept | 2.4727 | [0.0116] *** | 2.4445 | [0.0119] *** | 2.499 | [0.0126] *** |
| Auction | 0.0355 | [0.0019] *** | 0.0272 | [0.0021] *** | 0.0258 | [0.0022] *** |
| Fish-Size | 0.0373 | [0.0009] *** | 0.0296 | [0.0009] *** | 0.0300 | [0.0009] *** |
| Transaction-Quantity | 0.0028 | [0.0005] *** | 0.0037 | [0.0005] *** | 0.0014 | [0.0005] *** |
| Storage-Time | −0.0076 | [0.001] *** | −0.0176 | [0.0011] *** | −0.0208 | [0.0011] *** |
| Bottom-Trawl | 0.0245 | [0.0057] *** | 0.0563 | [0.0068] *** | 0.0346 | [0.0079] *** |
| Longline | 0.1133 | [0.0059] *** | 0.1448 | [0.0066] *** | 0.1161 | [0.0077] *** |
| Danish-Seine | −0.0647 | [0.0066] *** | −0.0244 | [0.007] *** | −0.0401 | [0.008] *** |
| Quality | 0.3533 | [0.0058] *** | 0.3495 | [0.006] *** | 0.3472 | [0.0061] *** |
| Year-2010 | 0.1333 | [0.0077] *** | 0.128 | [0.0068] *** | 0.1301 | [0.0068] *** |
| Year-2011 | 0.2038 | [0.0073] *** | 0.1975 | [0.0066] *** | 0.1971 | [0.0066] *** |
| Year-2012 | 0.0319 | [0.0077] *** | 0.0372 | [0.0071] *** | 0.0417 | [0.007] *** |
| Year-2013 | −0.1735 | [0.0067] *** | −0.1604 | [0.0063] *** | −0.1629 | [0.0063] *** |
| Year-2014 | 0.0379 | [0.007] *** | 0.0465 | [0.0067] *** | 0.0444 | [0.0067] *** |
| Year-2015 | 0.3374 | [0.0067] *** | 0.3411 | [0.0064] *** | 0.3365 | [0.0065] *** |
| Year-2016 | 0.3989 | [0.0067] *** | 0.4033 | [0.0065] *** | 0.3965 | [0.0065] *** |

(continued)

**Table 4.** (Continued)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Year-2017 | 0.4837 | [0.0068] *** | 0.4858 | [0.0066] *** | 0.4779 | [0.0067] *** |
| January | −0.0964 | [0.0042] *** | −0.0978 | [0.004] *** | −0.0948 | [0.0039] *** |
| February | −0.0748 | [0.0049] *** | −0.0756 | [0.0045] *** | −0.077 | [0.0045] *** |
| March | −0.0898 | [0.005] *** | −0.0869 | [0.0048] *** | −0.085 | [0.0048] *** |
| April | −0.0852 | [0.0047] *** | −0.0819 | [0.0046] *** | −0.0789 | [0.0045] *** |
| May | −0.0729 | [0.0045] *** | −0.063 | [0.0043] *** | −0.0614 | [0.0042] *** |
| June | −0.0575 | [0.004] *** | −0.0447 | [0.0039] *** | −0.0455 | [0.0039] *** |
| July | −0.0547 | [0.0042] *** | −0.0532 | [0.0041] *** | −0.0499 | [0.004] *** |
| August | −0.0344 | [0.0041] *** | −0.0222 | [0.0039] *** | −0.0196 | [0.0038] *** |
| September | −0.0166 | [0.004] *** | −0.0065 | [0.0038] * | −0.0057 | [0.0037] |
| October | −0.0047 | [0.0041] | 0.0018 | [0.0038] | 0.0046 | [0.0038] |
| November | 0.0189 | [0.0038] *** | 0.0201 | [0.0036] *** | 0.0215 | [0.0035] *** |
| Buyer dummies | No | | Yes | | Yes | |
| Seller dummies | No | | Yes | | Yes | |
| Pair dummies | No | | No | | Yes | |
| Adj. $R^2$ | 0.7389 | | 0.7735 | | 0.7852 | |

*Note*: The symbols * and *** indicate significance at the levels of 0.1 and 0.01, respectively.

Model C fits the data better than the other models with fewer variables. Thus, we focus on Model C. In Model C, the dummies for the three fishing methods are significant. Compared to cod caught with other fishing methods (the base), cod caught by longliners is 11.6 per cent more expensive, cod caught by bottom trawlers is 3.5 per cent more expensive and cod caught by Danish seiners is 4 per cent cheaper. The price premium for longline is similar to the premiums for line-caught cod (compared to other fishing methods) found in the UK grocery retail market (Sogn-Grundvåg, Larsen and Young, 2013, 2014), where cod products with the line-caught label also have been found to extend product longevity compared to similar products without the label (Sogn-Grundvåg *et al.*, 2019). Table 4 also shows that cod of regular quality was 34.7 per cent more expensive than cod that was downgraded.

Because the model specification is in the log–log form, the estimated coefficients for the continuous variables are explained as elasticities. Thus, a 1 per cent increase in fish size leads to a price increase of 3 per cent. As shown in the estimation results of Model C, a 1 per cent increase in the size of lots has a significant but marginal effect (0.14 per cent) on the price of cod. As expected, longer storage time results in a lower price, but the effect is rather small. The average storage time is only 16.25 days, which is low compared to how long frozen cod can be stored without significant quality reduction (Badii and Howel, 2002). The year and month dummies are mostly significant, probably reflecting changes in supply.

### 4.2. Estimation results for the auction and direct sales markets

Tables 5 and 6 report the results of separate regressions for Models A, B and C for the two markets. Table 5 shows that the adjusted $R^2$ value for Model A is 0.7441 for the auction market. When buyer and seller fixed effects are introduced in Model B, the adjusted $R^2$ value increases to 0.7912 (+6.3 per cent), and when buyer–seller fixed effects are added in Model C, the adjusted $R^2$ value increases further to 0.7986 (+0.9 per cent). The match effects account for 13.6 per cent of the overall contribution of unobserved heterogeneity terms.

Table 6, reporting the regressions for the direct sales market, shows that the adjusted $R^2$ value increases from 0.7458 in Model A to 0.78 in Model B (+4.6 per cent) when buyer and seller fixed effects are introduced. When match effects are added in Model C, the adjusted $R^2$ value increases to 0.7964 (+2.1 per cent). The calculated contribution of match effects to explaining variation in prices is substantial, accounting for 32.4 per cent of the overall contribution of unobserved heterogeneity terms, which is much higher than the corresponding value in the models for the auction market. This indicates that buyer–seller relationships may lead to a more informationally efficient market in direct sales than in the auction.

Tables 5 and 6 also report the effects of observable quality attributes. F-test results for the three models in both markets indicate that Model C fits the data better than the other models with fewer variables. Thus, we focus on Model C.

**Table 5.** Estimation results of Models A, B and C for auction

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Intercept | 2.6110 | [0.0154] *** | 2.5298 | [0.0182] *** | 2.5269 | [0.0181] *** |
| Fish-Size | 0.0376 | [0.0013] *** | 0.0253 | [0.0013] *** | 0.0263 | [0.0013] *** |
| Transaction-Quantity | –0.0045 | [0.0008] *** | –0.0008 | [0.0007] | –0.0001 | [0.0007] |
| Storage-Time | –0.0154 | [0.0021] *** | –0.0214 | [0.002] *** | –0.0207 | [0.002] *** |
| Bottom-Trawl | 0.0163 | [0.0067] ** | 0.0440 | [0.0139] *** | 0.0423 | [0.0138] *** |
| Longline | 0.0991 | [0.0069] *** | 0.1247 | [0.0135] *** | 0.1208 | [0.0134] *** |
| Danish-Seine | –0.0402 | [0.0075] *** | –0.0096 | [0.0140] | –0.0173 | [0.014] |
| Quality | 0.3350 | [0.0066] *** | 0.3303 | [0.0069] *** | 0.3283 | [0.0069] *** |
| Year-2010 | 0.1524 | [0.0104] *** | 0.1439 | [0.0084] *** | 0.1395 | [0.0083] *** |
| Year-2011 | 0.2280 | [0.0099] *** | 0.2163 | [0.0081] *** | 0.2159 | [0.008] *** |
| Year-2012 | 0.0701 | [0.0107] *** | 0.0754 | [0.0094] *** | 0.0793 | [0.0094] *** |
| Year-2013 | –0.1919 | [0.009] *** | –0.168 | [0.008] *** | –0.1736 | [0.008] *** |
| Year-2014 | 0.0207 | [0.0097] ** | 0.0383 | [0.0087] *** | 0.0345 | [0.0088] *** |
| Year-2015 | 0.3200 | [0.0091] *** | 0.3284 | [0.0083] *** | 0.3236 | [0.0082] *** |
| Year-2016 | 0.3786 | [0.0092] *** | 0.3911 | [0.0085] *** | 0.3850 | [0.0085] *** |
| Year-2017 | 0.4665 | [0.0092] *** | 0.478 | [0.0085] *** | 0.4724 | [0.0085] *** |

(continued)

**Table 5.** (Continued)

| Variable | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE |
| January | –0.0861 | [0.007] *** | –0.0828 | [0.0065] *** | –0.0792 | [0.0065] *** |
| February | –0.0871 | [0.0081] *** | –0.0772 | [0.0072] *** | –0.0756 | [0.0071] *** |
| March | –0.0983 | [0.0077] *** | –0.0879 | [0.0074] *** | –0.0827 | [0.0074] *** |
| April | –0.0924 | [0.0075] *** | –0.0847 | [0.0073] *** | –0.0813 | [0.0074] *** |
| May | –0.0660 | [0.0073] *** | –0.049 | [0.007] *** | –0.0462 | [0.007] *** |
| June | –0.0669 | [0.0068] *** | –0.0426 | [0.0064] *** | –0.0405 | [0.0064] *** |
| July | –0.0782 | [0.0071] *** | –0.0585 | [0.0068] *** | –0.0574 | [0.0068] *** |
| August | –0.0521 | [0.0069] *** | –0.0297 | [0.0064] *** | –0.0266 | [0.0064] *** |
| September | –0.0259 | [0.0065] *** | –0.0020 | [0.0060] | 0.0009 | [0.006] |
| October | 0.0076 | [0.0064] | 0.0125 | [0.0059] ** | 0.0154 | [0.0059] *** |
| November | 0.0380 | [0.0066] *** | 0.0381 | [0.006] *** | 0.0406 | [0.006] *** |
| Buyer dummies | No | | Yes | | Yes | |
| Seller dummies | No | | Yes | | Yes | |
| Pair dummies | No | | No | | Yes | |
| Adj. $R^2$ | 0.7441 | | 0.7912 | | 0.7986 | |

*Note*: The symbols ** and *** indicate significance levels of 0.05 and 0.01, respectively.

**Table 6.** Estimation results of Models A, B and C for direct sales

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Intercept | 2.4403 | [0.0173] *** | 2.4452 | [0.0182] *** | 2.5021 | [0.0195] *** |
| Fish-Size | 0.0370 | [0.0011] *** | 0.0313 | [0.0012] *** | 0.0316 | [0.0011] *** |
| Transaction-Quantity | 0.0060 | [0.0007] *** | 0.0051 | [0.0006] *** | 0.0020 | [0.0006] *** |
| Storage-Time | −0.0059 | [0.0012] *** | −0.0176 | [0.0013] *** | −0.0213 | [0.0013] *** |
| Bottom-Trawl | 0.0233 | [0.0095] ** | 0.0477 | [0.0122] *** | 0.0385 | [0.0143] *** |
| Longline | 0.1216 | [0.0096] *** | 0.1566 | [0.0113] *** | 0.1285 | [0.0131] *** |
| Danish-Seine | −0.0975 | [0.0111] *** | −0.0556 | [0.0119] *** | −0.0656 | [0.0137] *** |
| Quality | 0.3629 | [0.0096] *** | 0.3504 | [0.01] *** | 0.3462 | [0.0100] *** |
| Year-2010 | 0.1002 | [0.0112] *** | 0.0969 | [0.0104] *** | 0.1096 | [0.0105] *** |
| Year-2011 | 0.1775 | [0.0107] *** | 0.1686 | [0.0100] *** | 0.1807 | [0.0101] *** |
| Year-2012 | −0.0047 | [0.0111] | −0.0080 | [0.0105] | 0.0090 | [0.0106] |
| Year-2013 | −0.1734 | [0.0098] *** | −0.1714 | [0.0095] *** | −0.1630 | [0.0098] *** |
| Year-2014 | 0.0337 | [0.0102] *** | 0.0384 | [0.0100] *** | 0.0464 | [0.0103] *** |
| Year-2015 | 0.3353 | [0.010] *** | 0.3326 | [0.0098] *** | 0.3425 | [0.0100] *** |
| Year-2016 | 0.3987 | [0.0099] *** | 0.3948 | [0.0098] *** | 0.4018 | [0.0101] *** |
| Year-2017 | 0.4770 | [0.0100] *** | 0.4736 | [0.0100] *** | 0.4774 | [0.0103] *** |

(continued)

**Table 6.** (Continued)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| January | –0.0965 | [0.0052] *** | –0.1008 | [0.0050] *** | –0.0988 | [0.005] *** |
| February | –0.0595 | [0.0062] *** | –0.0651 | [0.0057] *** | –0.0718 | [0.0056] *** |
| March | –0.0803 | [0.0068] *** | –0.0788 | [0.0064] *** | –0.0826 | [0.0065] *** |
| April | –0.0820 | [0.0061] *** | –0.0766 | [0.0059] *** | –0.0758 | [0.0058] *** |
| May | –0.0799 | [0.0055] *** | –0.0740 | [0.0054] *** | –0.0732 | [0.0053] *** |
| June | –0.0510 | [0.0050] *** | –0.0472 | [0.0049] *** | –0.0491 | [0.0049] *** |
| July | –0.0405 | [0.0051] *** | –0.0514 | [0.0051] *** | –0.0457 | [0.0050] *** |
| August | –0.0167 | [0.0051] *** | –0.0145 | [0.0048] *** | –0.0134 | [0.0048] *** |
| September | –0.0056 | [0.0050] | –0.0080 | [0.0049] * | –0.0098 | [0.0048] ** |
| October | –0.0107 | [0.0054] ** | –0.0042 | [0.0051] | –0.0068 | [0.0050] |
| November | 0.0089 | [0.0046] ** | 0.0133 | [0.0044] *** | 0.0131 | [0.0043] *** |
| Buyer dummies | No | | Yes | | Yes | |
| Seller dummies | No | | Yes | | Yes | |
| Pair dummies | No | | No | | Yes | |
| Adj. $R^2$ | 0.7458 | | 0.7800 | | 0.7964 | |

*Note*: The symbols *, ** and *** indicate significance at the levels of 0.10, 0.05 and 0.01, respectively.

The dummies for *Fish-Size* and *Quality* are significant and positive in Model C in both markets, but the coefficients are larger in the direct sales market than in the auction market, indicating that large fish or fish of regular quality are priced higher in direct sales than in the auction. In addition, the estimate for longline, signalling high quality, is slightly larger in direct sales (0.1285) than in the auction (0.1208). Moreover, *Transaction-Quantity* is only significant (and positive) in direct sales, indicating that the size of the lots is an effective determinant of prices only in direct sales.

### 4.3. Robustness checks

The price differences in the auction and direct sale markets may vary over time as shown in Figure 4.[11] Thus, following Kristofersson and Rickertsen (2004), Hammarlund (2015) and Sogn-Grundvåg *et al.* (2021), we estimated a multilevel hedonic price model for the whole sample (Model A) by setting the dynamic coefficients of *Auction* by years. The estimation results (see Table A1) show that the fixed effect of *Auction* is insignificant, indicating a lack of price differences between the auction and the direct sales market after controlling for the random effects of the variable *Auction*.

As shown in Figure 4, for both auction and direct sale, prices were more volatile before 2013. After this, prices showed an upward trend. This indicates a potential structural change in the market. We therefore re-estimate the models for auctions and direct sales, by replacing the individual year dummies with a dummy for the years after 2013.[12] Tables A2 and A3 report the estimation results. The coefficient of the dummy is significant in all models, with a value of about 0.25 for auction and about 0.30 for direct sale.

In this study, we focus on the determinants of prices in the auction and direct sales markets and relate the estimation results to information asymmetries in those markets. Price dispersion may also reflect the level of information asymmetries in the markets. As an additional investigation, we follow Teoh *et al.* (2017) and Federico (2012) and use the coefficient of variation (CV) as a measure of price dispersion. During the sample period, the mean value of CV is 0.1867 in the auction market, which is marginally smaller than in the direct sales market (0.1872). As shown in Figure A4, since 2011, the values of the CV in the two markets tended to converge. However, the auction market experienced a more volatile price dispersion than direct sales after 2013. Finally, we obtain the value of the CV and the mean value of each explanatory variable for each buyer–seller pair by year. We estimate Models A, B and C for the

11 As one reviewer pointed out, Figure 4 does not clearly reject non-stationary of the price series, which may affect the estimation results. In response, we calculate the daily mean auction price and use the Augmented Dickey–Fuller approach to test the stationarity. The results fail to reject the null hypothesis of stationarity. We further plot the monthly average price in the two markets in Figure A3, which clearly indicates the rejection of non-stationarity.

12 We cannot include both the new dummy and individual year dummies in the model due to perfect multicollinearity. Since the yearly dummies are significant price determinants, as discussed above, removing them from the estimation leads to omitted variable bias. Thus, the estimation results in Tables A2 and A3 may only validate the coefficient of the dummy for the years after 2013.

markets, with the CV as dependent variables. The estimation results (available upon request) indicate that the calculated contribution of buyer and seller fixed effects that explain variation in price dispersion accounts for 48 and 67 per cent of the overall contribution of unobserved heterogeneity terms in the auction and direct sales markets, respectively. In the two markets, the buyer–seller matches are jointly insignificant, indicating no impact of buyer–seller pairs on price dispersion.

## 5. Conclusion

The question of selling by auction or directly is complex. The answer may depend on price differences between the two mechanisms, as well as how informationally efficient they are. For the case of the auction and direct sale markets for frozen Atlantic cod, our results show that in a setting where the costs of selling through the auction or directly is the same, the auction gains a 2.6 per cent price premium over direct sales, holding other variables constant, indicating that the auction should be the preferred sales mechanism. However, we also find that buyer–seller matches explain 13.6 and 32.4 per cent of the variation in prices in the auction and direct sales, respectively, indicating that direct sales are a far more informationally efficient market than the auction.

This indicates that direct sales are superior to the auction in terms of resolving information asymmetries caused by unobserved product quality. In other words, in direct sales, the price of cod is a much more accurate reflection of its true value than in the auction. The simple reason for this is that information asymmetry regarding unobserved quality is to a larger extent resolved through the dialogue between buyers and sellers facilitated by direct sales. Resolving this information asymmetry has the advantages that sellers can avoid complaints and maintain their reputations, and buyers can avoid buying 'lemons' and get products better suited to their production plans. This also means that the direct sales market performs better than the auction in terms of quality-based pricing. This is relevant because quality-based pricing is important in incentivising fishers to provide high-quality fish to the market, contributing to the optimal use of limited marine resources (Sogn-Grundvåg, Zhang and Dreyer, 2020; Sogn-Grundvåg *et al.*, 2021). The informational efficiency of the auction market may, however, be improved by providing more fine-grained quality attributes that capture more of the unobserved quality.

The initial observation that the share of auction sales decreased from 52 per cent in 2009 to 31 per cent in 2017 indicates that the benefits of direct sales in resolving information asymmetry relating to unobserved product quality are more important to buyers and sellers than the small price premium provided by the auction. These results indicate that merely comparing prices between different sales mechanisms may not fully capture the benefits of auctions, compared with direct sales. The econometric procedure with stepwise hedonic models presented here may be a more useful way of assessing performance differences between sales mechanisms.

In this study, we focus on the comparison of prices in the auction and direct sale markets for frozen Atlantic cod. Some unobservable factors may affect the choice of sale channels and may also influence prices. In addition, the unobservable factors may also relate to fish attributes, indicating omitted-variable bias for variables coded for these attributes. How to control for selection bias and endogeneity and to examine the determinants of choosing sales channels and the prices is an interesting direction for future research.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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## Appendix

**Table A1.** Estimation results of the multilevel regression for the full sample (Model A)

| Variable | Estimate | SE |
|---|---|---|
| Intercept | 2.4897 | [0.0274] *** |
| Auction | 0.0204 | [0.058] |
| Fish-Size | 0.0495 | [0.0011] *** |
| Transaction-Quantity | 0.0011 | [0.0006] * |
| Storage-Time | −0.0282 | [0.0014] *** |
| Bottom-Trawl | 0.1063 | [0.0092] ** |
| Longline | 0.1179 | [0.0087] *** |
| Danish-Seine | −0.0673 | [0.0091] *** |
| Quality | 0.3381 | [0.0057] *** |
| January | −0.0671 | [0.0051] *** |
| February | −0.0243 | [0.0057] *** |
| March | −0.0307 | [0.0065] *** |
| April | −0.0146 | [0.0063] *** |
| May | −0.0155 | [0.006] *** |
| June | 0.0040 | [0.0055] *** |
| July | −0.0131 | [0.0056] *** |
| August | 0.0221 | [0.0056] *** |
| September | 0.0308 | [0.0052] *** |
| October | 0.0215 | [0.0049] *** |
| November | 0.0483 | [0.0047] *** |
| Buyer dummies | Yes | |
| Seller dummies | Yes | |
| Pair dummies | Yes | |

*Note*: The symbols *, ** and *** indicate significance at the levels of 0.10, 0.05 and 0.01, respectively.

**Table A2.** Estimation results of Models A, B and C for auction (with a dummy for 2014–2017)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Intercept | 2.6253 | [0.0189] *** | 2.5768 | [0.0256] *** | 2.5777 | [0.0251] *** |
| Fish-Size | 0.0242 | [0.0019] *** | 0.0132 | [0.0018] *** | 0.0141 | [0.0018] *** |
| Transaction-Quantity | −0.0086 | [0.0012] *** | −0.0031 | [0.0011] *** | −0.0020 | [0.0011] * |
| Storage-Time | −0.0293 | [0.0028] *** | −0.0355 | [0.0026] *** | −0.0351 | [0.0026] *** |
| Bottom-Trawl | 0.0370 | [0.011] *** | 0.0417 | [0.023] * | 0.0356 | [0.0224] |
| Longline | 0.1010 | [0.0112] *** | 0.1025 | [0.0227] *** | 0.1038 | [0.0222] *** |
| Danish-Seine | −0.0911 | [0.0122] *** | −0.0812 | [0.0235] *** | −0.0918 | [0.0232] *** |
| Quality | 0.4036 | [0.01] *** | 0.3920 | [0.0095] *** | 0.3844 | [0.0094] *** |
| Dummy-Years | 0.2625 | [0.0046] *** | 0.2514 | [0.0053] *** | 0.2526 | [0.0054] *** |
| January | −0.0891 | [0.0097] *** | −0.0722 | [0.0088] *** | −0.0667 | [0.0087] *** |
| February | −0.0640 | [0.011] *** | −0.0402 | [0.0097] *** | −0.0394 | [0.0096] *** |
| March | −0.0726 | [0.0114] *** | −0.0484 | [0.0107] *** | −0.0415 | [0.0106] *** |
| April | −0.0446 | [0.0103] *** | −0.0255 | [0.0096] *** | −0.0217 | [0.0099] ** |

(continued)

**Table A2.** (Continued)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| May | –0.0277 | [0.0101] *** | 0.0053 | [0.0093] | 0.0052 | [0.0093] |
| June | –0.0378 | [0.0098] *** | –0.0017 | [0.009] | –0.0009 | [0.0089] |
| July | –0.0547 | [0.0105] *** | –0.0365 | [0.01] *** | –0.0363 | [0.0101] *** |
| August | –0.0253 | [0.0092] *** | –0.0007 | [0.0082] | –0.0005 | [0.0082] |
| September | –0.0144 | [0.0082] * | 0.0257 | [0.0077] *** | 0.0284 | [0.0077] *** |
| October | 0.0185 | [0.0077] ** | 0.0253 | [0.0071] *** | 0.0289 | [0.0072] *** |
| November | 0.0416 | [0.0079] *** | 0.0535 | [0.007] *** | 0.0558 | [0.0071] *** |
| Buyer dummies | No | | Yes | | Yes | |
| Seller dummies | No | | Yes | | Yes | |
| Pair dummies | No | | No | | Yes | |
| Adj. $R^2$ | 0.4265 | | 0.555 | | 0.5712 | |

*Note*: The symbols *, ** and *** indicate significance at the levels of 0.10, 0.05 and 0.01, respectively.

**Table A3.** Estimation results of Models A, B and C for direct sales (with a dummy for 2014–2017)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| Intercept | 2.3919 | [0.0189] *** | 2.3947 | [0.0194] *** | 2.4561 | [0.0215] *** |
| Fish-Size | 0.0357 | [0.0016] *** | 0.0335 | [0.0015] *** | 0.0332 | [0.0015] *** |
| Transaction-Quantity | 0.0043 | [0.0009] *** | 0.0046 | [0.0008] *** | 0.0016 | [0.0008] ** |
| Storage-Time | −0.0091 | [0.0015] *** | −0.0219 | [0.0017] *** | −0.0233 | [0.0017] *** |
| Bottom-Trawl | 0.0840 | [0.013] *** | 0.1226 | [0.016] *** | 0.1171 | [0.0191] *** |
| Longline | 0.1879 | [0.0132] *** | 0.2161 | [0.015] *** | 0.1921 | [0.0176] *** |
| Danish-Seine | −0.0924 | [0.0154] *** | −0.0520 | [0.016] *** | −0.0683 | [0.0185] *** |
| Quality | 0.3489 | [0.0114] *** | 0.3565 | [0.0114] *** | 0.3484 | [0.0113] *** |
| Dummy-Years | 0.3210 | [0.0036] *** | 0.2990 | [0.0042] *** | 0.2930 | [0.0044] *** |
| January | −0.1145 | [0.0073] *** | −0.1102 | [0.0069] *** | −0.1035 | [0.0068] *** |
| February | −0.0093 | [0.008] | −0.0316 | [0.0076] *** | −0.0376 | [0.0075] *** |
| March | −0.0421 | [0.0101] *** | −0.0414 | [0.0092] *** | −0.0446 | [0.0093] *** |
| April | −0.0334 | [0.009] *** | −0.0340 | [0.0083] *** | −0.0356 | [0.0082] *** |
| May | −0.0689 | [0.0079] *** | −0.0548 | [0.0073] *** | −0.0537 | [0.0071] *** |

(continued)

**Table A3.** (Continued)

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| Variable | Estimate | SE | Estimate | SE | Estimate | SE |
| June | –0.0277 | [0.0072] *** | –0.0204 | [0.0065] *** | –0.0258 | [0.0064] *** |
| July | –0.0286 | [0.0075] *** | –0.0429 | [0.0068] *** | –0.0323 | [0.0067] *** |
| August | 0.0263 | [0.0071] *** | 0.0149 | [0.0064] ** | 0.0125 | [0.0062] ** |
| September | 0.0129 | [0.0062] ** | 0.0116 | [0.006] ** | 0.0127 | [0.0058] ** |
| October | –0.0094 | [0.0061] | –0.0032 | [0.0056] | –0.0047 | [0.0055] |
| November | 0.0361 | [0.0055] *** | 0.0291 | [0.0052] *** | 0.0306 | [0.0051] *** |
| Buyer dummies | No | | Yes | | Yes | |
| Seller dummies | No | | Yes | | Yes | |
| Pair dummies | No | | No | | Yes | |
| Adj. $R^2$ | 0.483 | | 0.5968 | | 0.6243 | |

*Note*: The symbols *, ** and *** indicate significance at the levels of 0.10, 0.05 and 0.01, respectively.

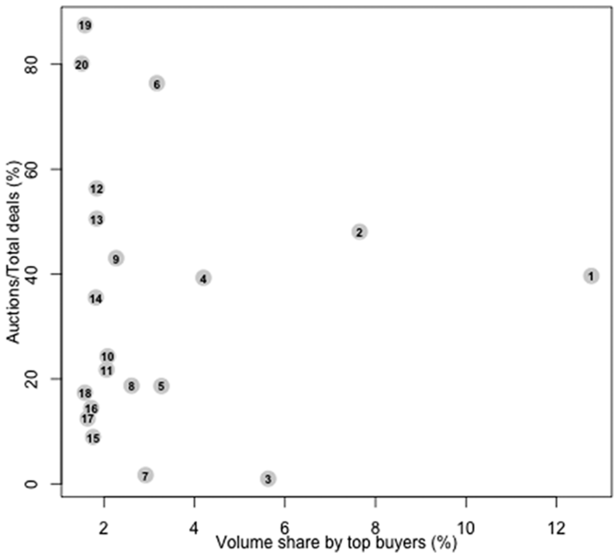


**Fig. A1.** The share of auction transactions versus volume share for the 20 largest buyers, 2009–2017.

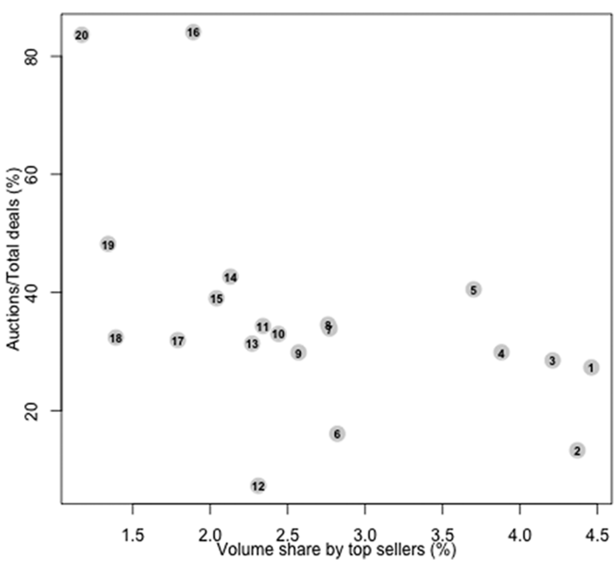


**Fig. A2.** The share of auction transactions versus volume share for the 20 largest sellers, 2009–2017.

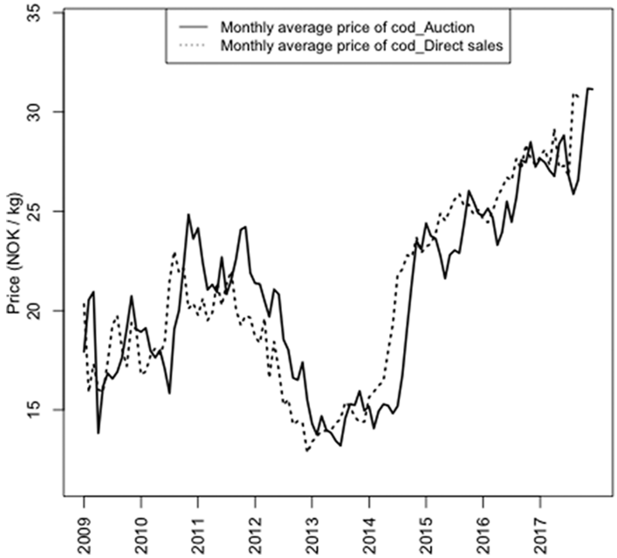


**Fig. A3.** The monthly average prices for cod at the auction and in direct sales, 2009–2017.


**Fig. A4.** Price dispersion (coefficient of variance) in the auction and direct sales markets, 2009–2017.