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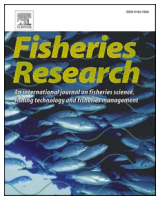

# A classification of buyers in first-sale fish markets: Evidence from France☆

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ABSTRACT

While numerous studies have addressed the issue of price formation in first-sale fish markets, little is known about the purchasing decisions of buyers. Using exhaustive data on 11.7 million transactions made in 2021 and 2022 by 1955 buyers in France, we provide an unsupervised classification that reveals the heterogeneous behavior of buyers in terms of quantity purchased, average price paid, number of markets visited, and type of transaction. The results of a hierarchical agglomeration cluster analysis led to eight buyer groups. We show that there are a small number of very active buyers, both at auction and over-the-counter, who purchase daily in large quantities and at many different markets, and whose main activity is wholesale. We find that the price-quantity elasticity values for first sales are very low, but the price paid by large buyers is even less sensitive to quantity than that observed for other buyer groups.

## 1. Introduction

From an economic perspective, a perfectly competitive market is characterized by certain conditions such as a large number of buyers and sellers, homogeneous products, perfect information, and no barriers to entry or exit, among others. In such an environment, both buyers and sellers are price takers, meaning that they accept prevailing market prices that reflect aggregate supply and demand. Because of their small size, individual buyers and sellers have no influence on market prices. While fish markets have historically been proposed as good candidates for competitive markets (Marshall, 1930), numerous studies have shown that first-sale fish markets are characterized by imperfect competition, with different buyers paying different prices for fish products of similar quality (Graddy, 1995, 2006; Gallegati et al., 2011; Giulioni and Bucciarelli, 2011; Vignes and Etienne, 2011; Cirillo et al., 2012; Fluvià et al., 2012; Lesur-Irichabeau et al., 2016; Salladarré et al., 2017; Sogn-Grundvåg et al., 2019).

To understand how changes in market conditions or supply and demand factors affect first- sale fish prices, economists rely on hedonic price equations à la Rosen (1974). The hedonic approach provides the implicit value of different characteristics of the seafood products, such as species, size, freshness, and fishing method (McConnell and Strand, 2000; Kristofersson and Rickertsen, 2004, 2007; Roheim et al., 2007; Asche and Guillen, 2012; Lee, 2014; Asche et al., 2015; Gobillon and Wolff, 2016; Gobillon et al., 2017; Sogn-Grundvåg et al., 2021, Asche et al., 2021; Kehoe et al., 2023). Curiously, the role of buyers in the formation of first-sale fish prices has received less attention. Gobillon et al. (2017) show that buyer heterogeneity captured by buyer fixed effects in hedonic pricing models plays a significant role in explaining the variation in fish prices, with a contribution typically above 10%. However, their study is silent on the characteristics of these buyers.

Our paper focuses on the purchasing decisions of buyers in first-sale fish markets (also called ex-vessel fish markets), where the landed seafood products are sold at an auction center to registered buyers (EUMOFA, 2023). A wide variety of companies and individuals are involved in markets for seafood products as buyers: wholesalers buy fish products in bulk and then resell them to other large customers; seafood processors process, package, and distribute their products to other buyers; supermarket chains and grocery stores may have dedicated seafood departments where they offer a variety of seafood options to their customers; independent fishmongers may operate as part of a larger market; retailers buy fish to sell to individual consumers through

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their own storefronts; restaurants and caterers sometimes buy seafood directly from fish markets to serve to their customers; and there may be international exporters and importers as buyers. We document for the first time how buyers operate in multi-species, multi-market contexts. Using transaction data, we provide a classification of buyers in first-sale fish markets and examine how different buyer groups differ in their price sensitivity to quantity.

Our study deals with the case of the French seafood primary market. With a long coastline along the Atlantic Ocean, the English Channel, and the Mediterranean Sea, France is an important country in terms of fisheries. France is the fourth largest producer of fish and aquaculture products (INSEE, 2020). In 2020, France produced 0.7 million tonnes of fish with a value of $1887 million USD: more than two thirds of this value originates from fisheries.[1] In the same year, employment in the seafood sector accounted for about 48,000 jobs (including processing) and the fleet consisted of more than 6000 vessels. We document the role of buyers in first-sale fish markets using a database containing all transactions (11.7 million) conducted in France in 2021 and 2022, with identifiers of sellers (vessels) and buyers for each transaction. Over the selected period, there were nearly 2000 buyers in these markets, but there was a very high concentration as nearly three-quarters of the sales (in value) were made by the 10% largest buyers.

First, starting with the transaction data, we construct a set of characteristics for each buyer that summarize their purchasing decisions. These include the daily quantity of fish purchased, the average price paid, the daily number of markets visited, the daily number of species, and the type of transaction (auction versus over-the-counter). Second, we apply a principal component analysis to the selected outcomes. The first two factors reflect the intensity of the buyer's presence in the markets (in terms of time, geography and number of products) and the economic decisions made (in terms of price and quantity). We consider a hierarchical clustering analysis that leads to a classification of eight buyer groups. Third, we provide a characterization of each group. We show that while three of the groups represent 83.4% of the sales value, they account for about only a quarter of the buyers. Large buyers pay lower prices on average than small buyers. Fourth, we investigate the possibility that the different groups are characterized by different price-quantity elasticities. Large buyers may behave differently due to their expertise (Lesur-Irichabeau et al., 2016; Sogn-Grundvåg et al., 2019). We find that the two groups with the largest buyers are less sensitive to price than the other groups.

Studying the role of buyers in first-sale fish markets is important for several reasons. Buyers are a key component of the supply and demand dynamics. By understanding the role of buyers, both sellers and auction organizers can gain insight into market trends, price fluctuations, and overall market dynamics. Fish auction markets rely on the competitive bidding process to determine fish prices, and efficient markets depend on the active participation of buyers. Some knowledge of buyers' needs and purchasing patterns allows auction organizers to effectively structure auctions and market operations, which promotes market efficiency and reduces transaction costs. Buyers' participation contributes to market transparency, which ensures fair trading practices and can build trust between buyers and sellers. Finally, understanding the role of buyers and their preferences can help to identify potential areas for market development and growth. Insight into preferences and demands enables market organizers to diversify fish supply and improve product quality, which can lead to increased market activity and trade volume.

Our empirical analysis contributes to a very scarce literature dealing with the perspectives of buyers in first-sale fish markets.[2] Three papers are particularly relevant. Lesur-Irichabeau et al. (2016) estimate hedonic equations explaining the price of scallops in French fisheries, including the type of buyer as a covariate. They find that fish merchants selling directly to consumers are more willing to pay a higher price than wholesalers or transformers. Salladarré et al. (2017) study the relevance of the declining price anomaly in sequential auctions, using the Norway lobster market in Lorient (France) as a case study. The authors show that the presence of fishmongers during the auction sales increases prices due to higher private values, but supermarkets bid more aggressively than fishmongers for a longer period of the day, especially when they need important quantities related to discount campaigns. Finally, Sogn-Grundvåg et al. (2019) investigate the role of buyers in the Norwegian pelagic auction (a sealed-bid electronic auction market). Focusing on the case of mackerel, the authors show that the largest buyers pay lower prices than smaller buyers and benefit from a price discount for fish size. One explanation is that the largest catches can only be handled by the largest buyers, leading to reduced competition in this market segment.

By focusing exclusively on buyers' purchasing decisions, we complement these studies with a broader perspective since we are considering all species sold in all first-sale fish markets in France. The rest of our paper is organized as follows. In Section 2, we briefly review the context of fish markets in France and describe the transaction data. Section 3 presents the hierarchical cluster analysis applied to our data. In Section 4, we provide a characterization of the different buyer groups, including their main activity. Section 5 examines the relationship between price paid and quantity, showing that the price-quantity elasticity remains low in all cases, but is even lower for the two groups with the largest buyers. In Section 6, we provide elements regarding limits of this study and perspectives for future research.

## 2. Description of the data

In France, there are currently 35 first-sale fish markets for seafood products, called "halles à marée" (FranceAgriMer, 2022a): 12 are located along the Channel and the North Sea, 19 along the Atlantic coast, and 4 along the Mediterranean. These markets are mainly supplied by the French metropolitan fleet, which consisted of 4163 vessels and employed 9537 fishermen in 2020 (IFREMER, 2022). In 2022, 169 509 tons of fish were sold by French vessels on first-sale fish markets and the value of these sales was 674 million euros (FranceAgriMer, 2022b). The five most important fish markets in terms of value are Le Guilvinec, Lorient, Boulogne, Les Sables d'Olonne, and Erquy.[3] In each market, the fish landed by the fishermen are offered for sale after being weighed and sorted into lots according to species, size, presentation (whole, gutted, filleted, etc.) and quality (freshness) (STECF, 2022). In 2022, the top three species landed in terms of value were scallops, monkfish and sole (see FranceAgriMer, 2022b).

The main form of market organization in the French first-sale markets is auction, but there are also some over-the-counter (OTC) transactions and direct sales transactions. In the former case (OTC), prices and quantities are determined through bilateral negotiations between buyers and sellers. Between 2010 and 2018, OTC sales accounted for more than 10% of the total value sold and more than 20% of the total value in France (Wolff and Asche, 2022). They are more common in certain locations (such as Boulogne) and generally involve many low-valued species (such as pilchard). Direct sales transactions concern seafood products sold directly by fishermen in quantities greater than 30 kg. Buyers must declare these transactions, which involve fishmongers, wholesalers, or processors. Seafood products are exchanged in special trading rooms where professional buyers (wholesalers, primary processors, supermarket chains, individual fishmongers, restaurant

[1] See https://www.oecd.org/agriculture/topics/fisheries-and-aquaculture/.

[2] We leave aside studies on loyalty in fish markets (Gallegati, 2011; Vignes and Etienne, 2011; Cirillo et al., 2012; Fluvià et al., 2012), which deal with interactions between buyers and sellers (the focus is not on buyers).

[3] For further detail, see https://www.franceagrimer.fr/Mediatheque/INFORMATIONS-ECONOMIQUES/PECHE-ET-AQUACULTURE/INFORMATIONS-DE-CONJONCTURE/2023/Note-de-conjoncture-CS-filiere-peche-et-aquaculture-du-09-Fevrier-2023.

owners, international exporters and importers) can either be present or place their purchase orders remotely. Most lots of fish are sold between Monday and Friday, usually in the mornings, and deals are made in a very short period of time.

In France, all transactions are recorded by the network of French fish markets (VISIOMer, sales data from the Réseau Inter-Criées - RIC), which is managed by the national agency for agricultural and seafood products, FranceAgriMer. This organization is responsible for supervising the management of market regulation systems and monitoring the market. The RIC database provides information on the characteristics of each fish lot sold at a fish market: date of sale (day), market location, fish species, size, presentation, quality, quantity of the fish lot (in kilograms) and sales value (in euros), from which we calculate the price per kilogram. In addition, there are identifiers for both the seller (vessel) and the buyer involved in each transaction. Each buyer is identified by a SIRET number, a business identification number issued by the French National Institute for Statistics and Economic Studies (Institut National de la Statistique et des Etudes Economiques, INSEE). By definition, the SIRET is the identifier of a company establishment. Since a given company may have several establishments in different locations, we instead define buyers using the SIREN number, which is a unique company number (Decree No. 97–497 of May 16, 1997).[4]

Our empirical analysis is based on the pooled datasets of all transactions completed either at auction or OTC in 2021 and 2022. The initial dataset consists of 11,768,975 transactions, from which we exclude a few transactions that either have incomplete information or correspond to unsold items or withdrawals. The final dataset contains 11,731,356 transactions. As shown in Table 1, most of the transactions take place in auctions, while the share of OTC transactions is only 5.6% (5.4% in 2021, 5.8% in 2022). The total value of fish sold amounts to 1.5 billion euros over the two years (698.0 million euros in 2021, 816.3 million euros in 2022). OTC sales represent 28.2% of this total (this is due to a volume effect). The average weight of a lot sold at auction is 21.4 kg, while an OTC lot weighs 240.5 kg. The share of OTC transactions in the total volume is 39.9%. Conversely, the average price per kilo is much lower for OTC than for auction, 2.70 euros instead of 4.60 euros.

During the whole period, 1955 different buyers were involved in fish markets in France: 1696 purchased at auction and 763 purchased by mutual agreement. In Table 1, we also distinguish buyers according to whether they appear exclusively in one or both types of sales. We find that 61.4% of buyers (1202/1955) were involved only in auction transactions, 13.2% (259/1955) only in OTC transactions, and 25.3% (494/1955) in both types of transactions. In terms of value, the share of buyers involved in both auction and OTC transactions amounts to 71.0% of the total volume.

The contribution of buyers to sales value is very heterogeneous. Fig. 1 shows the cumulative share of purchases from all buyers. There is a high concentration of purchases among a very small number of buyers. The 50% of the smallest buyers accounted for only 2.1% of total purchases. Conversely, the top 10% of buyers accounted for 77.6% of purchases, and 31.5% of purchases were made by only 1% of buyers. There is a higher concentration of sales value in OTC transactions than in auction transactions. The top 10% of buyers accounted for 84.0% of OTC transactions compared to 73.7% of auction transactions. We obtain similar results when comparing buyers who participate in either auctions only or OTC only. The contribution of the top 10% of buyers to total value is 58.5% for auctions only against 88.9% for OTC only.

To characterize the behavior of buyers, we transform the database of transactions (N=11,731,356) into a database of buyers (N=1955). For each buyer, we construct the following 11 variables that may reflect common market behaviors: total quantity purchased per day; average quantity of lots purchased; average number of species purchased per day; average price over the entire period; average number of local markets in which the buyer operates per day; proportion of transactions made at auction out of the total volume; total number of days in which the buyer made at least one transaction; average number of days with purchases per week; average number of vessels with which a buyer makes at least one transaction per day; proportion of purchases of extra quality out of the total volume; and proportion of purchases from vessels fishing with passive gear out of the total volume.

Since there may be very atypical buyers in the market, we turn to an outlier detection method. Specifically, we rely on the Blocked Adaptative Computationally efficient Outlier Nominators algorithm (BACON) described in Billor et al. (2000). The method detects outliers in multivariate data using an iterative algorithm, and we consider the 11 explanatory variables described above jointly to identify outliers. We consider the 0.80 percentile of the chi-squared distribution as the threshold for separating outliers from nonoutliers. The number of outliers detected is 43, so our final sample includes 1912 buyers.[5] Table 2 provides a description of the selected variables. The average quantity purchased per day is 563.9 kg, but the standard deviation is almost three times higher than the average. The median quantity purchased is 149.3 kg, the 95th percentile is 2.5 tonnes per day, and the 99th percentile is 7.8 tonnes per day. The average quantity per fish lot is 47.2 kg.

On average, buyers purchase 8.2 species per day, with a maximum of almost 50. The 95th percentile is 18.2 species per day. The average price is 6.20 euros, with a standard deviation of 3.70 euros. Buyers are not very mobile between auction markets. The average number of markets where they buy is 1.4 and the median is 1. A small number of buyers are really mobile, as the 95th percentile is 3.3 and the 99th percentile is 6.7. Auctions are the dominant transaction mode in French markets. The share of auctions in the total volume per buyer is 82.1%, but the median is 100%. A buyer spends an average of 215 days in the markets over the two-year period (about 4 months per year). Again, there is strong heterogeneity as the first quartile is 50 days and the third quartile is 367 days. At the top of the distribution, the 95th and 99th percentiles are 522 days and 593 days, respectively. The mean number of days with purchases per week is 9.3. Finally, the share of high-quality fish in the total volume is 65.3% and the share of volume from vessels using passive gear is 32.4%.

## 3. Hierarchical clustering of buyers

We rely on a hierarchical cluster analysis to group similar buyers into clusters. This method is an unsupervised learning technique commonly used in data analysis (Späth, 1980; Kaufman and Rousseeuw, 1990; Han et al., 2011; Everitt et al., 2011). We use an agglomerative clustering approach, which starts with each observation unit as a separate cluster and progressively merges the most similar clusters until a stopping criterion is met. Hierarchical clustering requires a measure of dissimilarity between groups of observations. This is achieved by using a distance metric (in our case, the Euclidean distance) and a linkage criterion that expresses the dissimilarity of groups as a function of the distances between observations in the groups. We choose to rely on the method proposed by Ward (1963), which seeks to minimize the variance within

[4] See https://www.legifrance.gouv.fr/loda/id/JORFTEXT000000201066. France has a national system for identifying and registering companies and their establishments which is managed by the National Institute for Statistics and Economic Studies (INSEE). The SIRET number corresponds to the nine digits of the SIREN number (company level) followed by five digits (specific to each establishment of the company).

[5] The choice of threshold has no influence on our results. For example, the number of outliers is 37 when using the 0.85 percentile and 46 when using the 0.75 percentile of the chi-squared distribution.

**Table 1**
Description of fish transactions 2021–2022.

| Variables | All | Auction | OTC | Auction only | OTC only | Both auction and OTC |
|---|---|---|---|---|---|---|
| Transactions | 11,731,356 | 11,076,486 | 654,870 | 5332,403 | 155,412 | 6243,541 |
| Value (in million euros) | 1514.3 | 1087.6 | 426.7 | 290.5 | 148.7 | 1075.2 |
| Quantity (in thousand tonnes) | 395.0 | 237.5 | 157.5 | 50.1 | 37.6 | 307.3 |
| Quantity per fish lot (in kilograms) | 33.7 | 21.4 | 240.5 | 9.4 | 242.1 | 49.2 |
| Average price (in euros) | 3.8 | 4.6 | 2.7 | 5.8 | 4.0 | 3.5 |
| Number of buyers | 1955 | 1696 | 753 | 1202 | 259 | 494 |

Source: RIC data 2021–2022, authors' calculations.

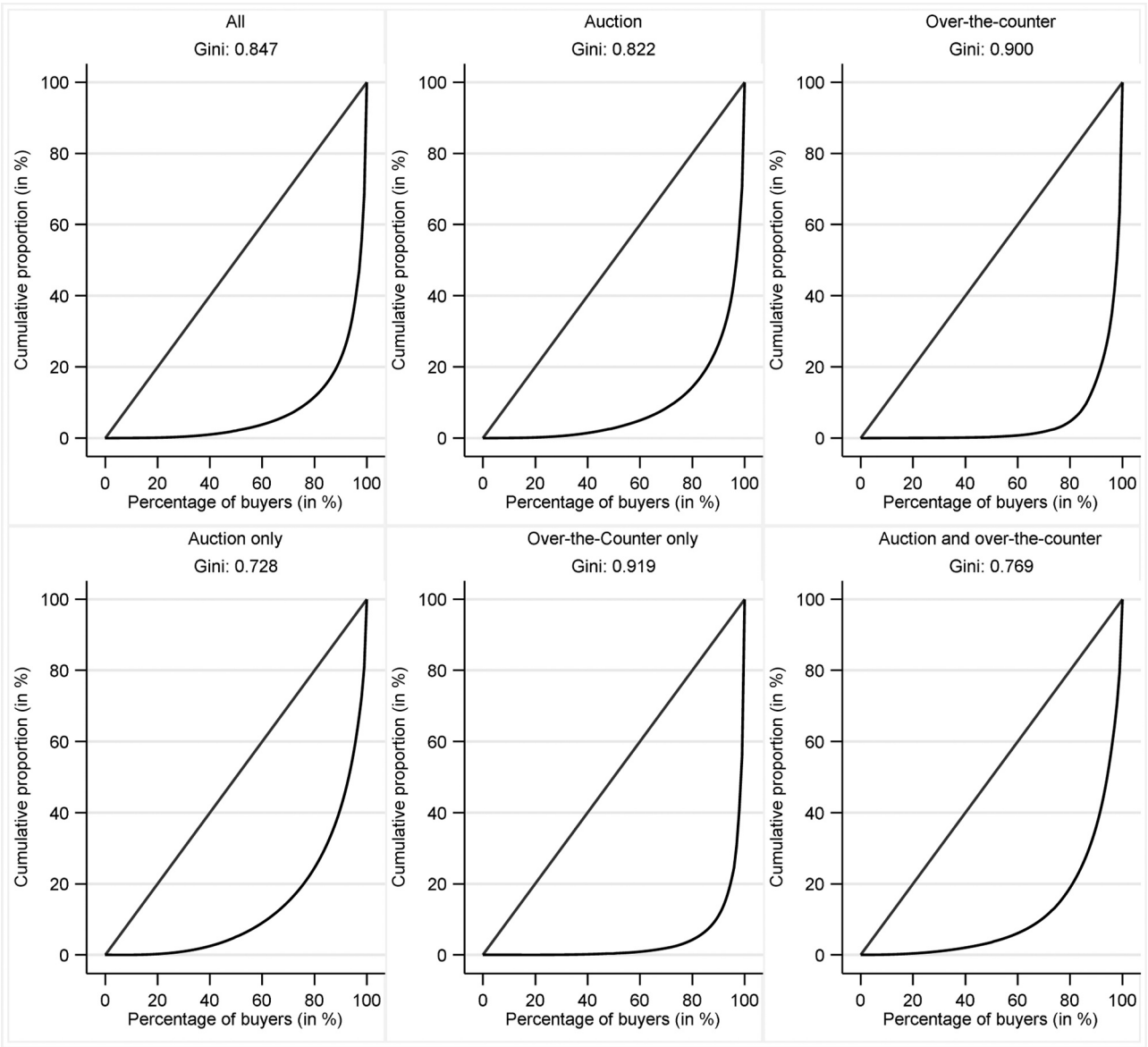


**Fig. 1. Lorenz curves of total fish value.** Source: RIC data 2021–2022, authors' calculations.

clusters during the agglomeration process.[6]

Since hierarchical clustering algorithms do not provide a natural stopping point (they continue to merge or split clusters until a predefined condition is met), a stopping rule is needed to determine when to halt the clustering process. A direct approach would be to specify the desired number of clusters before running the algorithm, but there are some statistical techniques that evaluate the quality of clustering at each step. The stopping point is based on certain criteria such as the Caliński-Harabasz pseudo-F index or the Duda-Hart index (Caliński and Harabasz, 1974; Duda et al., 2001).

In an unsupervised classification, the introduction of many explanatory factors does not always lead to a coherent grouping, since some

[6] The Ward linkage criterion aims to find the pair of clusters whose merging results in the smallest increase in the total within-cluster sum of squares, so that clusters remain as homogeneous as possible when groups of observations are aggregated.

**Table 2**
Description of variables at the buyer level.

| Variables | Mean | St.dev. | Min | Max |
|---|---|---|---|---|
| Average quantity per day (in kilos) | 563.9 | 1475.8 | 1.0 | 16870.9 |
| Average quantity per lot (in kilos) | 47.2 | 123.8 | 0.8 | 1264.7 |
| Average number of species purchased per day | 8.2 | 5.5 | 1.0 | 49.3 |
| Average price (in euros per kilo) | 6.2 | 3.7 | 0.1 | 50.7 |
| Average number of fish markets per day | 1.4 | 1.1 | 1.0 | 11.0 |
| Share of quantity purchased through auction (in %) | 82.1 | 35.4 | 0.0 | 100.0 |
| Number of days with purchase | 214.9 | 179.9 | 1.0 | 642.0 |
| Average number of days with purchase per week | 2.5 | 1.6 | 0.5 | 6.2 |
| Average number of vessels per day | 9.3 | 8.7 | 1.0 | 105.9 |
| Share of quantity with extra quality (in %) | 65.3 | 34.3 | 0.0 | 100.0 |
| Share of quantity from vessels using passive gear (in %) | 32.4 | 28.6 | 0.0 | 100.0 |

Source: RIC data 2021–2022, authors' calculations.

variables may play a minor role. Therefore, we decided to reduce the information provided by the 11 selected variables using principal component analysis. This statistical technique allows us to extract from a set of variables, a subset of orthogonal linear combinations of these variables, that capture the largest amount of information common to all variables (Dunteman, 1989, Jollife, 2002). We begin by calculating the eigenvalues of the correlation matrix obtained from our 11 covariates. The first principal component has a variance of 3.70 (33.7% of total variance) and the second principal component has a variance of 2.02 (18.4%). To determine the number of principal components to keep, we use the standard cutoff value of 1 for each eigenvalue. So, we consider the first five principal components, which explain 82.0% of the information contained in the data.

Fig. 2 shows the values of the variables for the first two components. Five variables are particularly correlated with the first component: the number of days with market purchases, the average number of days with purchase per week, the number of fish markets visited per day, the number of species purchased per day, and the number of vessels from which the buyer purchases per day. These five variables are highly positively correlated. The first axis describes the intensity of the buyer's presence in its different dimensions: temporal, geographical, and in terms of products. The second axis is negatively correlated with the average price per kilogram of the lots purchased, but positively correlated with the quantities (either the average quantities of the lots or the average daily quantity). The second axis is related to economic decisions.

Fig. 3 presents a clustergram showing how buyers are assigned to clusters as the number of groups increases (Schonlau, 2004). Large values of the Caliński-Harabasz pseudo-F and small values of the Duda-Hart pseudo-$T^2$ indicate distinct clustering. The Ward's clustering procedure applied to our data shows that the smallest pseudo-$T^2$ associated with the Duda-Hart stopping rule is 96.0 for the eight-group solution, with a Caliński-Harabasz pseudo-F of 423.7. Since the $T^2$ values after eight clusters are significantly higher (156.2 for nine groups or 136.6 for ten groups), we end up with a classification of buyers separated into eight distinct groups. As shown in Fig. 3, two groups have a much higher cluster mean than the others.

## 4. Buyer profiles in French fish markets

Table 3 shows the mean values per buyer group for the different explanatory variables included in the hierarchical classification. For ease of interpretation, we complement the results with a graphical representation of the buyer group using a spider plot (Fig. 4). We also consider two additional pieces of information: the main species sought by buyers (Table 4) and the main auction markets where purchases take place (Fig. 5).

The first group (Fig. 4, in blue) is the smallest of the eight clusters, with 55 buyers (2.9% of all buyers). They can be described as big auction market makers. They account for 25.8% of the transactions and have a market share of 36.3% in terms of volume and 37.7% in terms of value. On average, they buy almost 4.5 tonnes of fish per buying day at an average price of 5.40 euros per kilogram. They are very intensive in all dimensions of the fish markets. They are present every day of the week (5 days per week on average), and they shop throughout the year (514.7 days over two years). They also make transactions in more than six markets per day. They buy more than 20 species per day, and they buy from more than 40 different vessels per day on average. Their three main species are monkfish, scallops, and sole in terms of value and scallops, pilchard, and monkfish in terms of volume. As they operate in a large number of markets, the geographical concentration of their purchases is rather limited: about 50% of the transactions are made in seven markets (Le Guilvinec, Les Sables d'Olonne, Lorient, Erquy, Roscoff, Saint-Quay Portrieux, Concarneau), all located on the Atlantic coast.

The second group (in orange), with 107 buyers (5.6%), can be defined as big OTC market makers. They account for 4% of the transactions, but this represents 25.6% of the total volume and 15% of the sales value. The main characteristic they have in common with the first cluster is their high purchasing volume, with almost 3.3 tonnes of fish purchased per day. However, buyers of cluster 2 are highly specialized in their market buying behavior. They mainly make OTC transactions with vessels (88.2% of volume against 19.6% for cluster 1). They buy in about one market per day (1.2), a small number of different fish species (4 per day), and from a limited number of vessels (5.2 per day on average). They are much less present throughout the year, buying on average 2.6 days per week. They buy lots that are more than 10 times larger than those of cluster 1 (426.5 instead of 40.5 kg). This explains the much lower average price (2.50 euros per kilogram). The two most important species, both in terms of value and volume, are scallops and whelks. Pelagic fish are well represented in terms of volume (pilchard, mackerel, herring) and cephalopods in terms of value (squid, cuttlefish). As these are OTC transactions, the main place of purchase is Boulogne, and almost 30% of transactions are recorded as direct sales.

Groups 3 (204 buyers, 10.7%) and 4 (259 buyers, 13.5%) make a much smaller contribution to fish markets, each accounting for about 2.5% of the total value. They differ from clusters 5, 6, 7 and 8 in the importance of OTC transactions, which account for 40% of the quantities purchased in cluster 3 and 59.1% in cluster 4. In both cases, these are buyers who are essentially present in a single market, who target a reduced number of species (between 3 and 5) and who have a relatively low presence in markets with less than two purchasing days per week. The main difference between groups 3 and 4 is qualitative. For group 3, the average price is 3.30 euros per kilogram, and the fish is mainly purchased from trawlers with active gear (93% of the volume). Conversely, for group 4, the average price per kilogram is almost three times higher (9.60 euros per kilogram), while the average quantity per fish lot is three times smaller (28.9 instead of 85.8 kg). The vast majority of transactions are made with vessels boats using passive gear (75.0%). This has a strong influence on the main species purchased. Group 3 is dominated by scallops (37–38% in volume and value). Group 4 is dominated by whelk, but also includes yellowfin tuna, swordfish, spider crab, and edible crab.

Group 5 (in violet) contains 337 buyers (17.6%). It is the largest cluster in terms of number of transactions (42.1% of the total). It is the third group in terms of volume (25.0%) and the second group in terms of value (30.7%). Almost all of their purchases are made at auction (97.4%), and their presence in the markets is very consistent, with an average of 453.0 days over two years. On average, they buy in two local markets per day (1.9). The share of high-quality fish remains limited (about 50.7%). In this group, Norway lobster, sole, and monkfish are the most important species in terms of value, while hake, monkfish, and scallops are the most important species in terms of quantity. Buyers tend to go to markets located mainly in Brittany (Le Guilvinec, Lorient,

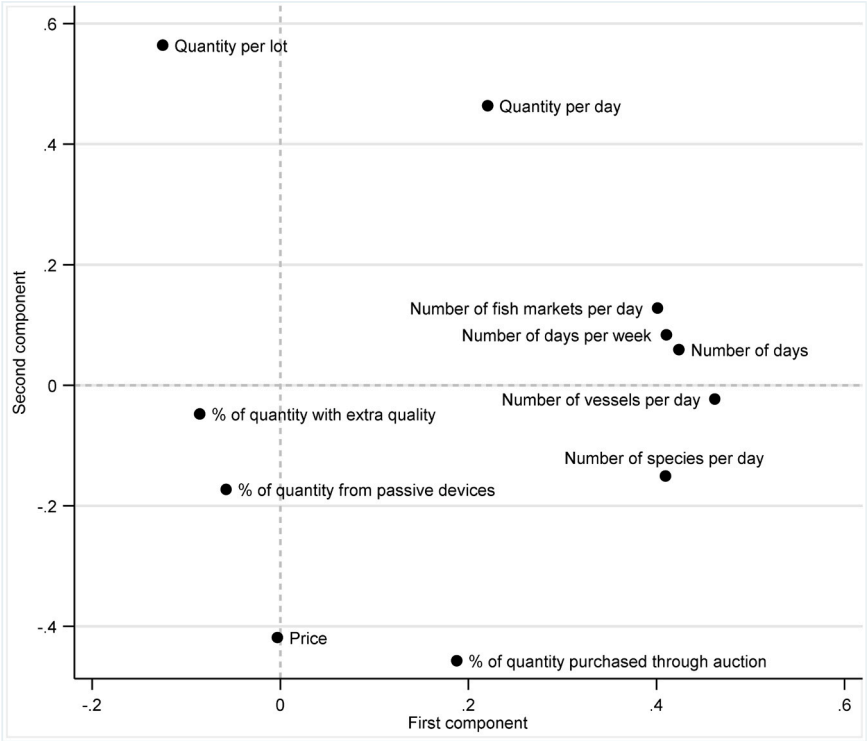


**Fig. 2.** Principal component analysis representation. Source: RIC data 2021–2022, authors' calculations.

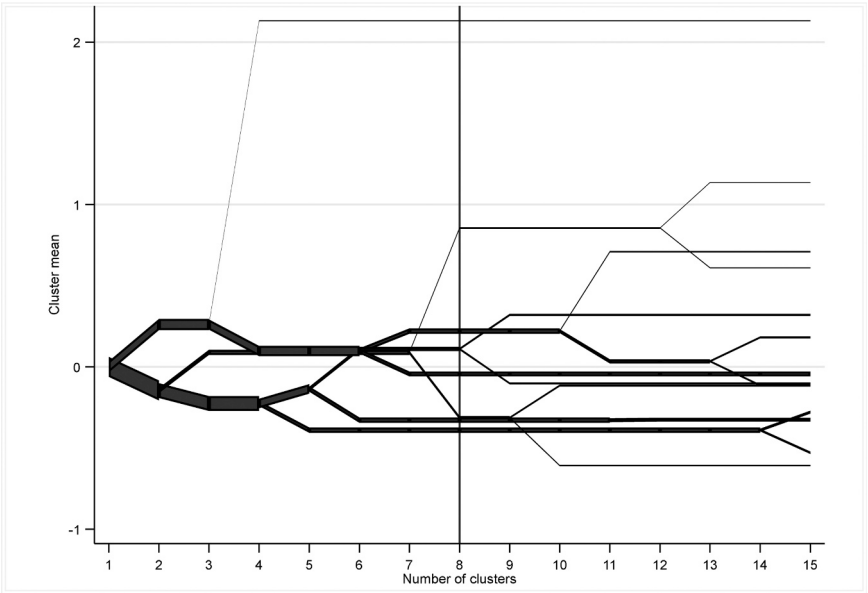


**Fig. 3.** Clustergram of the hierarchical classification. Source: RIC data 2021–2022, authors' calculations.

Roscoff) and Pays de la Loire (Les Sables d'Olonne, Le Croisic, La Turballe).

Groups 6 (294 buyers, 15.4%), 7 (332 buyers, 17.4%), and 8 (324 buyers, 16.9%) include buyers who almost exclusively buy at auction, with a share of more than 98% (and up to 99.4% for group 7). Their contribution in terms of volume ranges from 0.9% (group 8) to 4.3% (group 6), and group 6 ranks third in terms of transactions (15.4% of total transactions). A criterion that distinguishes these three groups is the number of days they are present: 310.7 days for group 6 (regular buyers), 148.0 days for group 7 (occasional buyers), but only 58.3 days for group 8 (infrequent buyers). On average, the three groups purchase less than 200 kg per day and they are active in only one market. In groups 6 and 8, the share of high quality in the purchase volume is more than 85%, while in group 7 this share is 32.5%. Norway lobster and sole are the most important species in terms of value in group 6; sole and hake are over-represented in group 7; and scallops are the preferred species in group 8 (23.4% in volume, 16.4% in value). Finally, there are contrasts between the buyer groups in terms of the geographical areas they visit. The main markets of group 7 are located on the Atlantic coast (Arcachon, Lorient, Les Sables d'Olonne, Saint-Jean de Luz), while the buyers in groups 6 and 8 buy more on the Mediterranean coast (Grau du Roi, Sète).

**Table 3**
Characterization of the buyer groups.

| Variables | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Group 8 |
|---|---|---|---|---|---|---|---|---|
| *Behavior of buyers* | | | | | | | | |
| Average quantity per day | 4487.4 | 3287.8 | 371.2 | 156.2 | 588.1 | 172.5 | 189.8 | 158.8 |
| Average quantity per lot | 40.5 | 426.5 | 85.8 | 28.9 | 16.5 | 8.5 | 13.2 | 15.5 |
| Average number of species purchased per day | 20.7 | 4.0 | 3.3 | 4.8 | 11.8 | 9.4 | 8.6 | 8.4 |
| Average price | 5.4 | 2.5 | 3.4 | 9.6 | 6.2 | 7.7 | 5.8 | 5.6 |
| Average number of fish markets per day | 6.2 | 1.2 | 1.0 | 1.1 | 1.9 | 1.1 | 1.2 | 1.0 |
| Share of quantity purchased through auction | 88.2 | 19.6 | 40.6 | 59.1 | 97.4 | 97.9 | 99.4 | 98.3 |
| Number of days with purchase | 514.7 | 205.8 | 117.1 | 95.3 | 453.0 | 310.7 | 148.0 | 58.3 |
| Average number of days with purchase per week | 5.0 | 2.6 | 1.8 | 1.5 | 4.6 | 3.4 | 1.9 | 1.1 |
| Average number of vessels per day | 43.3 | 5.2 | 2.9 | 4.7 | 14.2 | 9.9 | 8.1 | 8.0 |
| Share of quantity with extra quality | 44.6 | 82.8 | 58.5 | 72.1 | 50.7 | 86.6 | 32.5 | 91.4 |
| Share of quantity from vessels using passive gear | 29.7 | 20.6 | 7.0 | 75.0 | 27.3 | 26.0 | 43.3 | 18.7 |
| *Relative importance of the group* | | | | | | | | |
| Number of transactions (% of total) | 25.8 | 4.0 | 1.3 | 1.7 | 42.1 | 15.4 | 6.3 | 3.3 |
| Quantity (% of total) | 36.3 | 25.6 | 3.2 | 2.0 | 25.0 | 4.3 | 2.7 | 0.9 |
| Sales value (% of total) | 37.7 | 15.0 | 2.5 | 2.7 | 30.7 | 6.6 | 3.8 | 1.0 |
| Number of buyers | 55 | 107 | 204 | 259 | 337 | 294 | 332 | 324 |

Source: RIC data 2021–2022, authors' calculations.

Finally, we include data on the main activity declared by the buyer to the public authorities. For this purpose, we use a complementary database provided by FranceAgriMer, which is merged with our own database of buyers based on the SIREN number. The matching rate is 74.9%, with 1432 matched buyers. There are seven different profiles: retailers (48.2%), supermarkets and hypermarkets (11.8%), wholesalers (18.5%), canneries and processing plants (3.6%), fisheries (9.6%), restaurants (3.2%) and others (5.1%).[7] For each buyer, FranceAgriMer also indicates the size of the buyer's market, with three categories: international (2.6%), national (31.6%) and local (65.9%). The results confirm the relevance of our classification. Buyers with an international dimension are largely over-represented in group 1 (big makers at auction, with 21.6%) and to a lesser extent in group 2 (big makers at OTC, with 9.9%). Less than 13% of buyers in group 1 operate with a local dimension, while this proportion exceeds 75% in groups 3, 6, 7 and 8, where the buyers have small purchasing volumes and are mainly active in a single auction market.

In Fig. 6, we describe the composition of each group in terms of the primary activity of the buyers. In the first two groups, which include the largest buyers, the proportion of wholesalers is 68.6% in group 1 and 36.7% in group 2. Group 2 also includes 38.0% of canneries and processing plants, which explains the frequent purchases of these buyers through OTC transactions (with the largest volume per lot of fish). In the third group, there are about one third of retailers and one third of fisheries, which corresponds to the purchases of the organizations of producers in the fish markets. In groups 5, 6, 7 and 8, the share of retailers is always higher than 50% (in group 6, it is up to 65%). Among these four groups, the buyers in group 5 are the ones who purchase the largest volume, which is in line with the over-representation of wholesalers in this group (31.2%). Finally, there are proportionally more restaurants in both group 4 (through OTC) and group 8 (through auction). These are likely to be seasonal businesses, given the limited number of shopping days in these two groups.

Although our classification reveals different behaviors between buyer groups, there is still some heterogeneity within each group. Let $S_{gi}$ be the sales of buyer $i$ belonging to the buyer group $g$. By construction, the variance $V(S_{gi})$ is such that $V(S_{gi}) = V(S_{g*}) + V(S_{gi} - S_{g*})$, where $S_{g*}$ is the average sales value of group $g$. The between variance $V(S_{g*})$ measures deviations in the average sales value between groups, while the variance $V(S_{gi} - S_{g*})$ measures deviations in the sales values within each buyer group. We apply this variance decomposition to our sample of buyers. We find that the contribution of the between variance to the total variance is 57.6%, and the contribution of the within variance to the total variance is 42.4%. Applied to the total quantity purchased, the same decomposition shows that the weight of the between variance (44.1%) is lower than that of the within variance (55.9%).

As there is still some heterogeneity within the groups, we provide details of the respective contribution of the top 15 buyers (anonymous) in the three main buyer groups (1, 2 and 5) in Table A in the Appendix. Not surprisingly, we find that in all groups the main activity of the most influential buyers is wholesale. The largest buyers are very often located in Brittany and in particular in Finistère, but in the second group we notice that many large buyers operate (or at least are registered) in Pas-de-Calais. This is due to the fact that most OTC transactions in France take place in Boulogne, which is located in Pas-de-Calais. Finally, in the first and second groups, a few buyers are very active on the markets and their share of the total sales value of their group can be close to 5%. The contribution of the top-15 buyers to the total sales value of their respective group is 50% in group 1, 54.6% in group 2, but only 22.2% in group 5.

## 5. Buyer heterogeneity and the price-quantity relationship

We now examine the extent to which buyers in fish markets are sensitive to prices according to their profile. We hypothesize that large buyers in markets should be relatively less price sensitive than more occasional buyers. Indeed, the former type needs to be constantly supplied by markets in order to be able to offer seafood products to their customers. They operate in a wide range of markets and will be more interested in the quantities or lots that they can purchase than in the prices they are willing to pay. Conversely, smaller buyers (retailers) may choose to stay away from markets when prices are too high but position themselves to make more purchases when prices are low. They are also expected to spend less time buying fish at auction because they have to leave early in the morning to open their shops. They are more likely to adopt risk-averse behavior and increase their price sensitivity to quantity, especially on days of low quantity (Gallegati et al., 2011).

To test the hypothesis that the price-quantity elasticity for the species purchased varies across buyer groups, we proceed as follows. We use the transaction data to construct a database at the "group - fish product – auction - day" level. Let $P_{gfmt}$ be the average price of a specific fish product $f$ purchased by a buyer group $g$ in a fish market $m$ on day $t$ and

[7] The definition of retailers in the classification provided by FranceAgriMer is "retail trade of fish and shellfish". Unfortunately, it is not possible to know whether retailers are involved as fish processors or fishmongers, most likely because they often combine these two activities. This is clearly a limitation of such an ad hoc classification, which concerns the main activity of the buyer. As for "fisheries", the definition is "sea fishing and marine aquaculture", so that they can be considered as fish producers.

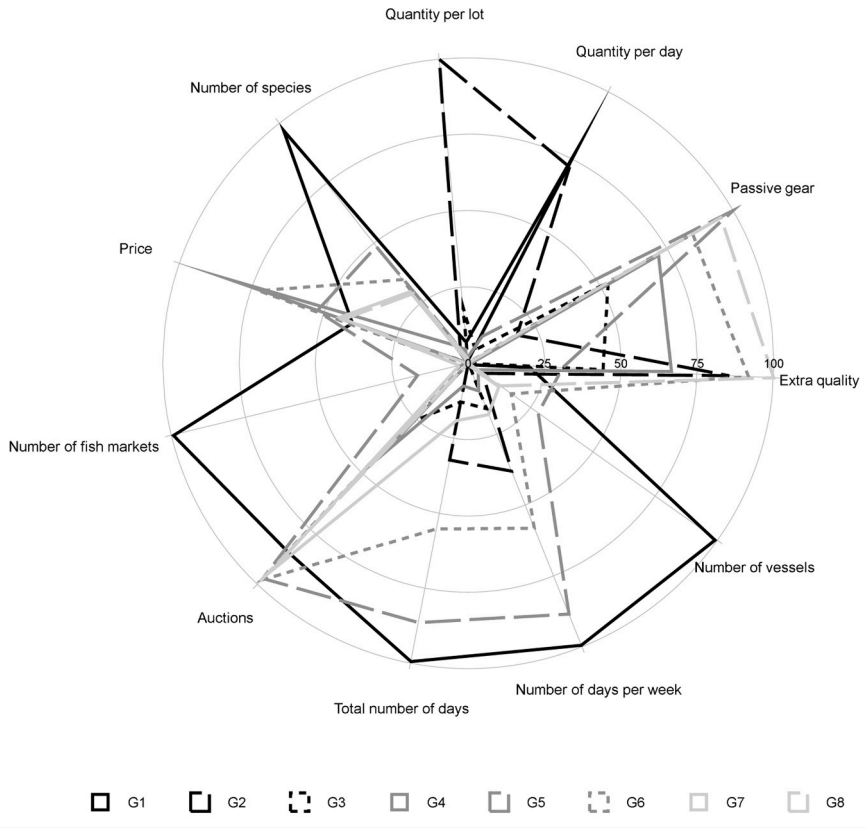


**Fig. 4. Situation of the different buyer groups.** Source: RIC data 2021–2022, authors' calculations.

$Q_{gfmt}$ be the total quantity of fish, defined in a similar way. We estimate the following equation:

$$\ln P_{gfmt} = c + \delta * \ln Q_{gfmt} + \gamma_g + \theta_f + \mu_m + \tau_t + \varepsilon_{gmft} \quad (1)$$

where $c$ and $\delta$ are parameters to be estimated and $\gamma_g$ is a fixed effect at the buyer group level. The fixed effect $\gamma_g$ will pick up differences in the average price paid by each buyer group. In Eq. (1), $\theta_f$, $\mu_m$, and $\tau_t$ are fixed effects at the fish product, market, and day levels, respectively. These fixed effects allow us to account for different sources of heterogeneity. First, $\theta_f$ will pick up the influence of the observed characteristics of the seafood products if, for example, buyer groups systematically opt for extra quality or if they prefer to buy certain more expensive species (sorting by species). Next, $\mu_m$ is used to capture geographic differences in fish prices. This variable captures not only effects related to the number of buyers and sellers in the markets but also the auction mode or any transaction costs that may be passed on to prices. Finally, $\tau_t$ takes into account changes in market supply conditions over time, as certain species may be more or less abundant throughout the year (seasonality).

In Eq. (1), the parameter of interest is the coefficient $\delta$, which measures the price-quantity elasticity for all buyers. The underlying assumption is that the different buyer groups behave similarly in the markets. In a second specification, we allow the price-quantity elasticity to vary with the different buyer groups. We therefore cross the quantity variable $\ln Q_{gfmt}$ with the different dummies $\mathbb{I}_g$ associated with each buyer group $g$ and estimate the following regression:

$$\ln P_{gfmt} = c + \sum_g \delta_g * \ln Q_{gfmt} * \mathbb{I}_g + \gamma_g + \theta_f + \mu_m + \tau_t + \varepsilon_{gmft} \quad (2)$$

The parameters of interest are now the coefficients $\delta_g$: they indicate the extent to which the prices paid vary with the quantities purchased according to the different buyer groups. Assuming that the buyer groups behave differently, we expect to reject the null hypothesis $H_0 : \delta_1 = \delta_2 = \ldots = \delta_8$. A potential problem here, the relevance of which will be discussed later, is that the quantity $\ln Q_{gfmt}$ in Eqs. (1) and (2) is supposed to be exogenous.

The corresponding estimates are presented in Table 5. In column (1 A), the estimate obtained for the elasticity $\delta$ is negative and highly significant (t=-110.04) but of very small magnitude: for a 1% increase in quantities sold, prices fall by −0.027%. As these are first-time sales at auctions, it may be that buyers are primarily concerned with procuring fish for which price changes can be passed on to customers and are therefore not very price sensitive. The explanatory power of the regression is good, as quantity and the included fixed effects explain 81.3% of the variation in the logarithm of prices. When only quantity is included in a linear model without fixed effects, the $R^2$ of the regression is 0.049. When only the time fixed effect is included, the $R^2$ is 0.058, suggesting that price differences depend mainly on the variability of the fish products purchased.

The estimates reported in column (1B) provide different price-quantity elasticities for each buyer group. A first result is that the hypothesis of equal price-quantity elasticities for the eight groups is rejected. The F-statistic associated with the null hypothesis $H_0 : \delta_1 = \delta_2 = \ldots = \delta_8$ is equal to 587.2 (p=0.000). A second result is that all the elasticities remain very low in absolute terms: they range from −0.002 (group 2, t=-2.26) to −0.048 (group 6, t=-78.67). It is interesting to note that the results obtained are compatible with the different profiles of buyers that we have identified. On the one hand, the buyers in groups 1 and 2 are those with the lowest price-quantity elasticities: these are the largest buyers in the markets, whether they buy at auction (group 1) or through OTC (group 2). Wholesalers will always need to buy very large quantities of fish, whatever the price, and canneries and other processing plants will always need to be supplied. On the other hand, the price-quantity elasticities are higher (in absolute values) for the other groups, which consist of smaller buyers who are less frequently present in the markets.

Because the different buyer groups may purchase different species,

**Table 4**
Top 5 fish species by buyer group.

| Variables | Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Group 7 | Group 8 |
|---|---|---|---|---|---|---|---|---|
| Panel A. Top 5 in volume | | | | | | | | |
| 1st | SCE 15.7% | WHE 13.9% | SCE 37.9% | WHE 18.5% | HKE 9.3% | SCE 15.5% | HKE 13.3% | SCE 23.4% |
| 2nd | PIL 10% | SCE 13.4% | POK 6.7% | PIL 9.6% | MNZ 7.1% | NEP 5.9% | SCE 10.9% | MAC 5.9% |
| 3rd | MNZ 9.5% | PIL 9.7% | WHE 6.3% | CRE 7.4% | SCE 6.2% | MAC 4.7% | SOL 5.9% | HOM 5.5% |
| 4th | HKE 4.6% | MAC 9% | MAC 3.8% | YFT 6.2% | NEP 4.5% | HKE 4.6% | MNZ 5.1% | HKE 4.3% |
| 5th | CTC 4.1% | HER 6.8% | WHG 3.8% | SCR 5% | WHG 3.9% | SCR 4.4% | MAC 4.6% | SBG 3.9% |
| Panel B. Top 5 in value | | | | | | | | |
| 1st | MNZ 12.4% | SCE 15.4% | SCE 37.4% | WHE 10.4% | NEP 11.1% | NEP 12.4% | SOL 16.2% | SCE 16.4% |
| 2nd | SCE 10.6% | WHE 14.2% | WHE 6.4% | YFT 8.4% | SOL 8.2% | SOL 8.9% | HKE 9.1% | SOL 7.1% |
| 3rd | SOL 10.4% | SQZ 10.9% | SOL 5.1% | ELE 6.2% | MNZ 8% | SCE 8.5% | BSS 7.1% | HKE 5.3% |
| 4th | BSS 7% | MAC 6.9% | POK 3.8% | CRE 5.7% | HKE 7% | OCC 5% | NEP 6% | SBG 5% |
| 5th | SQZ 4.7% | CTC 6.3% | SQZ 3.7% | SWO 5.3% | BSS 4.8% | BSS 5% | SCE 5.7% | BSS 4.5% |
| Number of buyers | 55 | 107 | 204 | 259 | 337 | 294 | 332 | 324 |

Source: RIC data 2021–2022, authors' calculations.
Note: BSS = seabass (*Dicentrarchus labrax*), CRE = edible crab (*Cancer pagurus*), CTC = cuttlefish (*Sepia officinalis*), ELE = eel (*Anguilla anguilla*), HER = herring (*Clupea harengus*), HKE = hake (*Merluccius merluccius*), HOM = horse mackerel (*Trachurus trachurus*), MAC = mackerel (*Scomber scombrus*), MNZ = monkfish (*Lophius spp*), NEP = Norway lobster (*Nephrops norvegicus*), OCC = octopus (*Octopus vulgaris*), PIL = pilchard (*Sardina pilchardus*), POK = pollack (*Pollachius virens*), SBG = gilthead seabream (*Sparus aurata*), SCE = scallops (*Pecten maximus*), SCR = spider crab (*Maja squinado*), SOL = sole (*Solea solea*), SQZ = squid (*Loliginidae*), SWO = swordfish (*Xiphias gladius*), WHE = whelk (*Buccinum undatum*), WHG = whiting (*Merlangius merlangus*), YFT = yellowfin tuna (*Thunnus albacares*).

we examine the robustness of our results by focusing on a more homogeneous set of fish species. Specifically, we select the top 20 fish species in value and re-estimate both Eqs. (1) and (2). The new dataset consists of approximately 1.3 million transactions. As shown in column 2 A of Table 5, we find a larger value for the price-quantity elasticity (in absolute value), −0.039 against −0.027. Again, the smallest quantity coefficients (in absolute value) are obtained for the first two buyer groups (-0.027 for group 1, −0.023 for group 2). The elasticity is much higher for buyers in group 6 (-0.057) and group 8 (-0.075). Furthermore, the null hypothesis $H_0 : \delta_1 = \delta_2 = \ldots = \delta_8$ is strongly rejected with a F-statistic of 316.1 (p=0.000).

So far, the quantities of fish purchased each day in a given market have been assumed to be exogenous. In the context of fish markets, this assumption remains challenging. Graddy (1995) argues that quantities sold (and thus purchased) and fish prices are simultaneous, but under certain conditions supply and demand can be determined recursively rather than simultaneously (Graddy and Kennedy, 2010). In France, there are no inventories and all lots landed by vessels are offered for sale to buyers: decisions about supply (which is also the demand at the equilibrium) through fishing effort are made prior to sales, but fishermen may still choose to spend more time fishing depending on their expectations of the prices they will receive. We now attempt to assess the extent to which the price-quantity elasticity could be affected by the endogeneity of the quantity purchased, since buyers are likely to jointly choose both the price they are willing to pay and the quantity of fish they need.

Since we do not have a convincing instrument in our data (weather is not a good instrument since nearby markets are subject to the same weather conditions and our regressions already include a daily fixed effect), we turn to the kinky least squares (KLS) estimator proposed by Kiviet (2020), which is an instrument-free approach (Kripfganz and Kiviet, 2021).[8] Let $\varepsilon$ be the disturbance in the price equation. The KLS estimator relies on the non-orthogonality condition $E[\ln Q\varepsilon] = \rho\sigma_{\ln Q}\sigma_\varepsilon$, where $\sigma_{\ln Q}$ is the standard deviation of the quantity, $\sigma_\varepsilon$ is the standard deviation of the perturbation $\varepsilon$, and $\rho$ is the coefficient of correlation between $\ln Q$ and $\varepsilon$..[9] The linear model (1) is a special case of the KLS estimator: it corresponds to the case where $\rho = 0$ (assumption of exogeneity). Since the correlation $\rho$ is unknown in the general case, it is proxied by a value of the endogeneity correlation $r$. The KLS estimator is thus estimated for a variety of values of $r$ in the interval $[r_{\min}; r_{\max}]$, so that the price-quantity elasticity $\delta$ depends on the value chosen for $r$ (the true value of $\rho$ remains unknown).

For each buyer group, we estimate group-specific KLS estimates for endogeneity correlations $r$ comprised between -0.8 and 0.8, with a step of 0.02. Our results, which are not reported, show that the price-quantity elasticity appears slightly positive when $r$ is negative. Since positive values for the price-quantity elasticity are not realistic, we decide to exclude the cases where $r < 0$ and apply the KLS approach to the following values: $r = 0$, $r = 0.1$, $r = 0.2$ and $r = 0.3$. We find much larger elasticity values (in absolute value) as $r$ increases, but our main interest lies in comparing the different elasticity values obtained for each buyer group.

Fig. 7 shows the KLS estimates for the full set of fish species and for the top 20 fish species. A first result is that the price-quantity elasticity increases (in absolute value) with the endogeneity correlation $r$. For example, consider the first buyer group, which consists of large buyers at auction. For this group, the elasticity is −0.011 under exogeneity ($r = 0$), −0.047 when $r = 0.1$, −0.084 when $r = 0.2$ and −0.124 when $r = 0.3$. Thus, the elasticity is much higher when we allow for the endogeneity of quantity in the price equation, but still the demand for fish at first sale remains inelastic with respect to price. In the best scenario, we obtain an elasticity slightly above 0.2 for group 8 (-0.218 with $r = 0.3$). A second result is that in all scenarios the lowest elasticity values are always found for the two groups that include the largest buyers (group 1 at auction, group 2 over-the-counter). There is less difference between the group-specific elasticities as the value of $r$ increases, but we still find that buyers in groups 1 and 2 have a lower elasticity. These results remain valid when the dataset is restricted to the top 20 fish species (in terms of sales value).

To date, most studies on fish prices have focused only on particular fisheries or markets, while here, we study the role of buyers at the na-

[8] Focusing on the end of withdrawal prices in France, Wolff et al. (2023) estimate fish price equations in which quantity is treated endogenously using weather conditions as instruments. Estimates from 2SLS regressions show that the coefficient associated with daily quantity is more than 10 times larger in absolute value than the coefficient estimated under exogeneity. We attempted to construct an instrument based on lagged quantities of fish landed, as these quantities are strongly related to weather conditions. Additional results (not reported) show that the IV coefficient of quantity in our price equations is about 7 times higher (in absolute value) than the exogenous coefficient. Interestingly, this order of magnitude is very close to the KLS estimate proposed by Kiviet (2020) with an endogeneity correlation close to 0.3.

[9] In the standard IV framework, consistent estimates are obtained using the orthogonality condition $E[Z\varepsilon] = 0$, where $Z$ is a set of instruments and $\varepsilon$ is the error term in the price equation.

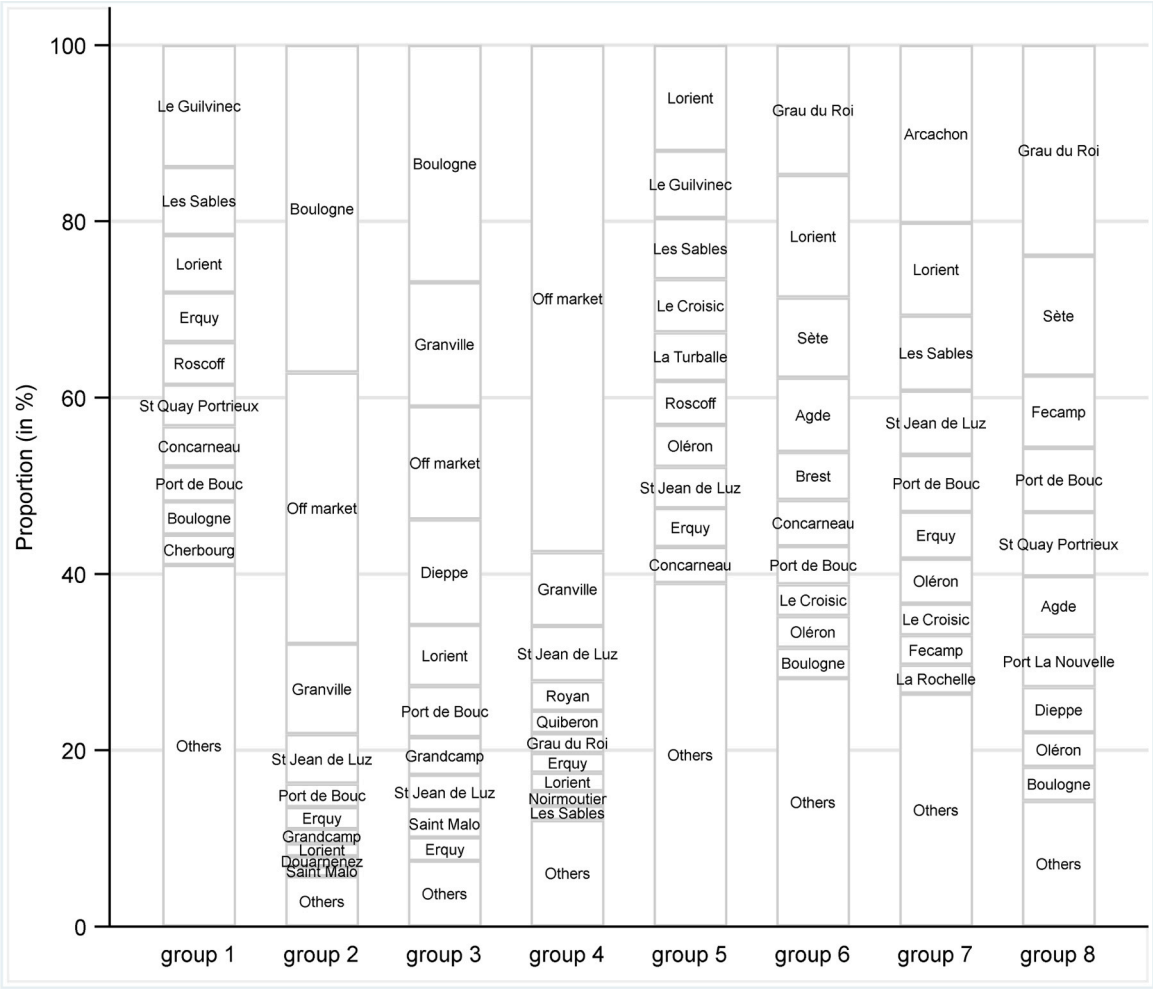


**Fig. 5. Top ten fish markets by buyer group.** Source: RIC data 2021–2022, authors' calculations.

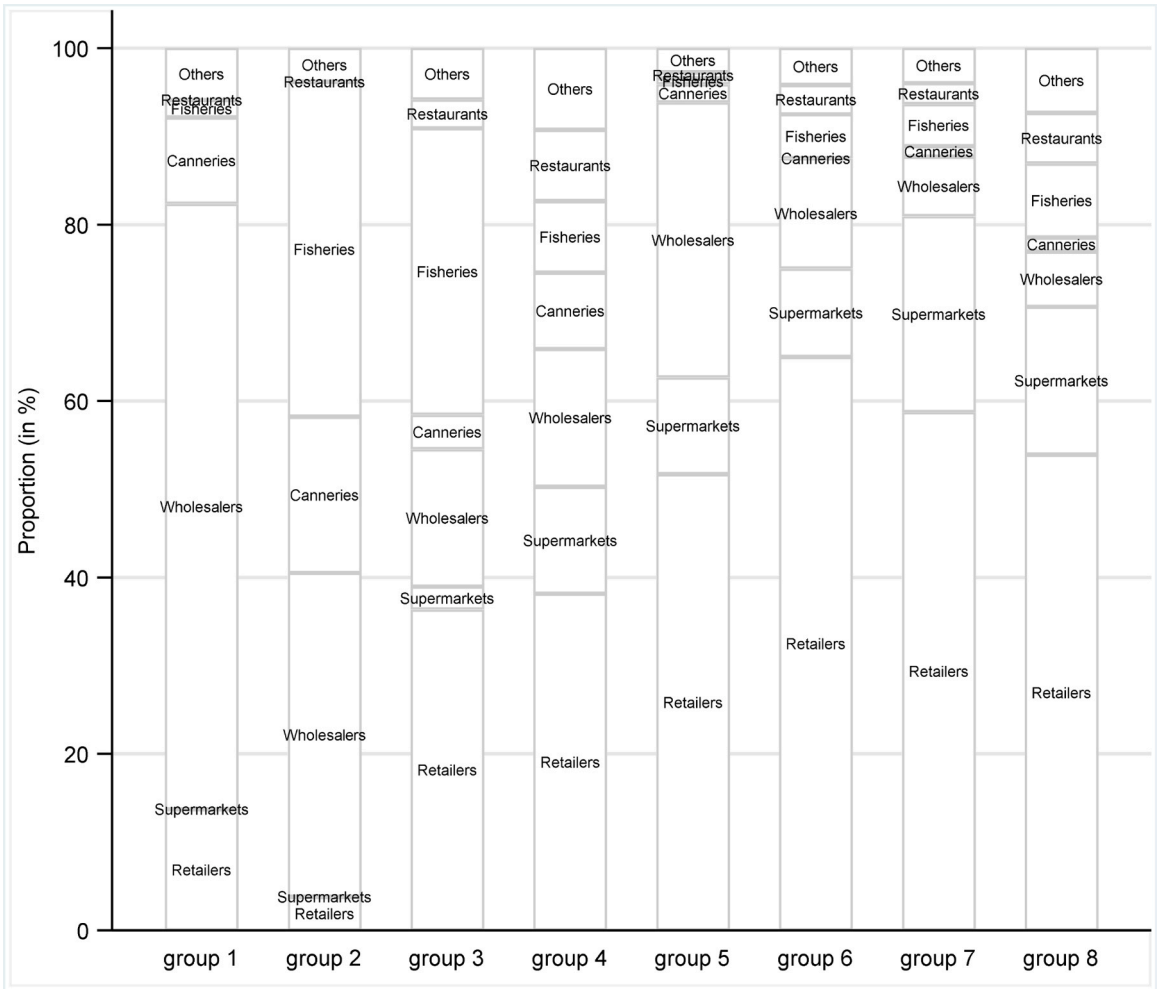


**Fig. 6. Primary activity by buyer group.** Source: RIC data 2021–2022, authors' calculations.

**Table 5**
Estimates of the price-quantity elasticity, by buyer groups.

| Variables | All fish species | | Top 20 species | |
|---|---|---|---|---|
| | (1 A) | (1B) | (2 A) | (2B) |
| Quantity (log) | -0.027*** | | -0.039*** | |
| | (-110.04) | | (-130.69) | |
| Quantity (log) x group 1 | | -0.015*** | | -0.027*** |
| | | (-35.21) | | (-56.16) |
| Quantity (log) x group 2 | | -0.002** | | -0.023*** |
| | | (-2.26) | | (-21.01) |
| Quantity (log) x group 3 | | -0.044*** | | -0.045*** |
| | | (-39.66) | | (-34.50) |
| Quantity (log) x group 4 | | -0.041*** | | -0.054*** |
| | | (-38.77) | | (-40.18) |
| Quantity (log) x group 5 | | -0.032*** | | -0.042*** |
| | | (-93.29) | | (-101.96) |
| Quantity (log) x group 6 | | -0.048*** | | -0.057*** |
| | | (-78.67) | | (-78.17) |
| Quantity (log) x group 7 | | -0.032*** | | -0.047*** |
| | | (-44.05) | | (-55.67) |
| Quantity (log) x group 8 | | -0.046*** | | -0.075*** |
| | | (-34.90) | | (-44.37) |
| Fixed effects: fish product + market + time | YES | YES | YES | YES |
| Observations | 2747,856 | 2747,856 | 1317,018 | 1317,018 |
| R-squared | 0.789 | 0.814 | 0.789 | 0.790 |

Source: RIC data 2021–2022, authors' calculations.
Note: estimates from fixed effect regressions (fish product, market, day), with robust t-values in parentheses.

tional level. Performing these analyses at the national scale could mask some regional differences and explain the flat relationship between price and quantity. We further investigate this issue by estimating price hedonic regressions for each market. We obtain a set of 36 market-specific price-quantity elasticities. The average elasticity (weighted by the number of transactions per market) is equal to −0.034, with a minimum of −0.080 and a maximum of 0.015. This suggests that the flat relationship between price and quantity holds for all fish markets in France. In Fig. 8, we present the price-quantity elasticities obtained for each market and each buyer group using a box plot. Assuming exogeneous quantity, we reach two main conclusions. First, prices are less sensitive to quantities since the highest elasticities in absolute value are lower than 0.15. Second, the median elasticity tends to be lower in absolute value in the groups including the largest buyers. These conclusions remain valid with the KLS estimates (assuming that $r = 0.3$), even though the elasticities are higher in absolute values for all groups.

## 6. Conclusion

Over the past two decades, a large number of studies have investigated the determinants of fish prices sold in first-sale fish markets using hedonic price equations. With a few exceptions (Lesur-Irichabeau et al., 2016; Gobillon et al., 2017; Salladarré et al., 2017; Sogn-Grundvåg et al., 2019), the role of buyers has received little attention, presumably due to the lack of appropriate data.

In this contribution, we attempt to fill in this gap by providing, for the first time, a very detailed analysis of the behavior of buyers in first-

sale fish markets. Our empirical study is based on exhaustive transaction data (11.7 million) from all auction markets in France in 2021 and 2022, for which we have both vessel and buyer identifiers. This allows us to provide results on a national scale, whereas many previous works have focused on specific fish markets to study the behavior of buyers and sellers. Information on the quantity purchased per day, the average price paid, the number of fish markets visited, the number of days with a purchase, and the share of auction versus OTC transactions allows us to provide a characterization of buyers in fish markets.

First, buyers in first-sale fish markets behave in a very heterogeneous way. The hierarchical agglomeration clustering results in a classification of buyers into eight different groups. We identify two small groups of very large buyers, mainly wholesalers and canneries or processing plants, with huge daily volumes (more than 3 tonnes). One group is very active at auctions in many different markets, while the other group buys almost exclusively OTC in very few markets with low average prices. A third group, mostly retailers and supermarkets, is very active throughout the year and is involved in more than 40% of the transactions. The contribution of the other five groups is much lower, with 28.1% of transactions, 13.1% of volume and 16.6% of sales value.

Second, we find that buyers, regardless of the group, are not really sensitive to prices in first-sale markets. When fish quantities are treated as exogenous, the price-quantity elasticity values range between −0.05 and −0.01. Lesur-Irabeau et al. (0216), also report very small negative price-quantity coefficients (between −0.05 and −0.03) for the two main fishing areas. We find even lower elasticities (in absolute value) for the two groups with the largest buyers. We argue that wholesalers and canneries or processing plants are more concerned with access to lots of fish than with the price they pay, since they can pass on any price increase to their own customers. This results in a rather flat relationship

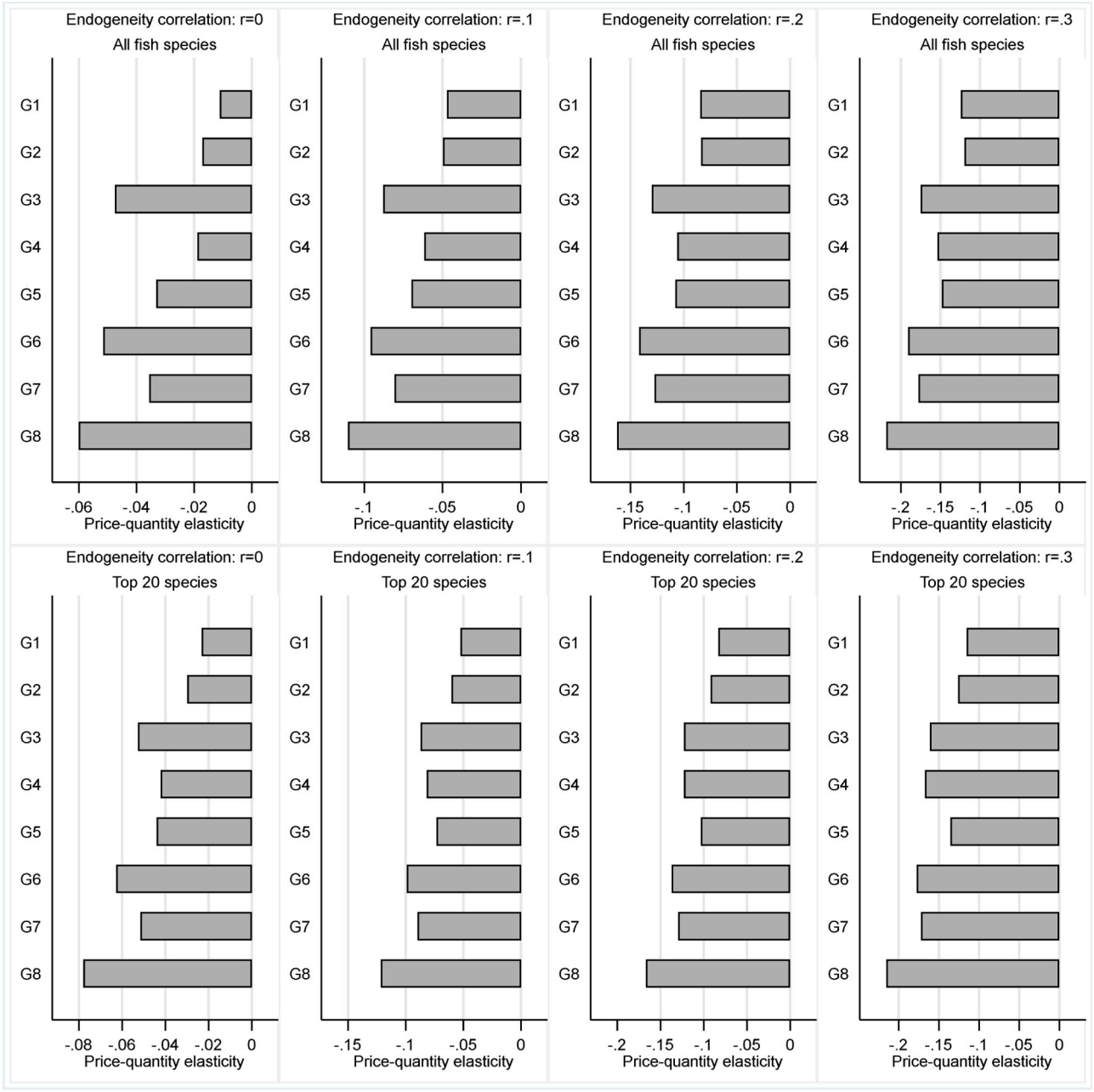


**Fig. 7. Price-quantity elasticity by buyer groups.** Source: RIC data 2021–2022, authors' calculations.

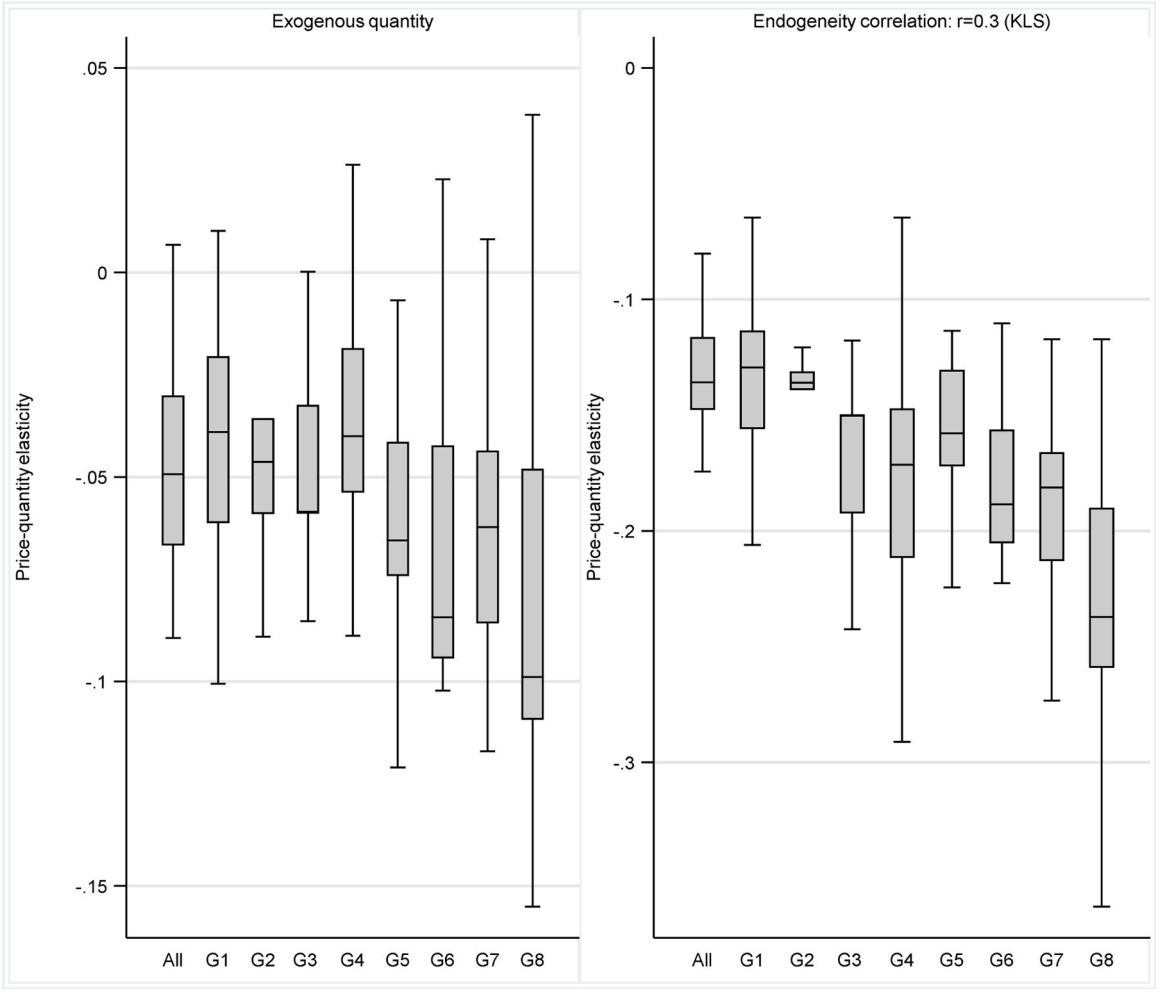


**Fig. 8. Market-specific price-quantity elasticities by buyer group (top 20 species).** Source: RIC data 2021–2022, authors' calculations.

between price and quantity.

Although descriptive, our empirical analysis provides new insights into the behavior of buyers in first-sale fish markets and sheds light on their heterogeneity. The main limitation of our work is that we rely on an unsupervised learning approach to classify buyers into different groups. Such a clustering technique is easy to implement, but the final classification depends on many parameters introduced in the estimation such as the clustering technique or the selected variables of interest. Nevertheless, we believe that such an unsupervised approach remains convincing with distinct groups that separate large buyers, such as wholesalers or processors, from smaller buyers, such as retailers. Another concern is the use of an external classification of buyer activities, with buyers embedded in only one type of activity. This is clearly restrictive, as buyers may combine different activities, such as fish processors and fishmongers, and some activities are not well defined. Our results must therefore be interpreted with caution, but they appear to be realistic as wholesalers or canneries are over-represented in the groups of large buyers.

As for future research, we plan to further study how buyers purchase lots of fish in a context where the supply of markets varies across seasons and even across days. It is expected that buyers' choice of different species depends not only on their preferences, but also on the local availability of seafood products. Estimation of a structural assignment model could help to better understand the shopping behavior of buyers in first-sale fish markets.

## CRediT authorship contribution statement

**François-Charles Wolff:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis. **Frédéric Salladarré:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis. **Laurent Baranger:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The authors do not have permission to share data.

## Appendix A

**Table A**
Description of the top-10 buyers for the three major groups

| Rank | Location | Main activity | Number of | Weight in group (in %) | |
|---|---|---|---|---|---|
| | | | employees | Sales value | Quantity |
| *Group 1* | | | | | |
| 1 | Finistère (29) | Wholesaler | 50–99 | 4.8 | 6.3 |
| 2 | Lot-et-Garonne (47) | Wholesaler | 250–499 | 4.8 | 2.9 |
| 3 | Finistère (29) | Processing | 20–49 | 4.6 | 2.4 |
| 4 | Charente-Maritime (17) | Wholesaler | 50–99 | 4.2 | 3.1 |
| 5 | Vendée (85) | Wholesaler | 20–49 | 3.3 | 1.5 |
| 6 | Pas-de-Calais (62) | Processing | 20–49 | 3.3 | 5.5 |
| 7 | Finistère (29) | Wholesaler | 20–49 | 3.2 | 2.8 |
| 8 | Côtes d'Armor (22) | Wholesaler | 20–49 | 3.0 | 2.7 |
| 9 | Loire-Atlantique (44) | Wholesaler | - | 2.9 | 4.0 |
| 10 | Côtes d'Armor (22) | Wholesaler | 20–49 | 2.8 | 4.4 |
| 11 | Manche (50) | Wholesaler | 20–49 | 2.7 | 3.8 |
| 12 | Pas-de-Calais (62) | Wholesaler | 20–49 | 2.7 | 2.6 |
| 13 | Finistère (29) | Processing | 20–49 | 2.6 | 3.8 |
| 14 | Finistère (29) | Fisheries | 10–19 | 2.6 | 6.0 |
| 15 | Spain | - | - | 2.6 | 1.5 |
| *Group 2* | | | | | |
| 1 | Pas-de-Calais (62) | Wholesaler | 20–49 | 5.9 | 5.2 |
| 2 | Pas-de-Calais (62) | Wholesaler | 20–49 | 5.0 | 6.0 |
| 3 | Pyrénées Atlantique (64) | Wholesaler | 10–19 | 4.7 | 3.8 |
| 4 | Pas-de-Calais (62) | Wholesaler | 3–5 | 4.5 | 7.6 |
| 5 | Manche (50) | Fisheries | 10–19 | 4.4 | 3.5 |
| 6 | Pas-de-Calais (62) | Fisheries | 20–49 | 4.4 | 4.7 |
| 7 | Pas-de-Calais (62) | Wholesaler | 10–19 | 4.3 | 3.1 |
| 8 | Pas-de-Calais (62) | Wholesaler | 20–49 | 3.4 | 3.0 |
| 9 | Pas-de-Calais (62) | Wholesaler | 20–49 | 3.2 | 2.6 |
| 10 | Manche (50) | Wholesaler | 50–99 | 2.7 | 4.1 |
| 11 | Pas-de-Calais (62) | Processing | 20–49 | 2.6 | 2.2 |
| 12 | Pas-de-Calais (62) | Processing | - | 2.6 | 1.8 |
| 13 | Marne (51) | Wholesaler | 50–99 | 2.3 | 1.4 |
| 14 | Morbihan (56) | Fisheries | 20–49 | 2.3 | 3.1 |
| 15 | Gironde (33) | Processing | 20–49 | 2.2 | 0.8 |
| *Group 5* | | | | | |
| 1 | Finistère (29) | Other | 1–2 | 2.5 | 3.3 |
| 2 | Ile-et-Vilaine (35) | Wholesaler | 10–19 | 2.0 | 2.6 |
| 3 | Loire-Atlantique (44) | Wholesaler | 3–5 | 1.8 | 1.5 |
| 4 | Gard (30) | Wholesaler | 10–19 | 1.6 | 2.0 |
| 5 | Vendée (85) | Wholesaler | 6–9 | 1.5 | 1.0 |
| 6 | Morbihan (56) | Wholesaler | 20–49 | 1.5 | 2.8 |
| 7 | Ile-et-Vilaine (35) | Wholesaler | 50–99 | 1.4 | 1.6 |
| 8 | Ile-et-Vilaine (35) | Wholesaler | 20–49 | 1.3 | 1.3 |
| 9 | Spain | - | - | 1.3 | 0.8 |
| 10 | Finistère (29) | Wholesaler | 6–9 | 1.3 | 1.6 |
| 11 | Morbihan (56) | Wholesaler | 20–49 | 1.3 | 2.3 |
| 12 | Finistère (29) | Retailer | 20–49 | 1.3 | 0.8 |
| 13 | Finistère (29) | Hypermarket | 250–499 | 1.2 | 0.8 |
| 14 | Finistère (29) | Wholesaler | 20–49 | 1.1 | 1.0 |
| 15 | Charente-Maritime (17) | Wholesaler | 1–2 | 1.1 | 0.7 |

Source: RIC data 2021–2022, authors' calculations and information from https://www.sirene.fr.

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