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Price volatility transmission in the value chain of fresh anchovies in Spain

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A R T I C L E I N F O

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A B S T R A C T

This study examines the price volatility transmission of fresh anchovies (*Engraulis encrasicolus*) among different markets along the value chain in Spain. For this purpose, the prices in the first-hand sale, wholesale, and retail markets are considered. A vector autoregressive (VAR) model and an asymmetric multivariate generalised autoregressive conditional heteroskedasticity (MGARCH) model are used to analyse the relationship of price volatility among the markets in the value chain. The results indicate that the retail market has the lowest volatility. Therefore, volatility in the first-hand sale and wholesale markets is only minimally transmitted to consumers. Finally, asymmetric effects are observed in the price volatility transmission along the fresh anchovy value chain.

1. Introduction

This study examines the price volatility transmission of fresh European anchovies (*Engraulis encrasicolus*) in Spain along the value chain. Therefore, it does not include other anchovy species which are used only by the processing industry and are not imported as fresh products.[1] To analyse the price of the European anchovy, it is important to note that it is a highly perishable product, and there is much uncertainty surrounding production in terms of the quantity and quality of the anchovies caught and sold across the supply chain. This study analyses three segments of the value chain: first-hand sale markets, wholesale markets at the destination (Central Market Network, Mercasa[2]), and retail markets. It uses biweekly data from the Spanish Observatory of Prices (Spanish Ministry of Agriculture, Fisheries and Food) and IDAPES (the Andalusian information system on fishing trade and production from the Ministry of Agriculture, Livestock, Fisheries, and Sustainable Development of the Andalusian Regional Government) from the 1st week of January 2012 to the 1st week of July 2022. Analysing price volatility is important because it is a measure of price uncertainty and, as a result, affects income, fishery costs, pressure on fish stocks, and food security (Pincinato et al., 2020). Seafood price volatility has a significant impact on welfare (Dahl and Yahya, 2019). As Dahl and Oglend (2014) point out, fishing and aquaculture activities involve risk and, consequently, might produce some price volatility. Additionally, Asche et al. (2015) state that price volatility has a significant effect on seafood markets and the aquaculture industry. According to them, these price changes could be caused by variations in supply and demand. The former may be due to seasonality and production shocks. The latter might be due to changes in the supply of close substitutes as well as trade barriers and exchange rates, as almost 40% of global fish production is traded internationally. Likewise, as indicated by the OECD/FAO (2022), some risks and uncertainties which could have a significant impact on the fishery sector for the period of 2022–2031 are volatility in energy markets, management practices, environmental policies, stock status, and domestic fishery policies. Price changes are also significant for seafood producers and businesses along the supply chain, as market and production risks lead to fluctuations in revenue and cash flow. Therefore, because of this price volatility, the seafood industry faces uncertainty, which eventually results in fluctuating profits over time. Price volatility impacts all of the actors in the supply chain. Assefa et al. (2015) highlight the importance of understanding the magnitude and direction of price volatility transmission in food supply chains for risk managers and policymakers. On one hand, changes in policy that affect price volatility in primary input markets influence price volatility along the supply chain. On the other hand, it is unrealistic to anticipate that stabilising one market will result in stability in other markets of the

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[1] As only fresh anchovies are taken into account in the three levels of the value chain for this study, this commodity can be considered homogenous.

[2] Mercasa is a Spanish state-owned company in the wholesale level of the value chain of food products that manages, together with the respective city councils, the Central Market Network. It was set up as a Public Limited Company on the 7th of April, 1966 as an autonomous organisation linked to the Ministry of Agriculture and Ministry of Trade, which are currently the Ministry of Industry, Trade and Tourism and Ministry of Agriculture, Fisheries and Food.

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supply chain if volatility is not passed along the levels of the value chain. Consequently, to adapt to these situations, decision makers need to take different types of measures in the various markets of the value chain. Assefa et al. (2015) also point out that the accuracy of agents' pricing forecasts in other markets is improved by the transmission of volatility along the supply chain. This has an impact on the hedging choices of chain actors. Volatility spillover can introduce cross-hedge linkages among the levels of the value chain. For these reasons, the analysis of price volatility is relevant in determining the degree to which each actor in the value chain is vulnerable to price volatility and the process by which price volatility is passed along the supply chain. Policymakers and value chain participants may find the examination of price volatility useful when developing their risk management and risk avoidance plans (Ferrer-Pérez and Gracia-de-Rentería, 2020). Regarding the European anchovy, several specific reasons necessitate the analysis of its price volatility. First, the European anchovy is a wild-caught species; thus, even though aquaculture helps reduce price volatility (Dahl, 2017), it cannot help stabilise European anchovy prices. Second, European anchovy demand is relatively stable, whereas its supply is volatile because of the unpredictable nature of fishing. Finally, European anchovy fishing is affected by volatile fuel prices.

The concepts of price-level transmission and price volatility analysis are complementary (Ferrer-Pérez and Gracia-de-Rentería, 2020). Price-level transmission analyses the relationship between the conditional mean of prices, while price volatility transmission studies the relationship between the conditional variance of prices (Assefa et al., 2015). Concerning the study of vertical price transmission, several studies of interest in the European seafood market should be highlighted, such as Fernández-Polanco and Llorente (2015) on the Spanish value chains of hake, anchovy, and mackerel; Asche et al., (2007, 2014), Guillotreau (2004), and Landazuri-Tveteraas et al. (2018) on the salmon market; Asche et al. (2002) on the cod market; Jiménez-Toribio and García-del-Hoyo (2006) on the red sea bream marketing chain in Spain; Jiménez-Toribio et al. (2010) on the world market and the major European marketplaces of frozen and canned tuna; and Bittmann et al. (2020) on the importance of nutritional product differentiation in vertical price transmission using eight fish species from the German market (farmed salmon, hake, redfish, plaice, cod, Alaska pollock, tuna, and saithe). Additionally, asymmetric price transmission along the value chain has been studied in European seafood markets. In this regard, decreases and increases in prices at one stage of the marketing chain are transmitted to other stages at different rates. Ferrer-Pérez and Gracia-de-Rentería (2020) state that this is important because it can be determined whether an increase in upstream prices has the same effect on middle and downstream prices as a reduction in prices. It also allows us to study whether an increase (reduction) in downstream prices decreases price instability at the middle and upstream levels of the value chain. Interestingly, many studies confirm asymmetric price transmission, such as Ankamah-Yeboah and Bronnmann (2017), Gizaw et al. (2021), Guillen and Franquesa (2015), Jaffry (2004), and Simioni et al. (2013). However, as pointed out by Dahl and Oglend (2014), there have been few studies on the analysis of fish price volatility. Dahl and Oglend (2014), Asche et al. (2015), and Dahl (2017) examine price volatility in wild and aquaculture products and conclude that the prices of aquaculture products are less volatile than those of wild products. In addition, some interesting studies focus on the study of the price volatility of salmon, which has increased over time, such as Oglend (2013), Solibakke (2012), Bloznelis (2016), Asche et al. (2019), and Dahl and Yahya (2019), who study price volatility dependence dynamics with markets of other species in the short, medium, and long run. The question of interconnected dynamics and volatility spillover in the seafood and aquaculture markets has been analysed by Dahl and Jonsson (2018a, 2018b). Dahl and Jonsson (2018b) analyse the price volatility spillover among the three largest regional import markets for fish and crustaceans (EU, Japan, and the USA) and conclude that there is a significant time-varying volatility spillover from net exporting markets to net importing markets. Dahl and Jonsson (2018a) examine price volatility spillover between seafood coming from fisheries and aquaculture and conclude a lower volatility in aquaculture production, as other studies have mentioned earlier, because volatility is transmitted from wild to aquaculture production. Finally, two studies on volatility price transmission along the value chain by Buguk et al. (2003) and Ferrer-Pérez and Gracia-de-Rentería (2020) should be highlighted. In the first, Buguk et al. (2003) analyse price volatility transmission along the US catfish value chain using an exponential generalised autoregressive conditional heteroskedasticity (EGARCH) model and conclude that significant volatility is transmitted from menhaden, corn, and soybean to catfish prices (i.e. feed, farm, and wholesale prices). Second, Ferrer-Pérez and Gracia-de-Rentería (2020) study price volatility transmission along the fresh wild hake value chain in Spain using first-hand sale, wholesale, and retail prices by means of an asymmetric MGARCH model and a vector autoregressive (VAR) model, concluding the existence of time-varying volatility and asymmetric effects in the value chain.

The remainder of this paper is organised as follows. First, we describe the demand and supply of the Spanish anchovy market. Second, the institutional arrangements of the Spanish market for fresh European anchovies are presented. Third, the data used are explained. Fourth, the methodology and theoretical basis for the analysis are developed. Fifth, the results obtained are presented and discussed. Finally, the main conclusions of this study are summarised.

2. Spanish anchovy market: demand and supply

2.1. Production

The European Anchovy (*Engraulis encrasicolus*) is a small, short-lived pelagic fish that inhabits the coastal waters of the Eastern Atlantic from Norway to the Gulf of Guinea, rarely found below it, and all of the Mediterranean, Black, and Azov Seas (Barange et al., 2009; Whitehead, 1985: 316–317).[3] Main landings of European anchovy fisheries are registered in Spain, France, Portugal, and Morocco in the Atlantic Ocean (28.3%); Spain, France, Italy, and Tunisia in the Western Mediterranean (6.2%); Italy, Croatia, Montenegro, Albania, and Tunisia in the Central Mediterranean (9.8%); Greece, Turkey, and Egypt in the Aegean Sea in the Eastern Mediterranean (5.2%); and finally, Turkey, Georgia, Russia, Ukraine, and Bulgaria in the Black Sea, with the most important landings (50.5%).[4,5]

There has been a sharp decrease in landings of European anchovies in all fishing grounds since a mid-80 peak of 700,000 mt/year (2/3 in the Black Sea). The total landings currently range between 400,000 and 500,000 mt/year (1/2 in the Black Sea) according to FAO statistics from

[3] The official name for anchovy in Spanish is *boquerón*, though the term *anchoa* is also used. The latter term is associated with semi-preserved salted anchovies in oil except for Basque Country. In this regard, official statistics of the processing industry used the term *anchoa* - *antxobat* in Basque - for semi-preserved salted anchovy in oil and *boquerón* for the rest of products.

[4] The main catches of anchovies in the Mediterranean and Black Seas are taken in the latter location. In the literature, there are indications of strong morphological and genetic differences between the populations in the three areas and even within each area. Therefore, they seem to be distinct stocks. On the other hand, the populations of the northern coast of Morocco and the Gulf of Cádiz seem to be the same. Although there is some evidence that they are different from those in Portugal and Galicia, ICES has not yet made a decision about it. However, they seem to be different from those in the Bay of Biscay and the French Atlantic coast (Giannoulaki et al., 2013; ICES, 2021: 80–81; Tudela, 1999; Ventero et al., 2017).

[5] The data are from the 'Fishery and Aquaculture Statistics' by FAO. However, we have used the FISHSTAT database (FAO, n.d.) and its Workspace 'Capture Production 1950–2020 (Release date: March 2022)', in which the information included in these serial publications can be found.

2015 to 2019 (FAO, 2019, 2018, 2017, 2016, 2015).[6] Landings show a pattern of high variability due to the sensitivity of anchovy recruitment to changes in environmental conditions in the sea (i.e. sea temperature, wind regime, freshwater discharge into their habitat, and changes in the strength and direction of the incoming jet of Atlantic waters into the Mediterranean Sea) (Macías et al., 2014; Ruiz et al., 2017). Therefore, the coefficient of variation ranged from 21% in the Mediterranean Sea to levels higher than 40% in the rest of the fishing grounds. The European anchovy is fished by boats that are equipped with purse seines. However, it was also targeted by mid-water trawlers, beach seines, and, to a lesser extent, driftnets in the past.

The most important fleets in terms of catches targeting the European anchovy are in Turkey and Georgia. They fish 100,000 mt/year of the total current landings. EU landings are between 100,000 and 130,000 mt/year, and Spain fishes 32% of them. Spain also consumes a significant share of fresh European anchovy coming from other EU countries, especially Portugal (6100 mt/year), Italy (2400 mt/year), and France (2500 mt/year), but also from outside the EU. The Spanish market consumes 40% of EU landings of European anchovies and 12.3% of landings worldwide.

The development of the Spanish market for European anchovies has been closely related to the Iberian Peninsula's fishing and processing sectors since Roman times (Escudero Domínguez, 2008; Homobono et al., 1993). Currently, the capture of European anchovies by the modern Spanish purse seine fleet is complemented by imports of different species of anchovies from Europe (fresh European anchovies) and South America (frozen and brined Argentine and Peruvian anchovies). The latter is only used in the processing industry. Therefore, they are not considered in the empirical analysis. These anchovies are supplied to Spanish markets for fresh consumption, and they are also used to produce canned preserved and semi-preserved anchovies in oil as input by the processing industry (Fig. 1). The evolution of this market has historically been subject to the evolution of the status of anchovy stocks, the fishing power of the fleet that exploits the European anchovy in Spain, and the demand for anchovies by national and foreign markets.

The Spanish anchovy fleet exploits European anchovy fishing grounds of the regional sea subdivisions VIIIb,c 'Bay of Biscay – Central & South' and IXa 'Atlantic Iberian waters' of the International Council for the Exploration of the Sea (ICES) in the Atlantic Ocean and subdivisions GSA-01 'Northern Alboran Sea', GSA-05 'Balearic Islands', GSA-06 'Northern Spain', and GSA-07 'Gulf of Lions' of the General Fisheries Commission for the Mediterranean (GFSM) in the Mediterranean Sea in the Spanish Economic Exclusive Zone (EEZ). Moreover, some vessels from Andalusia and Murcia fish in GSA3 'Southern Alboran Sea' (Fig. 2). The management of the European anchovy fisheries in the Spanish waters of the ICES sub-area IXa South (Gulf of Cádiz) is based on a programme of Individual Transferable Fishing Quotas (ITQ) combined with fishing licences that allocate the Annual Total Allowable Catch (TAC) set by the EU for each vessel. On the other hand, European anchovy fisheries are managed using TACs and fishing licences in ICES zones VIIIb,c and ICES IXa North. In contrast, management in the Mediterranean Sea is based on a combination of fishing licences, effort controls, and daily maximum catches according to specific regional management plans.

The evolution of landings from different regional subdivisions of the Spanish EEZ is shown in Fig. 3. Landings follow different patterns depending on the anchovy fish stock status and are highly dependent on marine environmental conditions (Macías et al., 2014) and fleet dynamics. Figs. 2 and 3 show that most of them come from ICES subdivisions VIIIb,c and IXa and GFCM subdivision GSA-06.

The ICES VIIIb,c fishing grounds traditionally produce the highest share of the total catch of European anchovies in Spain. The European anchovy fishery in the Cantabrian Sea collapsed during the period of 2005–2010 due to a series of low recruitment levels of this species, lower than 5000 mt in 2005. They were caused by adverse marine environmental conditions for this species, which resulted in a high variability in landings (between 4200 mt/year and 142,000 mt/year). The share of total catches of the ICES VIIIb,c anchovy stock reached 49% on average during the period of 2015–2021.

The GSA-06 fishing grounds are the second most important in landings of European anchovies in the Spanish EEZ, representing 25–30% of total Spanish landings in the period of analysis. European anchovy landings were over 20,000 mt/year during the period of 1988–1994, when many vessels from GSA-01 fished in the Gulf of Lions in spring and summer (Pertierra and Lleonart, 1996: 258). Landings of European anchovies declined sharply in this region from 1995 to 2400 mt in 2007. They recovered from this year until 2018, with landings close to those registered four decades prior. However, some landings were significantly lower in the period of 2019–2021 (11,685 mt). The variability of landings is consistent with the variability of recruitment of this fishery, with an increase in size and age in recent seasons (GFCM, 2021). Assessment shows a sustainable pattern of exploitation of the European anchovy in this area, despite high uncertainty.

European anchovy landings in ICES subdivision IXa, which is the third most important in terms of landings, were 17,837 mt in 2021 (46% caught by the Spanish fleet), given that this subdivision is shared with Portugal. The ICES *Working Group on Southern Horse Mackerel, Anchovy, and Sardine* (WGHANSA) distinguishes two management units from 2008: the western component of the stock from Finisterre Cape to San Vicente Cape and the southern component of the stock from San Vicente Cape to the Strait of Gibraltar (Ruiz et al., 2017). The current stock assessment of the European anchovy stock in the ICES subdivision IXa is close to the historical peak (ICES, 2021).

Anchovy catches are mainly traded in first-hand sale markets, but a low quantity is sold directly to the processing industry and supply chains or as live bait for tuna boats in the Cantabrian Sea. Fishers' guilds manage most first-hand sale markets. However, port authorities and other specialised companies (locally called *vendedurías*) manage 10% of these markets. Fig. 4 shows the high sensitivity of average first-hand sale nominal prices to changes in anchovy landing. Nonetheless, it is worth noting that real prices have significantly decreased in the last decades (65% from 1986 to 2020). This has resulted in a reduction in fleet profits.

2.2. Consumption

Per capita apparent consumption of fresh European anchovies is around 1.2 kg/person/year. This represents 85% of landings. The rest of the landings are processed as canned and semi-preserved salted anchovies in oil, which is locally known as *anchoas*. Semi-preserved salted anchovies in oil represent 4% of the Spanish apparent consumption of European anchovies (4000 mt/year on average). Semi-preserved salted anchovies in oil are prepared in different formats using not only the European anchovies but also other similar fishes of the *Engraulis* family, such as the Argentine anchovy (*Engraulis anchoita*) or Peruvian anchovy (*Engraulis ringens*). The Spanish apparent consumption of fresh European anchovies is five times the mean of that of the EU (0.23 kg/person/year). It is slightly higher than that in Greece (1 kg/person/year) and double that in Italy (0.6 kg/person/year). In contrast, it is much lower than the apparent consumption in Croatia (2.2 kg/person/year).

Spanish per capita consumption of fresh European anchovies, that is, fish without any type of processing or packing, is one of the highest in the European Union. Most recent surveys estimate per capita consumption of European anchovies at 0.90 kg/inhabitant and year on average (2017–2021), with a maximum of 0.97 kg/inhabitant in 2018 and a minimum of 0.81 kg/inhabitant in 2021 (MAPA, n.d.-a). Therefore, the total household consumption has changed in an interval

[6] From 1998 to 2007, the yearbooks were entitled 'Capture Production', not including aquaculture data, and from 1963 to 1998, they were entitled 'Catches and Landings'.

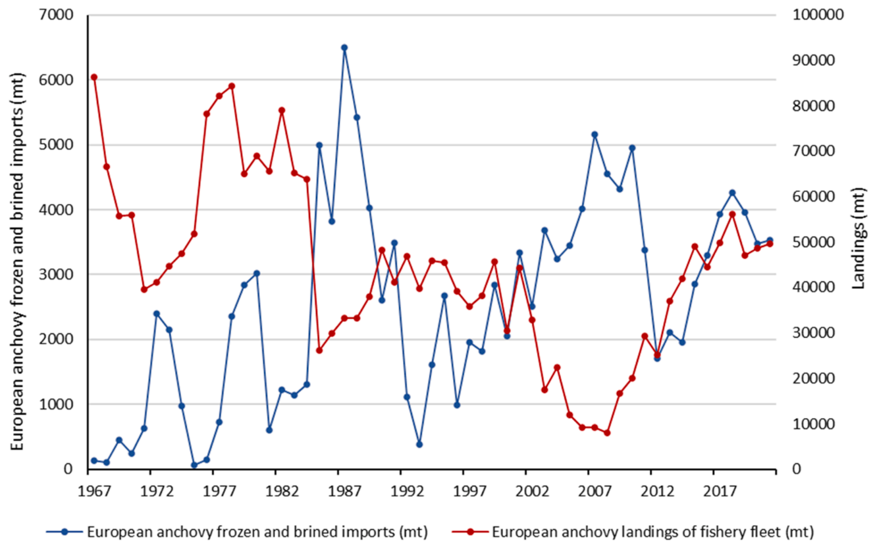

Fig. 1. Anchovy landings by the Spanish fishing fleet and anchovy imports in live equivalent weight (1967–2021).

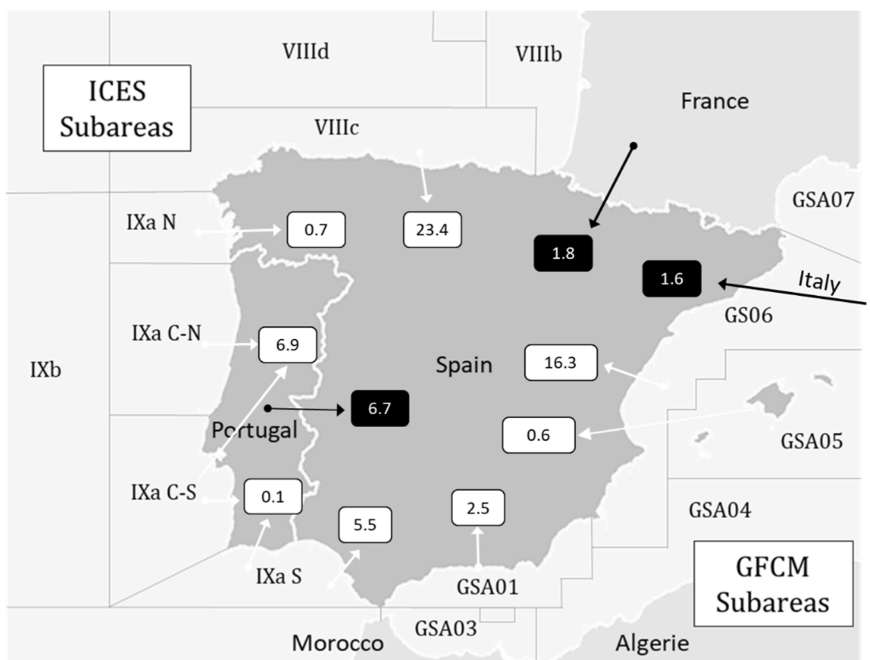

Fig. 2. Management units, European anchovy landings (white squares) and imports (black squares), both expressed in 10^3 mt (average for 2016–2020).

between 37,526 mt and 44,448 mt per year (Fig. 5). Additionally, between 1229 and 2899 mt of waste consumed in hotels and restaurants between 2017 and 2021 should be added to this amount.[7] These data are consistent with the apparent consumption estimated without including the consumption of the processing industry (Industrial Products Survey, Spanish Official Statistics, and National Association of Manufacturers of Canned Fish [ANFACO]), applying the corresponding conversion factors to the production of each type of canned anchovy (EUMOFA, 2021).

2.3. Foreign trade

Foreign trade is another component of the total supply of fresh European anchovies in the Spanish market. Anchovy imports have traditionally guaranteed the supply to the Spanish domestic fish market. Most imports came from Italy until 1987, but after the integration of Spain into the European Economic Community (EEC), a huge amount of European anchovies was imported from France and, to a lesser extent, from the United Kingdom and Germany. Imports of European anchovies amounted to between 20,000 and 30,000 mt/year in the period of 1993–2010 with a peak of 32,000 mt/year in 1998 and 2000 (MINCOTUR, n.d.). Later, imports of European anchovies decreased when fishing grounds in ICES subdivision VIIIb,c and GFCM subdivision GSA-06 recovered. Therefore, the minimum historical value of imports from

[7] The estimates of non-domestic food consumption made by the Ministry of Agriculture, Fisheries, and Food seem to be underestimated. They could not possibly include part of the consumption of non-resident households (tourists) in second homes. In fact, this series was stopped in 2006 and then restarted in 2015 with a different methodology and conflicting estimates because the estimate of non-domestic consumption was 19,973 mt for 2005, while it was only 526 mt for 2015.

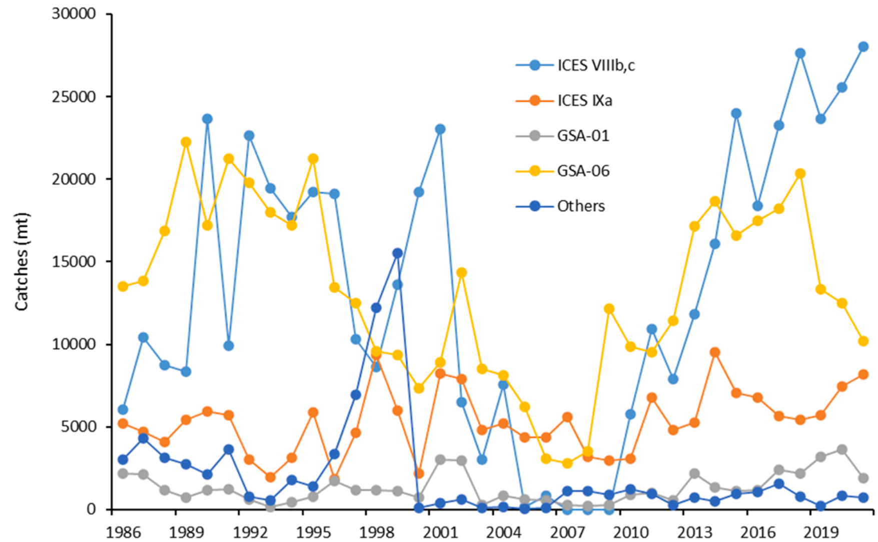

Fig. 3. Anchovy landings (*Engraulis encrasicolus*) of the Spanish fishing fleet by management subdivisions (1986–2021) (others include the GFCM areas GSA-03, GSA-05, and GSA-07, together with major FAO fishing area 34).

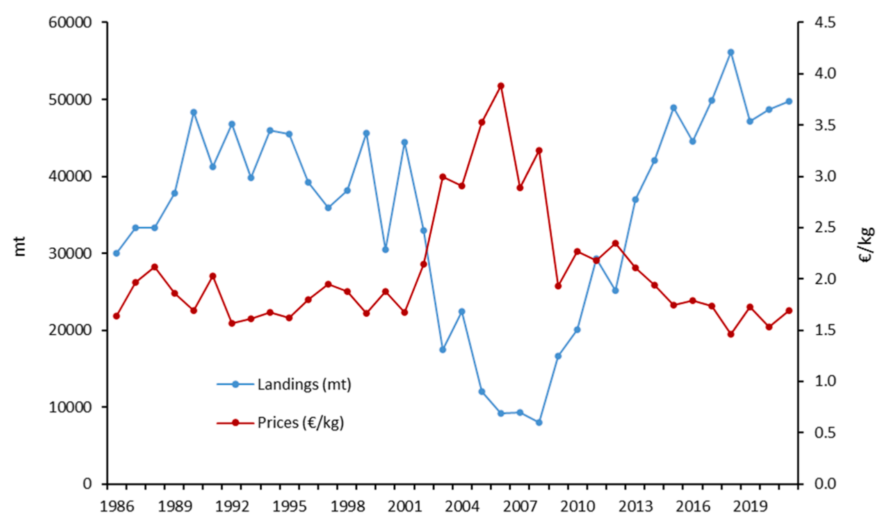

Fig. 4. Anchovy landings (*Engraulis encrasicolus*) of the Spanish fishing fleet and prices in first-hand sale markets (1986–2021).

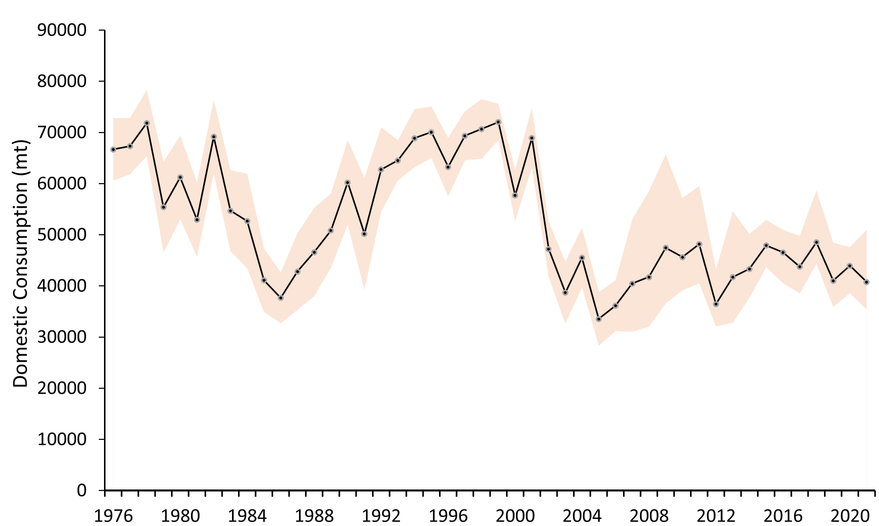

Fig. 5. Estimates of domestic consumption (mt) of fresh anchovies in Spain (1976–2021) (maximum, minimum, and average of different sources). Sources: Industrial Products Survey conducted by the Spanish National Statistics Institute (INE) and statistics from the National Association of Manufacturers of Canned Fish (ANFACO).

1988 was reached by 2021 (7728 mt). The destination of imported fresh European anchovies is usually wholesale markets that belong to the Central Market Network (MERCASA), where domestic production is also sold to retailers.

European anchovy exports are very low. They were only greater than 1000 mt/year, three times during the period of 1976–2011. Exports increased progressively from 2011, when the fishing grounds of ICES VIIIb,c and GFCM GSA-06 recovered. They were commercialised in markets that previously supplied the Spanish anchovy market (France, Italy, Morocco, and Portugal). Exports and imports were almost equal from 2017 onwards. Imports are sent to wholesale markets, whereas exports mainly affect first-hand sale markets, where exporters buy part of the production. At present, there are business groups that purchase anchovies from the Cantabrian fish markets to export them to factories located in third countries where they produce anchovy fillets in olive oil to pack them as 'Cantabrian anchovy' and sell them in the Spanish market.

The deficit in the balance of trade in terms of weight with France, Italy, Morocco, and Portugal during the period of 1986–2013 began to reverse with the first three countries from 2014. It is worthwhile to note the significant surplus with Morocco due to the outsourcing of the canning industry in the last few years and the deficit with Portugal due to the shift in the target species of the Portuguese fleet from sardine to European anchovy in the ICES subdivision IXa as a consequence of the reduction in TAC allocated to sardines in the Portuguese EEZ in the last few years.

Fig. 6 depicts the evolution of the average current prices in first-hand sale markets, the average prices of imports and exports, and the anchovy catch auctioned in first-hand sale markets. The evolution of first-hand sale and export prices is very similar, with a strong increase between 2001 and 2008, which coincides with the collapse of ICES VIIIb,c and the severe reductions in landings in GFCM GSA-06. In current terms, the first-hand sale prices for the period of 2018–2020 were 11.1% lower than those for the period of 1990–1992, with more landings. By contrast, the average prices of imports and exports increased by 9.2% and 20.5%, during the same period. Nonetheless, import and export prices experienced reductions of more than 40% in real terms, while the average first-hand sale price of Spanish landings decreased by 56%.

2.4. *Anchovy: a key species in the Spanish fish market*

In summary, anchovies are of great importance for the Spanish fishing sector and in terms of guaranteeing food security. The fleet involved in their capture in 2019 consisted of 328 purse seiners in the Atlantic (FAO region 27) and 205 purse seiners in the Mediterranean (FAO region 37). Therefore, they represent 6.3% of the total number of vessels operating in national fishing grounds and 24.7% of their tonnage, expressed in GT (MAPA, n.d.-b). The relative importance of this species in the total catches of vessels operating in both regions is very high: 9.6% of the catches in live weight in the Atlantic and 26.1% in the Mediterranean. This represented 14% of the total weight in 2020. There has been a gradual increase in this percentage from 1% in 2008 to 8.9% in 2013 per the latest figure mentioned above (MAPA, n.d.-c). Furthermore, regarding income, the income generated by purse seine vessels stands at 13.5% of the total generated by all fleets in Spanish territorial waters of the Atlantic and 40% in the Mediterranean, with anchovies being the main species caught. Thus, 22.6% of all income generated by the Spanish fleet operating in its territorial waters corresponds to the fleet dedicated to catching anchovies (MAPA, n.d.-d). In market terms, fresh anchovies represent 0.3% of the total value of household food consumption, 5.8% of the total value of fresh fishery products, and 8.5% of the average weight during the period of 2019–2021 (MAPA, n.d.-e).

3. Spanish market of fresh European anchovies: institutional arrangements

There are three basic elements in the value chain of fresh anchovies: first-hand sale markets and central wholesale markets as centres for the internal redistribution of fishing products and the retail market, made up of very different commercial typologies (Fig. 7). The interaction between these three elements sets up different types of market distribution channels, mainly traditional (fisher - first-hand sale - wholesaler - retailer - consumer) and modern (fisher - first-hand sale - retailer - consumer).

3.1. *First-hand sale market*

In first-hand sale markets, daily catches of fishing fleets are sold using Dutch auctions. The catches of each vessel are usually sold in the first-hand sale market at its home port. However, given the mobility of shoals, in some fishing seasons some vessels usually go to ports close to the place of capture, and their catches are sold there. Particularly, anchovy sales of the Basque fleet have concentrated in ports in Asturias in the year 2020 in the Cantabrian Sea. Authorised buyers are usually wholesalers in origin, trading companies, and, increasingly, agents of large retail distribution chains (supermarkets). The wholesalers in origin sell to local retailers or wholesalers at the destination market, located in the Central Market Network (MERCASA), or in different facilities. The central markets also receive consignments sent by foreign wholesalers (imports) or those purchased by Spanish wholesalers to be sold, regardless of whether they are Spanish catches or imports. Wholesalers in the destination market sell to other wholesalers in their area of influence and retailers, who sell directly to consumers. In the retail distribution sector, hypermarkets and large supermarket chains have increased their market share by 6% over the last decade, maintaining a steady trend for the last 30 years. In contrast, the traditional retail establishments (traditional fishmongers) have lost 9% of their market share since 2010.

Only 39.4% of active first-hand sale markets (198) in Spain sell fresh European anchovies. However, it is worth noting that 20% of those with the highest volume of sales accumulated 93.1% of total sales throughout Spain in 2019 (Table 1). It is also relevant that there is a significant degree of concentration of landings, especially in ports of ICES subdivisions, and the degree of specialisation varies depending on the fishing grounds, with the highest in ports of the GCFM subdivisions.

3.2. *Wholesale market*

The Central Market Network (23 markets) conducts the wholesale distribution of fishery products in Spain. This network sold 64.9% of the total of fresh anchovies consumed in Spain in 2009, while this proportion stood at 84% in 2019, with an upward trend (MERCASA, 2020, 2010). Fig. 8 shows the increase in the quantities sold in the Central Market Network with respect to total consumption. It reached 91% in 2005, followed by a sharp decrease, and it stood at 62.9% in 2011, coinciding with the decrease in catches both in ICES subdivision VIIIb,c and GFCM subdivision GSA06. Subsequently, there has been an increase in the proportion in the Central Market Network as Spanish landings have recovered, standing approximately 67–84% of the total consumed between 2012 and 2020.

The wholesalers in the wholesale Central Market Network—-wholesalers in the destination market—purchase quantities from wholesalers at the origin or buyers from coastal first-hand sale markets. In addition, they import significant quantities of fresh European anchovies from Portugal and, to a lesser extent, from France and Italy. The

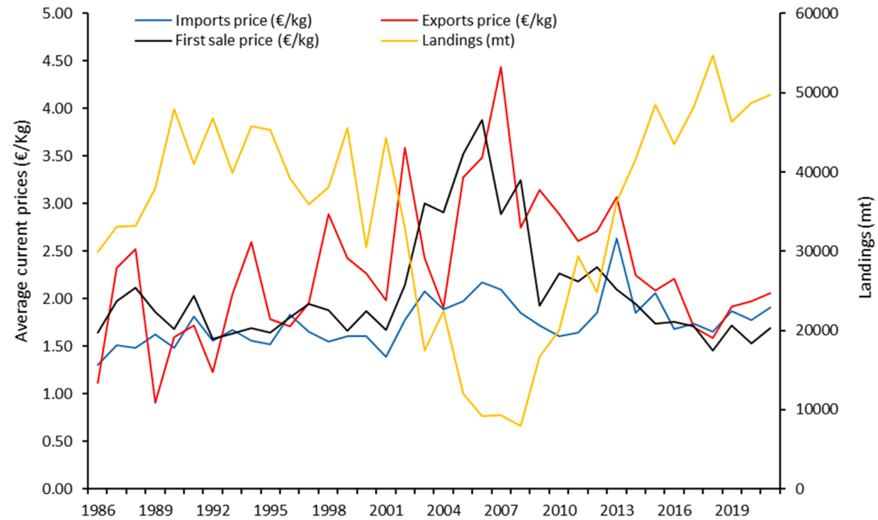

Fig. 6. Average prices of imports, exports, and first-hand sale markets and landings of the Spanish fleet auctioned in first-hand sale markets (1986–2021).

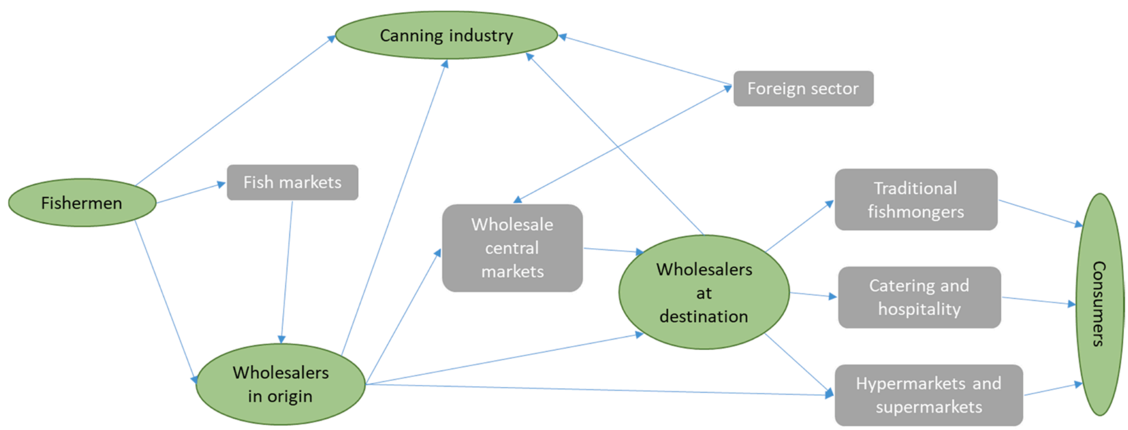

Fig. 7. Main trade channels of fresh anchovies in Spain.

Table 1
Summary of first-hand sale markets in 2019.

	Fishing area						Total
	ICES		CGCM			FAO	
	VIIIbc	IXa	GSA01	GSA05	GSA06	34	
A. Number of vessels	191	134	80	10	104	14	533
B. Anchovy landings (mt)	24689	5764	3172	149	13415	13	47202
C. Average landings per vessel (A/B)	129.3	43.0	39.6	14.9	129.0	0.9	88.6
D. Total number of first-hand sale markets	59	49	16	8	40	26	198
E. Number of first-hand sale markets with anchovies	19	16	15	1	25	2	78
F. Number of vessels per first-hand sale market (A/E)	10.1	8.4	5.3	10.0	4.2	7.0	6.8
G. Average weight per first-hand sale market (mt) (B/E)	1299	360	211	149	537	7	605
H. Average price in first sale (€/Kg)	1.61	1.89	2.70	1.96	1.64	2.58	1.73
I.% of weight in 20% largest first-hand sale markets	96.3%	98.8%	70.8%	100.0%	72.8%	95.4%	93.1%

Sources: Fishery statistics of the different Autonomous Communities. ICES WGHANSA Reports. GFCM Reports.

Central Market Network sold a total of 34,095 mt of fresh European anchovies of any origin in 2019, with Mercamálaga being the most relevant wholesale market with 11,418 mt, followed by Mercamadrid and Mercasevilla (Table 2). The former clearly specialises in fresh anchovies, with a weight of 33.5% of total anchovy sales in the network (Fig. 9). This uneven distribution of the sold quantities of fresh anchovies is a consequence of the inhabitants' eating habits in that area and the tourist activities and gastronomic traditions offered to visitors. It is also worth highlighting that fluctuations observed in prices do not respond to variations in supply; rather, to a certain extent, they are partially related to the evolution of first-hand sale prices (Fig. 6), as shown below.

3.3. Retail market

Over the last two decades, the retail market has experienced the greatest changes in the value chain. The consumption of fresh anchovies in hotels and catering establishments has fallen by 78% in the last two

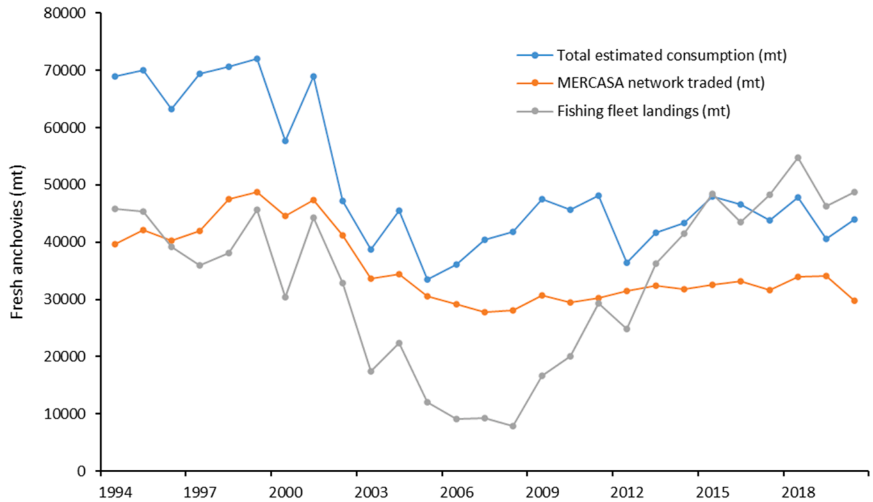

Fig. 8. Evolution of fresh anchovy landings, estimated consumption and quantities sold in the wholesale markets at destination (Central Market Network, MERCASA) (1994-2020).

Table 2
Importance of fresh anchovy sales in the Central Market Network (MERCASA) in 2019.

MERCASA wholesale markets	No. of wholesalers	Anchovy sales			Total fish sales			Average sales per wholesaler		Importance of anchovies (%) on total sales	
		mt	10^3 €	€/kg	mt	10^3 €	€/kg	mt	10^3 €	of the Merca	of anchovies
Mercamadrid	137	6397	29794	4.66	171192	1262500	7.37	1250	9215	3.7%	18.8%
Mercavalencia	22	4155	14895	3.58	106942	742400	6.94	4861	33745	3.9%	12.2%
Mercabarna	60	2294	8121	3.54	71373	546717	7.66	1190	9112	3.2%	6.7%
Mercasevilla	40	4813	13565	2.82	44038	235000	5.34	1101	5875	10.9%	14.1%
Mercamálaga	25	11418	42041	3.68	38295	192300	5.02	1532	7692	29.8%	33.5%
Mercazaragoza	11	922	3749	4.06	31371	216800	6.91	2852	19709	2.9%	2.7%
Mercabilbao	23	1561	7303	4.68	24355	166900	6.85	1059	7257	6.4%	4.6%
Others	76	2534	7499	2.96	46787	302900	6.47	616	3986	5.4%	7.4%
Totals	394	34095	127674	3.74	534353	3665517	6.86	1356	9303	6.4%	100.0%

Sources: MERCASA (2020) and annual reports of each wholesale market.

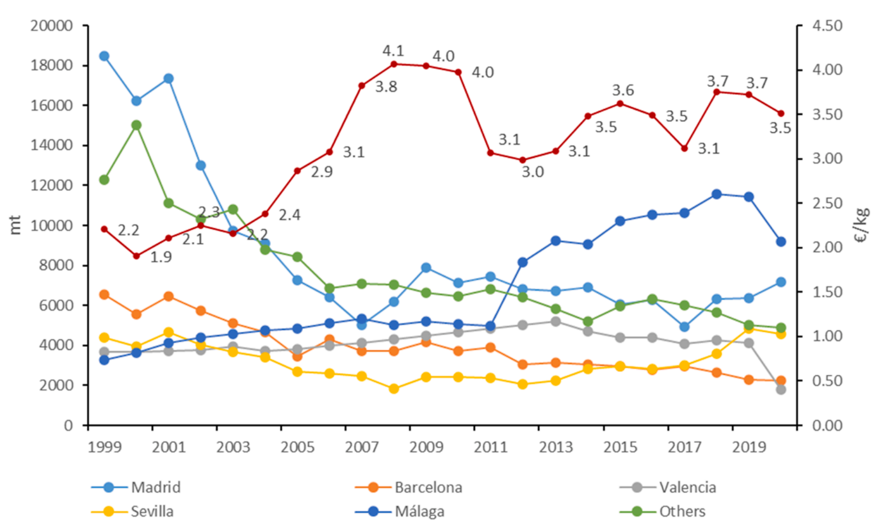

Fig. 9. Volume of fresh anchovies sold in the main wholesale central markets and the weighted average price (1999–2020).

Table 3
Structure of the food retail distribution sector and relative importance of fresh anchovy purchases in Spain (1999–2019).

	1999	2009	2019
Total number of establishments in Spain			
Hypermarkets	298	440	477
Supermarkets	12026	17082	22145
Traditional shops and supermarkets < 100 m^2	57848	34964	31702
% of the total number of establishments in Spain			
Hypermarkets	0.4%	0.8%	0.9%
Supermarkets	17.1%	32.5%	40.8%
Traditional shops and supermarkets < 100 m^2	82.4%	66.6%	58.4%
% of anchovy purchases			
Hypermarkets	6.1%	7.1%	7.0%
Supermarkets	21.9%	44.3%	51.9%
Traditional shops and supermarkets < 100 m^2	70.4%	46.4%	38.3%

Sources: Food Consumption Panel (MAPA, n.d.-a); NIELSEN (2021).

decades. This decrease is greater than that experienced by all fishery products (−57.9%) and fresh fish (−51.2%). Therefore, in 17 years, the non-domestic consumption of anchovies has decreased from 0.47 kg per inhabitant per year in 2005 to 0.04 kg per inhabitant per year in 2021. Additionally, total consumption has shifted from 1.74 kg per inhabitant per year in 1994 to growing slightly until 1999 and has subsequently decreased to around 0.92 kg per capita between 2017 and 2021, despite that the recovery of landings and the decrease in the price of the first-hand sale market have resulted in a recovery of consumption. Per capita consumption by households, excluding non-domestic consumption, has also decreased slightly by 10.5% when comparing the periods of 2007–2011 and 2017–2021.

The retail distribution of fishing products has experienced significant changes over the last two decades (Álvarez Blanco, 2015; Fernández Polanco et al., 2012). Most anchovy purchases have historically been concentrated in traditional establishments (fishmongers, stalls in food markets, etc.). However, the importance of this type of retail distribution fell from 70.4% (1999) to 38.3% (2019). This is due to an important change in purchases characterised by the concentration of most purchases of anchovies in supermarkets, which increased from 21.9% (1999) to 51.9% (2019; Table 3).

The prices in traditional retail establishments are much higher than those in the other types, at 115–120% of the average price of each year. However, the trends in the series were very similar (Fig. 10). This seems to be more closely related to fluctuations in total consumption (Fig. 1) than to those in the domestic household purchases.

3.4. Changes in the structure of the distribution sector

Regarding changes in the distribution sector structure, there have been extreme changes in consumer habits (Bilal et al., 2018; Collantes, 2016; Vignali et al., 2001). Considering fresh sardines and anchovies together, household penetration reached 39.8% in 1999, while it stood at 24.1% in 2019. In 1999, the penetration was higher in households in municipalities with fewer than 500,000 inhabitants, while the opposite is currently the case.

All these changes affect the evolution of prices at different levels in the value chain, as we analyse in the next section using biweekly data from the Observatory of Prices of the Food Chain of the Spanish Ministry of Agriculture, Fisheries, and Food.

4. Data

This study uses the prices of fresh anchovies in the first-hand sale market (PBO), wholesale market (PBM), and retail market (PBD) of the value chain. The prices of the first-hand sale and wholesale markets come from the Observatory of Food Prices of the Spanish Ministry of Agriculture, Fisheries, and Food. Retail market prices are derived from IDAPES.[8] It should be noted that 30% of the total fresh anchovy consumption in Spain is consumed by resident households in Andalusia. In addition, non-domestic consumption by resident and non-resident households (national and foreign tourists) should be added. This means that more than 50% of the total fresh anchovies traded in Spain are sold in the central wholesale markets located in Andalusia.

All these prices have a weekly frequency, as shown in Fig. 11. The price pattern is similar in the three markets of the value chain. However, to reduce the number of missing observations, we converted the data from weekly frequency to biweekly frequency, and we used linear interpolation for the remaining missing observations. The frequency of the data was transformed using average observations, which computed the average of weekly observations for a biweekly observation. The considered time period is from the 1st week of 2012 to the 27th week of 2022. Therefore, 275 biweekly observations were considered in this study. In addition, prices were transformed into logarithms to facilitate the estimation of the model and interpretation of the results (Sidhoum and Serra, 2016). In addition, as Bierlen et al. (1998) state, logarithmic transformation allows diminishing heteroskedasticity and produces normality in error terms. This allows us to obtain well-behaved error terms.

Table 4 shows a summary of the descriptive statistics for the three prices considered. We find positive skewness and excess kurtosis for all prices because the skewness coefficients are all greater than 0, and the kurtosis coefficients are all greater than 3. According to the results of the Jarque-Bera normality test, the null hypothesis that the variable is normally distributed is rejected for all three prices at the 1% significance level.

5. Methodology

We estimate two models of price volatility along the value chain: 1) a VAR model (Sims, 1980), which is a conditional mean model that explains the behaviour of prices in levels, and 2) a MGARCH (Engle, 1982; Bollerslev, 1986), which is a conditional variance model that explains the price volatility of the residuals of the conditional mean model. Both the conditional mean and variance models were estimated jointly using quasi-maximum likelihood procedures to ensure more efficient estimates than those obtained with the two-step procedure (Abdelradi and Serra, 2015; Ferrer-Pérez et al., 2020; Sidhoum and Serra, 2016). Additionally, Woźniak (2018) states that the joint analysis of the conditional mean and conditional variance model is necessary, and the inference related to transmissions is more reliable.

First, unit root and stationarity tests were performed to determine

[8] The price data of the retail market from the Observatory of Food Prices from the Spanish Ministry of Agriculture, Fisheries, and Food are not collected from 2019 onwards. The end date of this time series is the last week of 2018. As reviewers suggested updating the sample, it was necessary to use an alternative data source for prices of the retail market collected by the Observatory of Food Prices. This new retail price provided by IDAPES is a good proxy of the other variable. IDAPES is a reliable source for fresh anchovy prices in the retail market. Interestingly, this is a statistical activity included in the Statistical and Cartographic Programmes of Andalusia from 2007 under the denomination 'Analysis of prices of fishing products in retail establishments in Andalusia' with code 05.05.06 (Junta de Andalucía, n.d.-a). The data are disseminated via the Internet (Junta de Andalucía, n.d.-b) and the website of the Andalusian information system on fishing trade and production (IDAPES) (Junta de Andalucía, n.d.-c). The information is updated weekly through a panel of establishments classified into Fishmongers (traditional trade), Supermarkets, and Hypermarkets, classifying the products by commercial categories according to size and origin. We have used the weighted average series of all categories, which is provided by IDAPES.

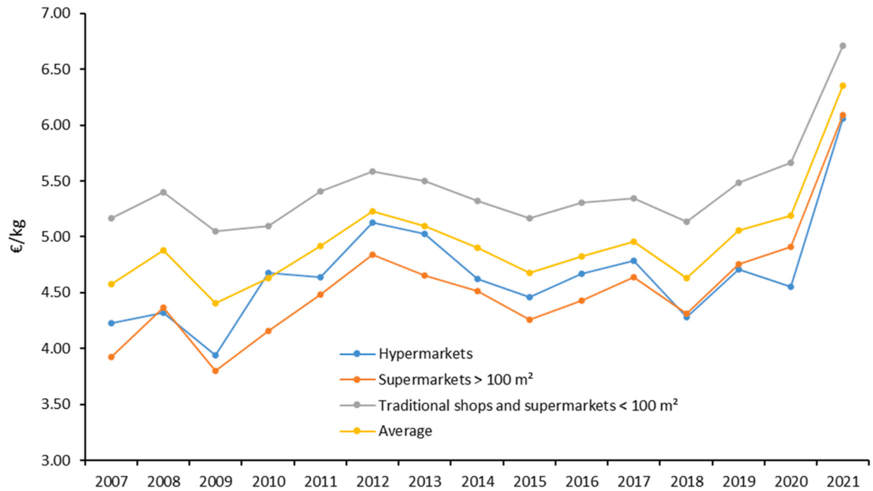

Fig. 10. Fresh anchovy prices by type of retail establishment (2007–2021).

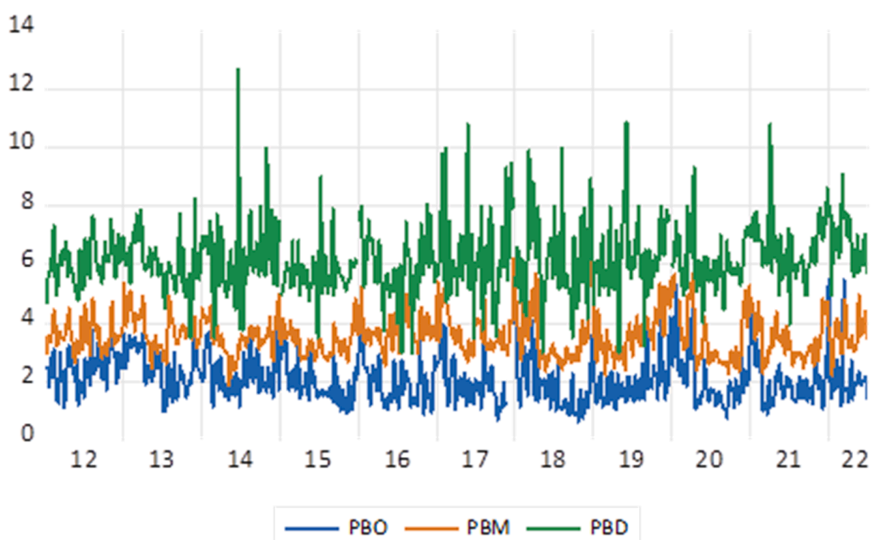

Fig. 11. Weekly price of fresh anchovies in the first-hand sale market (PBO), wholesale market (PBM), and retail market (PBD). Prices are expressed in €/kg.[91]

Table 4
Summary of biweekly price data used in empirical estimation (before being log-transformed).

	Price in the first-hand sale market (PBO)	Price in the wholesale market (PBM)	Price in the retail market (PBD)
Mean	2.110361	3.579991	6.186809
Median	2.000000	3.509400	6.065000
Minimum	0.800000	2.361250	4.000000
Maximum	4.985000	5.691250	9.900000
Std. Dev.	0.714791	0.654124	0.912000
Skewness	0.939155	0.656866	0.562649
Kurtosis	3.955550	3.181323	4.004158
Jarque-Bera	50.88788 * **	20.15260 * **	26.06348 * **

Note: * ** Significant at the 1% level. * * Significant at the 5% level. * Significant at the 10% level.

whether the price time series of the value chain are stationary or nonstationary. Once the orders of integration of the price series are determined, the unrestricted VAR model (i.e. the conditional mean model) is specified and defined as follows:

$$P_t = \mu + \sum_{i=1}^{k} \phi_i P_{t-i} + \varepsilon_t \quad (1)$$

where P_t is a 3 × 1 vector which contains the three prices in the first-hand sale, wholesale, and retail markets of the fresh anchovy value chain (PBO, PBM, and PBD), μ is a 3 × 1 vector of intercepts, k represents the optimal lag length chosen using information criteria, ϕ_i are 3 × 3 matrices of coefficients that capture short-run dynamics, $\varepsilon_t \sim iidN(0, H_t)$, and H_t is the 3 × 3 variance-covariance matrix.

Then, as the assumption that the matrix H_t is constant over time cannot be guaranteed in (1) because prices may present time-varying variability, the parametric generalised MGARCH model (i.e. the conditional variance model) is used here to study volatility transmission along the different markets of the value chain. We use the MGARCH model to test the hypothesis that shocks result in asymmetric price behaviour, that is, that negative and positive market shocks do not have the same effect on price volatility. The conditional variance model is specified using the Babba, Engle, Kraft, and Kroner (BEKK) model developed by Engle and Kroner (1995), which was generalised by Kroner and Ng (1998) and is defined as follows.[10]

$$H_t = CC' + A' u_{t-1} u'_{t-1} A + B' H_{t-1} B + D' v_{t-1} v'_{t-1} D \quad (2)$$

where H_t is the conditional variance matrix which was defined earlier; C is a lower triangular matrix of constant parameters; A is a 3×3 matrix of coefficients of ARCH terms, which indicates the own and cross-transmission effects of the past shock; B is a 3×3 matrix of coefficients of GARCH terms, which reflects the own and cross-transmission effects of past volatility; and D is a 3×3 matrix that includes the asymmetries. Therefore, the presence of asymmetric effects is considered in this conditional variance model. It can help identify whether a negative shock (unexpected reduction) in prices may result in greater subsequent volatility than an unexpected increase in prices of similar magnitude. This asymmetric model should allow us to determine whether price increases at the level of the value chain have the same effect on price volatility at levels other than price decreases or whether price instability in a market of the value chain worsens when there are increases in prices in other stages of the marketing chain than when there are reductions in prices at other levels of the value chain. Therefore, asymmetries in volatility models should be considered because if they are not considered, it might cause a misspecified model. If asymmetric effects are ignored when significant, it might lead to potential misspecification (Abdelradi and Serra, 2015). The empirical analysis was mainly carried out using the econometric software RATS version 10.0 (Doan, 2018a, 2018b). EViews version 11.0 (IHS Global Inc, 2019a, 2019b) was also used to compute descriptive statistics and perform unit root and stationarity tests. The RATS code was mainly obtained from Doan (2018b).

6. Results

As mentioned earlier, to study the integration order of the prices considered, the DF-GLS unit root test (Elliott et al., 1996) was performed to determine the order of integration of the variables. Considering the results in Table 5, all the series are I(0); that is, they are stationary.[11]

Next, we select the optimal number of lags for the VAR model. According to the FPE criterion (Final Prediction Error), AIC (Akaike Information Criterion), and LR criterion (Likelihood Ratio Criterion), the optimal number of lags is two, with eight being the maximum considered. Subsequently, the conditional mean model used for the estimation is a VAR model of order two, denoted as VAR(2).

Table 5
DF-GLS unit root test on price time series.

Price variable (in logs)	Exogenous regressors	No. of lags	Statistic
Log of price in the first-hand sale market (LPBO)	τ_τ	1	-7.0102 * **
Log of price in the wholesale market (LPBM)	τ_μ	2	-5.7080 * **
Log of price in the retail market (LPBD)	τ_τ	1	-8.4248 * **

Notes: Critical values are provided by Elliott et al. (1996).
* ** Significant at the 1% level. * * Significant at the 5% level. * Significant at the 10% level.
Exogenous regressors: τ_τ indicate that an intercept and a linear trend have been included in the auxiliary regression; τ_μ indicates that only an intercept has been included in the auxiliary regression.

Table 6 presents the misspecification tests for the VAR(2) model. The multivariate autocorrelation test described in detail by Lütkepohl (2005: 171), Hosking's (1981) multivariate autocorrelation test, and the multivariate test to determine whether the model residuals present ARCH effects (Hacker and Hatemi-J, 2005) were performed. Furthermore, we verified whether the VAR(2) model satisfies the stability condition. The results allow us to conclude that the null hypothesis of the absence of multivariate autocorrelation in the VAR(2) model is not rejected at a significance level of 10% according to both types of multivariate autocorrelation tests performed. Therefore, there is no residual autocorrelation in the VAR(2) model. Additionally, the null hypothesis of no ARCH effects in the residuals of the VAR model is rejected at a significance level of 5%. The results of this last test lead us to conclude that the use of a MGARCH model is appropriate. Finally, the VAR model satisfies the stability condition because no root lies outside the unit circle, as shown in Fig. 12.

Next, we performed a Granger causality test for the three model variables. As shown in Table 7, log of price in the first-hand sale market (LPBO) is caused by log of price in the wholesale market (LPBM) at the 1% significance level but it is not caused by log of price in the retail market (LPBD). Additionally, LPBM is caused by LPBO at the 10% significance level and LPBD at the 1% significance level. Finally, LPBD is not caused by either LPBO or LPBM. In summary, the first-hand sale market price is only Granger-caused by the wholesale market price. The wholesale market price is Granger-caused by the prices of the other markets in the value chain. Finally, the retail market price is not Granger-caused by any price in other markets in the supply chain. Therefore, the results show that the direction of causality in prices was from the wholesale market to the first-hand sale market, from the first-hand sale market to the wholesale market, and from the retail market to the wholesale market. This indicates the influence of wholesale price on first-hand sale price and the influence of first-hand sale and retail prices on wholesale price in the Spanish fresh anchovy supply chain. In this regard, for the value chain of fresh hake in Spain, Ferrer-Pérez and Gracia-de-Rentería (2020) do not find causal relationships from the retail market to the first-hand sale market or from the wholesale market to the retail market, and find a causal relationship between the wholesale market and the first-hand sale market. Furthermore, unlike Ferrer-Pérez and Gracia-de-Rentería (2020), for the value chain of fresh

Table 6
Multivariate tests for misspecification in the model.

Misspecification test	Statistic
Multivariate autocorrelation test F_{Rao} (12)	0.701063 (0.9888)
Hosking (1981) multivariate test (12 lags)	67.90878 (0.96027)
Multivariate ARCH test (2 lags)	101.59 (0.01237)

Note: p-values are in parentheses.

[9] There were some missing observations in the time series. Missing data in PBO were associated with weeks 2017:1, 2017:47, 2017:48, 2017:49, 2017:50, 2017:51, 2017:52; and 2022:12. Missing data in PBM were associated with weeks 2020:4 and 2020:5. Missing data in PBD were associated with weeks 2015:1, 2015:53, 2016:52, 2017:52, 2019:52, and 2020:1. The data for the first-hand sale and wholesale prices can be downloaded from MAPA (n.d.-f). The data for the retail prices can be downloaded from the website (Junta de Andalucía, n.d.-c).

[10] As Bauwens et al. (2006) state, the difficulty when estimating a BEKK-MGARCH model is the high number of unknown parameters, even after imposing several restrictions. It is thus not surprising that these models are rarely used when the number of series is larger than 3 or 4. Hassan and Malik (2007) point out that MGARCH models are widely known for convergence problems.

[11] The augmented Dickey-Fuller (Dickey and Fuller, 1981), Phillips-Perron (Phillips, 1987; Phillips and Perron, 1988), and Ng-Perron (Ng and Perron, 2001) unit root tests, and the KPSS (Kwiatkowski et al., 1992) stationarity test were performed.

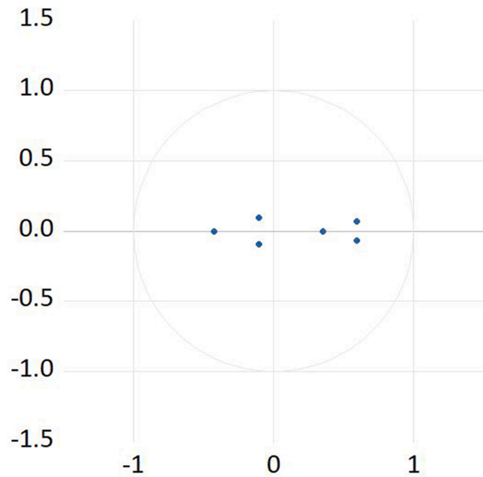

Fig. 12. Inverse roots of the AR characteristic polynomial.

Table 7
Granger causality tests.

Equation of the first-hand sale market	F statistic
LPBO is not Granger-caused by LPBM	8.10059 * **
LPBO is not Granger-caused by LPBD	1.58841
Equation of the wholesale market	F statistic
LPBM is not Granger-caused by LPBO	2.30953 *
LPBM is not Granger-caused by LPBD	7.26175 * **
Equation of the retail market	F statistic
LPBD is not Granger-caused by LPBO	0.51316
LPBD is not Granger-caused by LPBM	0.73760

Note: * ** Significant at the 1% level. * * Significant at the 5% level. * Significant at the 10% level.

anchovies, causal relationships from the first-hand sale market to the wholesale market and from the retail market to the wholesale market were identified, and a causal relationship from the first-hand sale market to the retail market was not found. The results obtained for the value chain of fresh anchovies in Spain also contrast with others, such as those for fresh red seabream (Jiménez-Toribio and García-del-Hoyo, 2006) because for this species, the price in the first-hand sale market determines the price in the wholesale markets considered, while the opposite causal relationship does not occur. Likewise, for fresh red seabream, Jiménez-Toribio and García-del-Hoyo (2006) find a bidirectional causal relationship between the wholesale markets considered and the retail market as well as between the retail market and the first-hand sale market.

These results are consistent with the evolution of the markets and foreign trade. The gradual increase in imports from Portugal, the ports of which are often closer to the main Spanish consumption centres, helps soften the shocks caused in the wholesale markets by the decrease in first-hand sale supply with its corresponding increase in price. Thus, although the influence of the first-hand sale markets on the wholesale markets is significant, the effect of the wholesale markets on first-hand sale markets is much more significant. Therefore, the large inflows of imports into wholesale markets have a substantial influence on first-hand sale prices because of the influence they exert on wholesalers at the origin or on first-hand sale buyers. However, the price in wholesale markets is also clearly influenced by the price in the retail market, where consumer demand determines prices. In addition, the changes in the retail market due to the COVID-19 pandemic, which led to an increase in the number of local shops, have increased the market share of traditional retail shops to the detriment of hypermarkets and supermarkets. However, the most relevant aspect is the foreseeable deviation towards non-domestic consumption by non-resident family units (tourists). This can be determined in the absence of specific statistical data by comparing the difference between the series of quantities sold in first-hand sale markets and the consumption series of Spanish households with that of tourists crossing the border.

The impulse response functions were estimated, as shown in Fig. 13, to analyse the dynamic behaviour of prices in the short run and, therefore, to determine the response of first-hand, wholesale, and retail prices over time to unexpected shocks at time t (Ben-Kaabia and Gil, 2007). The effects of a shock on all prices are temporary, and all prices revert to equilibrium after a few fortnights. In particular, a shock in the first-hand sale price has a temporary negative effect on the wholesale price. In contrast, the impact of this shock on retail prices appears to be positive. A shock in wholesale prices has a small positive temporary impact on retail price. However, it has a greater positive impact on first-hand sale prices. Finally, the shock in retail prices has a similar impact on the first-hand sale and wholesale markets, being slightly higher in the former. This impact seems to fade faster at the wholesale level than in the first-hand sale market.

Table 8 shows the estimation of the asymmetric BEKK-MGARCH model which has been previously described.[12] In addition, some misspecification tests that ensured that the model was adequate for the data are included. The results lead us to reject the null hypothesis that all the parameters in matrices A, B, and D as a whole are not significantly different from zero at the 1% significance level as well as the null hypothesis that all the parameters in matrices A and B as a whole are not significantly different from zero at the 1% significance level. According to these results, time-varying volatility can be confirmed by the model. Furthermore, the null hypothesis that the parameters in matrix D as a whole are not significantly different from zero at the 1% significance level is rejected. Therefore, the existence of asymmetric effects was confirmed in the model. Finally, Nyblom's (1989) joint stability test allows us to accept its null hypothesis; that is, the joint stability of the model is guaranteed at the 10% significance level.

It should be noted that the estimated individual parameters of the BEKK-MGARCH model cannot be interpreted directly. Nonetheless, interesting conclusions can be drawn from the equations of the conditional variances in Table 9. The coefficients that accompany $h_{i\,j,t-1}$, $i, j = 1, 2, 3$ indicate the transmission of direct and indirect volatility between prices, the coefficients that accompany $u^2_{i,t-1}$ and $u_{i,t-1}u_{j,t-1}$, $i, j = 1, 2, 3$ show how price volatility is affected by market shocks, and finally, the coefficients that accompany $v^2_{i,t-1}$ and $v_{i,t-1}v_{j,t-1}$, $i, j = 1, 2, 3$ indicate how price volatility is affected by asymmetric market effects.

The results indicate that volatility in the first-hand sale market (h_{11}) is only explained by past volatility in wholesale prices ($h_{22,t-1}$) and not by its own lags ($h_{11,t-1}$) or past volatility in retail prices ($h_{33,t-1}$). Additionally, the parameters which accompany $h_{12,t-1}$ and $h_{23,t-1}$ are significant. Therefore, the strength of the correlations between the volatility of the price in the first-hand sale market and that in the wholesale market and between the volatility of the price in the wholesale market and that in the retail markets have an impact on the instability of the price in the first-hand sale market. The correlation between the first-hand sale and wholesale markets ($h_{12,t-1}$) contributes to increasing first-hand sale price volatility if both prices move in the same direction. Additionally, the correlation between the wholesale and retail markets ($h_{23,t-1}$) contributes to reducing first-hand sale price instability if both prices move in the same direction. In addition, volatility in the wholesale market (h_{22}) is explained by its own lags ($h_{22,t-1}$), but it is not explained by past volatility in the prices of the first-hand sale market ($h_{11,t-1}$) or the retail market ($h_{33,t-1}$). However, the parameter which accompanies $h_{12,t-1}$ differs significantly from zero. Consequently, this correlation between the first-hand sale and wholesale markets ($h_{12,t-1}$) may decrease wholesale price volatility if both prices move in the same

[12] The asymmetric BEKK-MGARCH model has achieved convergence in 182 iterations.

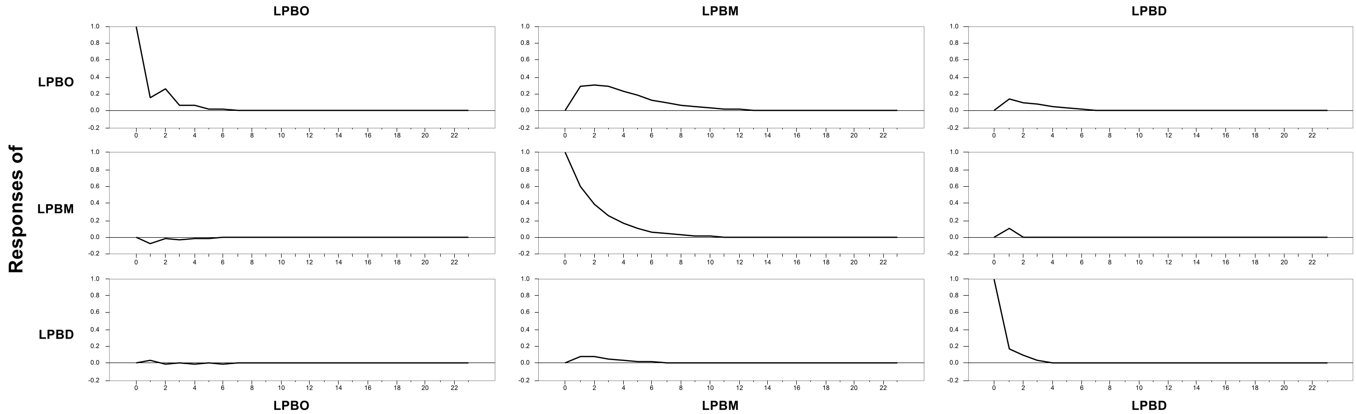

Fig. 13. Impulse response functions of prices. Note: The abscissa axes represent the 24-fortnight time horizon, and the ordinate axes show the response of prices to an orthogonal shock at another price along the value chain.

Table 8
Asymmetric BEKK-MGARCH(1,1) estimation: First-hand sale market - Wholesale market - Retail market.

$$H_t = CC' + A' u_{t-1} u'_{t-1} A + B' H_{t-1} B + D' v_{t-1} v'_{t-1} D$$

$$C = \begin{pmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{pmatrix}, A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}, B = \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix}, D = \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix}$$

	i = 1	i = 2	i = 3
c_{1i}	0.142557096 * **		
c_{2i}	0.020558495	0.032592047	
c_{3i}	0.022448266	0.085215051 * **	0.000015522
a_{1i}	-0.221758608	0.030261308	0.006797775
a_{2i}	0.902398978 * **	0.333255597 * *	0.126315011
a_{3i}	-0.308416692	-0.042160034	-0.421359200 * **
b_{1i}	0.458776660 * **	-0.228294200 * *	0.104673467
b_{2i}	0.834397334 * **	1.083097029 * **	0.078304029
b_{3i}	-0.716522010 *	-0.198021233	0.387187984 * *
d_{1i}	0.171331543	-0.050095030	-0.442360534 * **
d_{2i}	0.220467272	0.328188172 *	0.609492304 * **
d_{3i}	-0.330077631	-0.067806214	0.005288229
LR test for the null hypothesis of joint significance of parameters of matrices A, B, D			120.75600 * **
LR test for the null hypothesis of joint significance of parameters of matrices A, B			134.74218 * **
LR test for the null hypothesis of asymmetric effects			4.27216 * **
Nyblom (1989) joint stability test			10.3912295 (0.11)

Notes: The Nyblom test is shown with its p-value in parentheses.
* ** Significant at the 1% level. * * Significant at the 5% level. * Significant at the 10% level.

Table 9
Conditional variance equations: First-hand sale market - Wholesale market - Retail market.

$$h_{11} = 0.0203^{*} + 0.0492u_{1,t-1}^2 + 0.8143^{*}u_{2,t-1}^2 + 0.0951u_{3,t-1}^2 - 0.4002u_{1,t-1}u_{2,t-1} + 0.1368u_{1,t-1}u_{3,t-1} - 0.5566u_{2,t-1}u_{3,t-1} + 0.0294v_{1,t-1}^2 + 0.0486v_{2,t-1}^2 + 0.1090v_{3,t-1}^2 + 0.0755v_{1,t-1}v_{2,t-1} - 0.1131v_{1,t-1}v_{3,t-1} - 0.1455v_{2,t-1}v_{3,t-1} + 0.2105h_{11,t-1} + 0.6962^{*}h_{22,t-1} + 0.5134h_{33,t-1} + 0.7656^{***}h_{12,t-1} - 0.6574h_{13,t-1} - 1.1957^{*}h_{23,t-1}$$

$$h_{22} = 0.0004 + 0.0009u_{1,t-1}^2 + 0.1111u_{2,t-1}^2 + 0.0018u_{3,t-1}^2 + 0.0202u_{1,t-1}u_{2,t-1} - 0.0026u_{1,t-1}u_{3,t-1} - 0.0281u_{2,t-1}u_{3,t-1} + 0.0025v_{1,t-1}^2 + 0.1077v_{2,t-1}^2 + 0.0046v_{3,t-1}^2 - 0.0329v_{1,t-1}v_{2,t-1} + 0.0068v_{1,t-1}v_{3,t-1} - 0.0445v_{2,t-1}v_{3,t-1} + 0.0521h_{11,t-1} + 1.1731^{***}h_{22,t-1} + 0.0392h_{33,t-1} - 0.4945^{**}h_{12,t-1} + 0.0904h_{13,t-1} - 0.4290h_{23,t-1}$$

$$h_{33} = 0.0005 + 4.6210\mathrm{e}^{-05}u_{1,t-1}^2 + 0.0160u_{2,t-1}^2 + 0.1775u_{3,t-1}^2 + 0.0017u_{1,t-1}u_{2,t-1} - 0.0057u_{1,t-1}u_{3,t-1} - 0.1064u_{2,t-1}u_{3,t-1} + 0.1957^{**}v_{1,t-1}^2 + 0.3715v_{2,t-1}^2 + 2.7970\mathrm{e}^{-05}v_{3,t-1}^2 - 0.5392^{*}v_{1,t-1}v_{2,t-1} - 0.0047v_{1,t-1}v_{3,t-1} + 0.0064v_{2,t-1}v_{3,t-1} + 0.0110h_{11,t-1} + 0.0061h_{22,t-1} + 0.1499h_{33,t-1} + 0.0164h_{12,t-1} + 0.0811h_{13,t-1} + 0.0606h_{23,t-1}$$

Notes: h_{11} is the variance of the first-hand sale market, h_{22} is the variance of the wholesale market, and h_{33} is the variance of the retail market.
* ** Significant at the 1% level. * * Significant at the 5% level. * Significant at the 10% level.

direction. Finally, volatility in the retail market (h_{33}) is not explained by its own lags ($h_{33,t-1}$) or by past volatility in first-hand sale prices ($h_{11,t-1}$) or wholesale prices ($h_{22,t-1}$). Furthermore, none of the coefficients accompanying the covariance terms are significant.

Concerning market shocks, past shocks in the first-hand sale market ($u_{1,t-1}^2$) and in the retail market ($u_{3,t-1}^2$) are not significant in explaining any variances in the markets considered. However, past shocks in the wholesale market ($u_{2,t-1}^2$) seem to increase the first-hand sale variance (h_{11}). Additionally, the coefficients which accompany $u_{1,t-1}u_{2,t-1}$, $u_{1,t-1}u_{3,t-1}$ and $u_{2,t-1}u_{3,t-1}$ are not significant in any conditional variance equation.

Regarding the asymmetries in price volatility, past shocks to the first-hand sale market ($v_{1,t-1}^2$) are found to have an asymmetric effect on retail price volatility (h_{33}). This indicates that first-hand sale price decreases appear to have a greater impact on retail prices than do price rises. Additionally, consumers' consumption habits and demand expectations may change when transmitting first-hand sale price increases along the value chain. Finally, a reduction in the first-hand sale price can make the product more competitive. In addition, the volatility of the retail market (h_{33}) is affected by the asymmetric effect of the covariance term ($v_{1,t-1}v_{2,t-1}$). This shows that reductions in first-hand sale and wholesale prices may promote competition in the long run because they tend to have a greater impact on retail pricing responses than increases.

Fig. 14 shows the predicted volatility in the three markets of the fresh anchovy value chain in Spain. It should be mentioned that the market with the highest volatility is clearly the first-hand sale market, followed by the wholesale market and, finally, the retail market, the average predicted volatility of which is only slightly lower than that of the wholesale market.

In this regard, we found one or two values that appear to be outliers that can increase volatility in this market. This has also occurred in other studies on volatility price transmission along the value chain, such as that on fresh hake in Spain by Ferrer-Pérez and Gracia-de-Rentería (2020). In addition, according to Fernández-Polanco and Llorente (2015) and Guillen and Franquesa (2015), anchovy prices in Spain show less volatility in the retail market than at the first-hand sale or wholesale levels of the value chain. Therefore, the same conclusion is reached; that is, the retail market shows a certain degree of rigidity, and consequently, price volatility in the first-hand sale and wholesale markets of the value

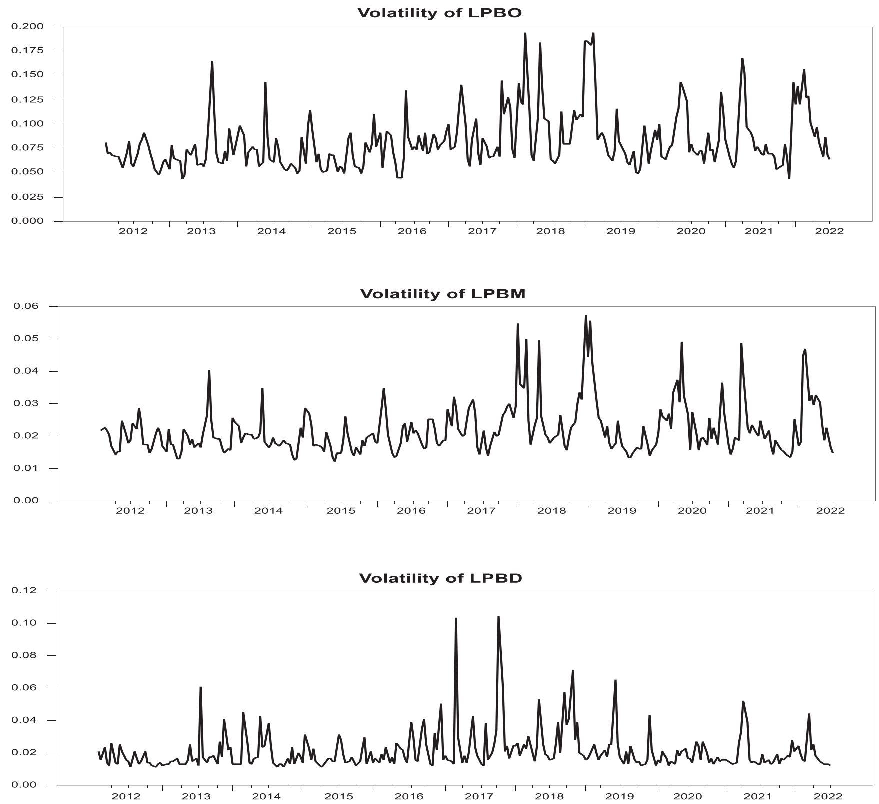

Fig. 14. Predicted conditional variances.

chain is only minimally passed along the value chain to the retail market.

7. Conclusions

This study investigates price volatility transmission along the fresh anchovy value chain in Spain. The anchovy is a fishing species of great commercial value for fishers and the fishing industry in Spain and has substantial economic and social relevance. Research has been conducted to analyse price transmission along the fresh anchovy value chain in Spain (Fernández-Polanco and Llorente, 2015; Guillen and Franquesa, 2015). However, this is the first study of the transmission of price volatility along the value chain of this fishing product.

We estimate a multivariate VAR(2) model for the conditional mean model, and an asymmetric BEKK-MGARCH(1,1) model for the conditional variance model using biweekly price data from 2012 to 2022. The conditional variance model allows us to analyse the transmission of price volatility among different levels of the value chain as well as the volatility interactions between them, and it also allows asymmetries in the transmission mechanism along the value chain.

In this regard, interestingly, as Dahl and Oglend (2014) state, the volatility of the group of pelagic species excluding tuna, in which the supply comes entirely from fishing, presents the highest volatility among the products considered in their study. Therefore, the results obtained in this study (i.e., the existence of ARCH effects in the residuals of the VAR model) are consistent.

Additionally, the existence of time-varying volatility and asymmetric effects is verified in the estimated BEKK-MGARCH model. The results indicate that the market with the highest volatility is the first-hand sale market, where the harsh effects of catch fluctuations are shown, followed by the wholesale market and, finally, the retail market, which has a degree of volatility only slightly lower than that of the wholesale market. Therefore, price volatility in first-hand sale and wholesale markets is only minimally passed on to consumers. However, asymmetric effects have been observed in the transmission mechanism of the fresh anchovy value chain. This phenomenon occurs in the retail market. Past shocks to first-hand sale and wholesale markets have direct and indirect asymmetric effects on retail price volatility, respectively. This means that the price response in the retail market is not affected symmetrically by increases and decreases in the first-hand sale and wholesale prices, but it tends to be more affected by reductions in the first-hand sale and wholesale prices than by increases in the prices at those levels of the value chain. These results show that the first-hand sale market exerts market power.

It is worth noting that 96.6% of the total fresh anchovy supply in Spain came from landings during the period of time considered in the empirical application. However, this is seasonal, and market power shifts to the wholesale market during periods of the year when landings are very low and imports are significantly high (mainly in January, February, September, and October). This situation may be caused by the large imports of anchovies from Portugal, which increased beginning in 2014, rising from an annual average of 589 mt during the period of 2012–2014 to an average of 7146 mt during the period of 2016–2018. They are concentrated in periods of high prices in the first-hand sale market, with reduced supply. Imports compete with the first-hand sale supply in wholesale markets, especially during periods when landings are smaller. Consequently, wholesale prices soften. However, low prices in wholesale markets coincide with periods of higher first-hand sale supply. In addition, imports from Portugal have a fundamental advantage over imports from other countries that have traditionally supplied the Spanish market with fresh anchovies (France, Italy, and Morocco): the reduced transport costs owing, to a large extent, to the fact that the landing ports are closer to the centre of Spain than many of the Spanish fishing ports. Therefore, in addition to the high quality and size of the catch, its price is usually very competitive.

Interestingly, these asymmetric effects imply that markets are not completely efficient. Information from one market in the value chain cannot be instantly incorporated into other markets in the value chain and vice versa. If markets are efficient, they would dissipate any shock with a non-persistent effect on volatility (Buguk et al., 2003; Ferrer-Pérez and Gracia-de-Rentería, 2020).

Likewise, these asymmetric effects support the idea of the existence of market power on the part of the first-hand sale and wholesale markets in the value chain depending on the period of the year (Buguk et al., 2003; Ferrer-Pérez and Gracia-de-Rentería, 2020). This results in a lack of transparency in price formation as well as potentially unfair commercial practices and anti-competitive measures that distort the market and reduce competitiveness. In addition, as previously mentioned, the wholesale market, represented by the prices of the Central Market Network, includes not only the quantities of anchovies auctioned in the first-hand sale markets but also varying quantities of imports from Portugal, France, Italy, and, to a lesser extent, Morocco, which have lower prices and an influence on the final price reached in the Central Market Network. The difficulties in having a differentiated series of anchovies traded in central markets according to origin prevents us from studying this phenomenon in depth. Moreover, periods of high volatility seem to correlate inversely with the first-hand sale supply and directly with Portuguese import inflows. This can be seen between 2012 and 2016, with relatively low catches in the Bay of Biscay, and between 2017 and 2019, with periods of low catches in the Gulf of Cádiz and maximum import levels. The volatility found by the BEKK-MGARCH model seems to be transmitted from the wholesale market to the first-hand sale market as are the effects of past shocks.

As pointed out by Pincinato et al. (2020), an increase in price volatility implies greater risks and costs associated with fishing activity, and consequently, the stability of the income of the fishing industry decreases. Considering that most fishers are risk-averse (Håkan and Martinsson, 2004; Pincinato et al., 2020; Smith and Wilen, 2005), it would be desirable to reduce volatility in the anchovy value chain in general and in the first-hand sale market in particular to avoid reducing their investment in fishing activity. Thus, measures should be taken to reduce volatility.

First, fishery management can be improved. Following Pincinato et al. (2020), efficient fishery management gives individuals more control over their catches, resulting in more predictable revenue as well as healthier fish stocks and higher fish quality. Furthermore, fishing sustainably would make it easier to achieve stable prices under transparent conditions, offering clear benefits to consumers, according to the 2013 reform of the European Union Common Fisheries Policy. For this, it is important to maintain sustainable management of the resource that leads to greater stability in the supply of anchovies, which will contribute to improving price stability.

It should be noted that, unlike fisheries in ICES area VIIIb,c, fisheries in ICES area IXa South (Gulf of Cádiz) are subject to TAC and transferable quotas, and the effective length of the season is established by fishers depending on the time at which they expect to obtain higher prices. Unfortunately, although the system of individual transferable quotas was implemented in 2018 for the Spanish fleet in ICES subdivision IXa South (Gulf of Cádiz), the regulation makes it impossible to obtain information about the prices at which these quotas are traded. Fishers are not required to report the quota sale price but only the quantities transferred. This prevents us from analysing the possible interrelations between the quota and product markets.

It is interesting to note that Portuguese catches are adjusted to periods in which the supply in the Spanish market is smaller. Therefore, they are not distributed homogeneously throughout the fishing season, which increases volatility in these markets.

Additionally, as Ferrer-Pérez and Gracia-de-Rentería (2020) suggest, activities to create a more dynamic, transparent, and simple system of fishing quotas are recommended to ensure sustainability consistent with moderate price volatility. This includes a quota exchange system that can improve the overall fish supply and price stability during difficult times. In 2018, Spain introduced a system of individual transferable quotas only in ICES subarea IXa South (Gulf of Cádiz); previously, the quotas were not transferable. Therefore, improvements in both the price stability and fish supply are expected in the future. However, it is difficult to extend this system to the Bay of Biscay and, above all, to the Mediterranean fleet, in which management is conducted using effort limitations.

Improving the productivity of fishing fleets and establishing better conditions for financial support to access technical progress (particularly for small-scale agents) may be additional policy advice suggestions. Nonetheless, although better management can effectively decrease harvest and price volatility, it is insufficient to counteract the effects of greater natural variability (Pincinato et al., 2020).

Second, aquaculture reduces price volatility because the supply is more stable (Dahl, 2017). However, to date, there has been no anchovy aquaculture. In addition, it does not seem profitable because of the price of this species and the massive amount that should be produced.

Third, market integration with other fish species should be considered because it would limit price fluctuations due to changes in their supply (Pincinato et al., 2020). It should be noted that there is a market with a high level of integration for pelagic fisheries (Tveteras et al., 2012). This would contribute to limiting the volatility of anchovy prices because of its high degree of substitution with other pelagic species. The period of time that we analysed is characterised by serious restrictions on sardine catch due to overexploitation. As has been mentioned, this has had an impact on the substitution of this species as a target species of the purse seine fleet in ICES subarea Northern IXa, where anchovies have mostly been targeted when the sardine quotas were exhausted.

Finally, market transparency should be increased in the anchovy value chain. Greater transparency in the fresh anchovy supply chain can help develop competition and improve price volatility resilience. According to Ferrer-Pérez and Gracia-de-Rentería (2020) and as has been shown in this work, the Spanish food value chain in general—and the anchovy value chain in particular—is characterised by a high degree of complexity due to the large number of middlemen involved. This sometimes makes the price formation process unstable and not transparent, which produces asymmetries. Therefore, this measure is expected to reduce price volatility. Enhancing the use of quality-differentiated marketing strategies with quality labelling can help offer higher-quality fish products with full traceability. This may ensure transparency and higher added value for consumers and provide more credibility for wholesalers and retailers. Consequently, it could be useful for achieving greater transparency in the fresh anchovy value chain. Additionally, it should be noted that recently, the law of the food value chain has been modified to achieve more equitable, balanced, and transparent trade relationships in Spain. Law 16/2021 of 14 December, which modified Law 12/2013 of 2 August, was approved by the Spanish Parliament.

Additionally, according to Pincinato et al. (2020), the impact of climate change on the volatility of the price of small pelagic species such as anchovies, measured by the variability of landings, should not be ignored. Likewise, the effect of the set-up of an online sales platform for fishing products on price volatility, as the Andalusian regional government plans to carry out, must be considered (Guillotreau and Jiménez-Toribio, 2006, 2011).

In conclusion, we would like to mention several limitations of the information used in this study. First, the time series used to represent retail market prices corresponds to estimates for Andalusia as a whole, which represents 50% of fresh anchovy consumption in Spain. Its pattern was very similar to that of the series provided by the Ministry of Agriculture, Fisheries, and Food until 2018. However, the latter time series was smoother. Second, the simple value chain first-hand sale market – wholesaler – retailer is not used for some traded quantities. There are other alternative value chains of growing importance, such as retail supermarket chains that buy directly from the first-hand sale market or import directly, as well as small local shops that buy in the first-hand sale markets. Therefore, there may have been small distortions in the results. In fact, the MERCASA wholesale network sold 80%

of the fresh anchovies in the Spanish market in 2012. However, currently, it only represents 60% due to these new commercial practices of the large retail distribution chains.

CRediT authorship contribution statement

Juan José García-del-Hoyo: Conceptualization, Writing – original draft, Methodology, Investigation, Writing – review & editing, Formal analysis, Visualization. **Ramón Jiménez-Toribio:** Conceptualization, Formal analysis, Writing – original draft, Methodology, Investigation, Software, Writing – review & editing. **David Castilla-Espino:** Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

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

We have provided the links to the data and references about the software used and code.

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