



## Product forms and price transmission in major European salmon markets

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### ABSTRACT

Product development is often an important component in increasing demand for successful aquaculture species. However, this topic has not received much attention due to limited data availability. In this paper, we investigate how the composition of salmon sales differ by product form by comparing the four largest European countries in terms of salmon consumption: France, Germany, Spain and the United Kingdom. The composition of salmon products varies significantly across countries, with unprocessed products dominating in Spain and highly processed products being the most important in the United Kingdom. We also find a high degree of price transmission for the less processed consumer products in all markets, while the price transmission is zero for most highly processed products. This is important since it implies that the more processed consumer products are largely insulated from the high price volatility of salmon at the producer level.

### 1. Introduction

Increased demand has been an important factor in facilitating the rapid growth in aquaculture production (Asche and Smith, 2018; Asche et al., 2022b; Brækkan et al., 2018). While expansion of the geographical market by exporting to more countries can increase demand, deepening the market by the introduction of new product forms is often the most important factor to increase demand (Asche et al., 2018), and this is particularly true in more mature markets (Cojocararu et al., 2021, 2022). Farmed salmon provides a good example in that the number of product forms in retail sales has increased significantly after the turn of the century (Landazuri-Tveteraas et al., 2018). However, as consumer preferences generally vary between markets (Torrissen and Onozaka, 2017), there may also be important differences between markets. This paper will investigate the main product forms of farmed salmon in retail for France, Germany, Spain and the United Kingdom (UK), the four largest salmon-consuming countries in Europe. In addition, the degree of price transmission will be compared in the four markets for the various supply chains.

There exists a literature showing that consumers find seafood hard to prepare and that there is a preference for more convenient products, although this preference is tempered by the higher price that is often associated with more processed products (Onozaka et al., 2014; Torrissen and Onozaka, 2017; Adhikari et al., 2021; Gosh et al., 2022). This is a perception that gives suppliers incentives to provide product forms that are easier to prepare, and the introduction of such products may increase demand as one may reach consumers who otherwise would eat less seafood (Asche et al., 2018).

Product development and the introduction of new product forms in conjunction with productivity growth to increase competitiveness are, to a large extent, the story of the increasing sales of farmed salmon. Until the 2000s, most farmed salmon were sold in relatively unprocessed product forms such as fresh (fillets or steaks) or smoked (Asche and Bjørndal, 2011). Product development was most visible in the smoked salmon category as smaller packet sizes were introduced, flavors were added, and firms, as well as country-of-origin and eco-labeling became more common. However, after the turn of the millennium, there has been an increasing pace of product development, with a number of new

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product forms being introduced, as shown by [Asche et al. \(2018\)](#) and [Landazuri-Tveteraas et al. \(2018\)](#).<sup>1</sup>

There are two rapidly growing literatures showing the heterogeneity of consumer preferences for different seafood species in various countries. Stated preference studies use survey data to estimate Willingness-to-Pay (WTP) for different product attributes ([Uchida et al., 2014](#); [Bronnmann and Asche, 2017](#); [Bronnmann and Hoffman, 2018](#); [Ankamah-Yeboah et al., 2020](#); [Weir et al., 2021](#); [Hossain et al., 2022b](#); [Yang et al., 2022](#); [Onozaka et al., 2023](#); [Phong and Trong, 2023](#)). While [Johnston et al. \(2001\)](#) is the only study we are aware of that explicitly compares preferences in different countries (Norway and the USA), the wide range of reported WTP estimates indicate significant differences in preferences. Hedonic price investigations investigate the value of specific product attributes ([Blomquist et al., 2020](#); [Hukom et al., 2020](#); [Asche et al., 2021](#); [Sogn-Grundvåg et al., 2021](#); [Sogn-Grundvåg and Hermansen, 2022](#); [Sogn-Grundvåg et al., 2022](#); [Hossain and Xue, 2022a](#); [Wolff and Asche, 2022](#); [Andersson and Hammarlund, 2023](#); [Bronnmann et al., 2023](#); [Botta et al., 2023](#); [Pascoe et al., 2023](#); [Pettersen et al., 2023](#)). Also, here, there are significant differences between countries. For instance, the premium associated with an ecolabel varies from zero to over 30%.

The supply chains for seafood are in many cases becoming longer as seafood is increasingly being processed in a third country between the producer and consumer countries ([Asche et al., 2022a](#); [Iversen and Hydle, 2023](#); [Svanidze et al., 2023](#)). This is to a significant extent true for Atlantic salmon since the most common product form of Norwegian exports is whole fresh ([Straume et al., 2020](#); [Oglend et al., 2022](#)), while the largest direct export market is Poland where a significant processing industry has developed primarily for further exports ([Svanidze et al., 2023](#)). In addition, there have been structural changes in fish retailing with the increasing importance of large retail chains ([Guillotreau et al., 2005](#); [Asche and Smith, 2018](#)). The retail chains have also led to an increasing share of salmon being bought on contracts ([Larsen and Asche, 2011](#)) and sold on private labels ([Guillotreau et al., 2005](#); [Love et al., 2022a](#)). These are all features that may reduce the information about market conditions being transferred by the prices through the supply chain as price transmission is reduced. In addition, [Landazuri-Tveteraas et al. \(2018\)](#) show that the degree of price transmission for the more processed products is lower than for unprocessed products as the cost share of other input factors increases. This is a feature that has received limited attention in the otherwise rapidly expanding literature on price transmission for seafood ([Acharjee et al., 2023](#); [Ankamah-Yeboah and Bronnmann, 2017](#); [Bronnmann and Bittmann, 2019](#); [Deb et al., 2022a, 2022b](#); [Gizaw et al., 2021](#); [Polanco and Llorente, 2019](#); [Polanco et al., 2021, 2023](#); [Surathkal et al., 2022](#); [Prodhan, Md.M.H., Khan, Md. A., Palash, Md.S., Hossain, M.I, Kumar, G., 2023](#)).

In this paper we will first use household panel data to describe retail sales of salmon for different product forms in France, Germany, Spain and the UK. Given that there is a global market for salmon ([Landazuri-Tveteraas et al., 2021](#); [Salazar and Dresdner, 2021, 2023](#); [Roll et al., 2022](#)) at the export level, we will use the Norwegian export price of whole fresh salmon to represent the upstream price in all supply chains. We will then estimate price transmission elasticities, the most common measure of the degree of price transmission in all the supply chains, recognizing that the price series may have different time series properties.

## 2. Data and background

We analyze salmon retail sales using monthly sales and prices for the four largest European markets for salmon: France, Germany, UK, and Spain. The data are derived from household panels collected by Kantar

Worldpanel and GfK, and the prices are unit prices computed from sales value and quantity. The panel size of the raw data (no. of households) is 32,000 in France, 30,000 in Germany and Great Britain, and 12,000 in Spain. The data cover the purchases of seafood made by private residential households for in-home use. The Norwegian Seafood Council has harmonized the product categories for all countries, and provide the actual data set we are using for our analysis. The data contain monthly observations of total retail value and quantity as well as information about processing, condition and product type for all salmon sales in each country for the period 2017–2021. This gives us 60 observations for each product. In addition, we use the Norwegian export price for whole fresh salmon, the main export product provided by the Norwegian Seafood Council. For the computations of market shares, the data will be aggregated to a annual frequency.

[Guillotreau et al. \(2005\)](#), [Asche et al. \(2014\)](#), and [Gizaw et al. \(2021\)](#) analyzed the French and UK salmon markets using data until the early 2000s for the two most important product forms; whole fresh and smoked. [Landazuri-Tveteraas et al. \(2018\)](#) show that in the 2010s, there was rapid product development in France, and even the fresh category changed fundamentally after the turn of the century as fresh fillets replaced whole fresh.

In terms of total sales value, France is the largest retail market for salmon with sales of 1.55 bn EUR in 2021, followed by Germany with 1.50 bn EUR, Spain with 1.02 bn EUR, and the UK with 0.94 bn EUR. However, it is of interest to note that while these four countries constitute the largest markets for final consumption, Poland has, in recent years, been a larger importer ([Asche et al., 2022c](#)). However, Poland's imports are not primarily for domestic consumption but rather to be processed and re-exported, exploiting the competitive advantage implied by lower labor costs ([Svanidze et al., 2023](#)). Important markets for Polish salmon exports are particularly Germany, but also France and Spain. Denmark is another large importer ([Straume et al., 2020, 2024](#)) that primarily packages or processes salmon for re-export.

[Fig. 1](#) shows volume shares in retail of the major salmon product categories for the four countries in 2021. These major product categories can be further broken down into more specific categories. For France the six major product categories shown in [Fig. 1](#) can be further disaggregated into 19 product categories. Underlying the six major product categories for Germany are 17 products, for the UK there are 14 products, and for Spain 21 products. For example, in France, the 'prepared fresh' category in [Fig. 1](#) contains 'caviar substitute', 'delicatessen', 'marinated', 'ready main meal', 'sushi', and 'other'. 'Prepared fresh' is a relatively small category in terms of retail volume. The largest of the major product categories, 'fresh', can only be broken down into three products: 'fillets', 'steak/fish meat', and 'whole'. Hence, the overall retail volume share of any major product category is not an indicator of how many specific products it is made up by. The unprocessed fresh product categories are relatively homogenous and commodified, thus offering limited opportunities for product differentiation. In contrast, 'prepared fresh' and 'prepared frozen' contain the more highly processed products, where also packaging, bundling, and branding are creating a broad range of convenience and value-added salmon-based food products.

The four markets differ significantly in terms of which product forms are sold. Fresh is by far the largest product category in Spain as it makes up 82% of the retail sales, and frozen makes up another 7%. This is not surprising as the seafood retail market in Spain is still relatively traditional, with a significant share of fresh fish prepared at home ([Petereit et al., 2022](#)). Also, in the UK, fresh makes up more than half the consumption with a share of 57%, and 4% frozen, which brings the relatively unprocessed category to 61%. In France, the fresh share is lower at 47%, but with 9% frozen. In Germany, the fresh share is significantly lower at 33%, while the frozen is as high as 16%. This is likely a function of the strong presence of discount stores ([Bronnmann and Asche, 2017](#); [Bronnmann et al., 2021](#)).

Germany is the only country where more processed forms (prepared

<sup>1</sup> Using data until the early 2000s, [Asche et al. \(2014\)](#) still only considered whole salmon and salmon fillets in the fresh and frozen categories.

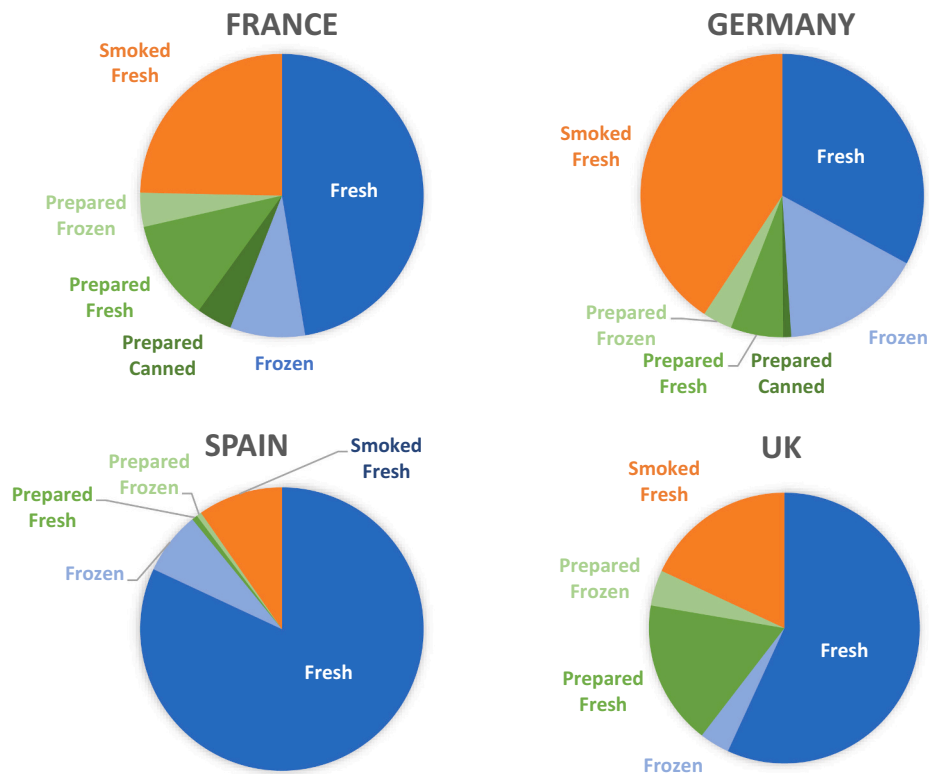


Fig. 1. Volume shares of salmon retail products in France, Germany, Spain and the UK, 2021.

and smoked) have a retail sales share of over 50%. Moreover, Germany is the only country where the fresh is not the largest individual product category by volume. This position is held by smoked salmon with a 41% share. Smoked salmon is a highly varied sector that has undergone significant product development since the 1980s (Asche and Bjørndal, 2011). While it started out as whole fillets in the fresh fish counter, it is now a varied category with prepacked salmon of a number of sizes and flavors targeting households of different sizes and consumption settings. Smoked salmon is the second most important product form in the three other countries, although with significantly different sales shares. In France it is 25%, in the UK it is 18%, while in Spain it is only 10%.

Other more processed product forms also vary in their levels of market penetration, although in all markets, they represent the fastest-growing categories. In the UK, processed products now make up 21% of the sales, and a similar trend in France has resulted in a share of 19%. In Germany, the share of these processed product categories is 10%, while in Spain it is only 1%. It is of particular interest that the difference across markets in this category is mainly due to the size of the prepared fresh category. In the UK, the prepared fresh category is as large as 17%. This illustrates the point that new product forms help facilitating demand growth (Brækkan et al., 2018).

A potentially important feature is that processing tends to increase the price of the final consumer product while also making preparation for the consumers easier (Torrissen and Onozaka, 2017). Fig. 2 shows average retail prices by product form and market for the most important disaggregated product categories. Because of the large number of unique product prices for the four markets (71 prices in total), Fig. 2 only shows the prices of the five largest retail products for each of the four markets. The figure consists of 21 prices: 20 retail prices plus the Norwegian export price for fresh whole salmon as a reference price.

The colors in Fig. 2 indicate product category. Fresh products are dark blue, frozen are light blue, prepared are yellow, and smoked are orange. Since prepared products (yellow) are more niche, few of them resides among the top five products. Unprocessed products (dark and light blue) dominate the lower price ranges, while smoked products

(orange) dominate the higher ranges. There are also interesting price differences across markets for identical product categories. For example, among smoked salmon prices (orange), smoked salmon products in Germany have a lower average retail price than the smoked salmon categories in the other three markets. Likewise, among fresh salmon prices (dark blue), products in Spain are the cheapest, followed by UK, France, and Germany. This implies that markets where consumption is dominated by fresh (Spain) and smoked (Germany) also offer the lowest retail prices for these products.

The wide spread of variation in fresh salmon prices may not only explain the relative popularity in Spain but also in the UK, where the prices are significantly lower compared to France and Germany. However, smoked salmon in France deviates from this pattern as we observe both a high retail price and a large volume in this product category.

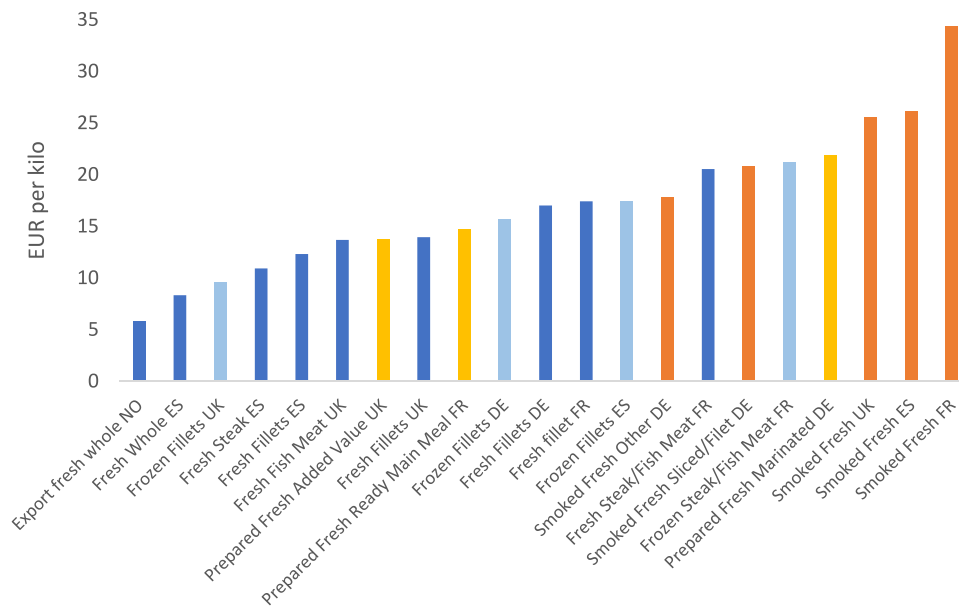
Fig. 3 shows price development over time for the 20 retail prices from Fig. 2 by major product categories.<sup>2</sup> To make a visual comparison of price variation easier, all prices have been normalized by the average price for 2017. There are some differences in price trends across the four groups of products. For instance, the graph with fresh product prices shows a slight downward trend. In contrast, the frozen prices appear to trend slightly upward. The other two categories prepared fresh and smoked fresh, exhibit no clear trends, or, if any, it is the lack of trend that characterizes them during this period.

### 3. Price transmission – method

When investigating the relationship between prices at different levels in the supply chain, the standard framework (see e.g. Guillotreau et al., 2005; Asche et al., 2014; Landazuri-Tveteraas et al., 2018) is based on the following equation:

$$\ln P_{r,t} = \hat{\alpha} + \hat{\beta} \ln P_{e,t} + e_t, \quad (1)$$

<sup>2</sup> The Norwegian export price for fresh whole salmon is excluded.



**Fig. 2.** Average Prices from Jan 2019 to Dec 2021. Color codes represent different product categories: fresh (dark blue), frozen (light blue), prepared (yellow), and smoked (orange). Except for the Norwegian export price to the far left, all prices are average retail prices for product categories in France (FR), Germany (DE), Spain (ES), and the United Kingdom (UK). Compared to the total value of salmon product sales, the five product categories chosen from each national market constitute a combined share of 85% in France, 92% in Germany, 90% in Spain, and 95% in the UK. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

where  $P_{r,t}$  and  $P_{e,t}$  are respectively the retail and Norwegian export prices.<sup>3</sup> Marketing costs and quality differences are assumed constant and included in the intercept term. All other factors impacting price are assumed random and collected in the error term,  $e_t$ , which is assumed to have an expected value of zero. The main parameter of interest is  $\hat{\beta}$ , which is an estimate of the price transmission elasticity. The price transmission elasticity measure to what extent a change in the upstream price  $e$  impacts the retail price  $r$ . Importantly, if the null hypothesis that  $\hat{\beta} = 1$  holds, this implies complete price transmission, while if the null hypothesis that  $\hat{\beta} = 0$  holds, there is no relationship between the prices. The alternative hypothesis for both null hypothesis are that  $0 < \hat{\beta} < 1$ , and indicate incomplete price transmission. This latter case implies there is a relationship between the prices and therefore a degree of price transmission, but it is not full as intermediaries respond to an increased price upstream by substituting other input factors.<sup>4</sup>

Since price series for salmon and other seafood species are frequently nonstationary, the tests on the parameters in eq. (1) are normally conducted using a time-series framework based on unit root tests and cointegration analysis.<sup>5</sup> However, we know from the market integration literature that the same tests can be conducted for stationary prices provided the time series are integrated of the same order (Asche et al., 2004). Moreover, if the data series is not integrated of the same order, there cannot be a long-run relationship (Engle and Granger, 1987). The first step in the empirical analysis of the prices is therefore to use unit root tests to determine the order of integration of the data series.

We use the most common test, the Augmented Dickey-Fuller (ADF) test to test for unit roots. For nonstationary data series integrated of the

<sup>3</sup> If the prices are at the same level, equation (1) specifies the price relationship that is used in market integration testing (Asche et al., 2004).

<sup>4</sup> Similarly, intermediaries increase the use of the input factor of interest if the upstream price is reduced in this case.

<sup>5</sup> Some recent examples are Asche et al. (2022c), Pincinato et al. (2022), Roll et al. (2022), Polanco et al. (2023) and Salazar and Dresdner (2023). While seasonality is typically important in quantities (Love et al., 2023a), it is not important for prices (Asche et al., 2017).

same order, the Johansen cointegration procedure (Johansen, 1988) is used to investigate if there is a long-run relationship as well as additional hypotheses. The structure of the data in a price transmission setting indicate that all prices have the same stochastic trend (Asche et al., 1999), and one can then test all the economic hypothesis by estimating bivariate relationships (Johansen and Juselius, 1994).<sup>6</sup>

Eq. (1) specify the long-run relationship when there are short-run dynamics such as adjustment cost. When short-run dynamics are specified, this approach also allows a test for price leadership or in technical terms, weak exogeneity (Asche et al., 1999). In general, the relationship between prices is bi-directional so that a shock to one price will impact the other. The prices are then determined jointly and in technical terms both prices are endogenous. In some settings, one level at the supply chain provides price leadership or a reference price. If this is the case, this price is exogenous as it will not be impacted by shocks to the other price, but any changes in the leading price will be reflected in the other price, and any demand response will then be in the form of adjustments in the quantities transacted.<sup>7</sup>

#### 4. Price transmission – Empirical results

The empirical analysis will be carried out for the 20 largest product forms as shown in Fig. 2 relative to the Norwegian export price. As discussed in the previous section, unit root tests are the first step of the analysis, as the price series have to be integrated of the same order for a long-run relationship to exist. Table 1 shows the results of the ADF tests. Each line shows two tests of the same price series, one in ln levels and the next in ln of the first differences. The optimal lag length is chosen using Akaike's Information Criterion and is reported in the last column.

The Norwegian export price is non-stationary, but stationary in first differences. Of the 20 retail prices, six ADF tests reject the null

<sup>6</sup> The prices will have the same stochastic trend when measured in the same currency. If the prices are in different currencies, the exchange rate must be a part of the cointegration relationship (Tveteras and Asche, 2008).

<sup>7</sup> An exogenous price can also have impact over time when there exist markets for futures contracts (Asche et al., 2016).

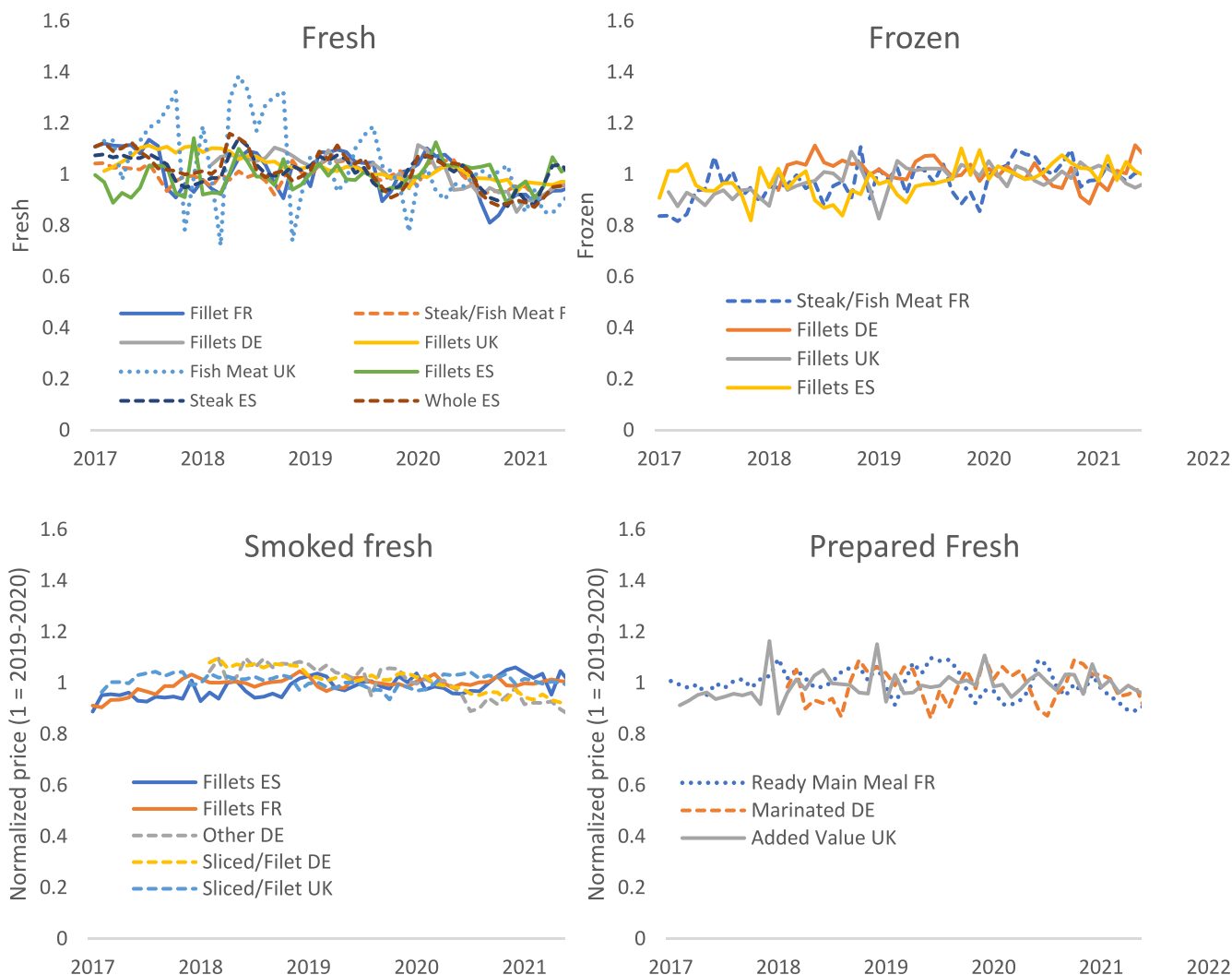


Fig. 3. Normalized prices show price trends and variability for different product categories.

Table 1  
Results augmented dickey fuller tests.

Product	Market	Levels t-ADF	Lag	First-diff t-ADF	Lag
Fresh whole (export)	Norway	-1.955	0	-7.979**	2
Fresh fillet	France	-2.444	2	-4.033**	2
Fresh Steak/Fish Meat	France	-1.932	2	-3.390*	3
Frozen Steak/Fish Meat	France	-5.442**	0	-4.292**	3
Prepared Fresh Ready Main Meal	France	-1.801	3	-4.728**	2
Smoked Fresh	France	-3.558*	3	-5.213**	1
Fresh Fillets	Germany	-1.778	3	-4.122**	2
Frozen Fillets	Germany	-1.994	3	-4.175**	3
Prepared Fresh Marinated	Germany	-3.607**	2	-3.955**	3
Smoked Fresh Other	Germany	-2.489	0	-2.991*	3
Smoked Fresh Sliced/Filet	Germany	-1.495	2	-4.958**	1
Fresh Fillets	UK	-2.120	3	-3.051*	3
Fresh Fish Meat	UK	-2.728	3	-8.306**	0
Frozen Fillets	UK	-3.387*	3	-7.702**	0
Prepared Fresh Added Value	UK	-3.960**	3	-4.623**	3
Smoked Fresh	UK	-1.939	3	-3.486*	3
Fresh Fillets	Spain	-2.814	3	-8.293**	0
Fresh Steak	Spain	-2.121	0	-3.779**	2
Fresh Whole	Spain	-2.155	0	-3.703**	1
Frozen Fillets	Spain	-3.266*	0	-4.269**	2
Smoked Fresh	Spain	-1.172	3	-3.912**	3

\*indicates significant at a 5% level and \*\* indicates significant at a 1% level.

hypothesis of a unit root for the level of the price series. These are treated as stationary and include the products frozen steak/fish meat (FR), smoked fresh (FR), prepared fresh marinated (DE), frozen fillet (UK), prepared fresh added value (UK), and frozen fillet (ES). Two characteristics put these six products into two categories: frozen or highly processed products. Frozen products are storable and can smooth out the price volatility of the spot price of fresh salmon. Highly processed products consist of other major cost components besides the salmon raw material and are, for that reason, not necessarily much influenced by price volatility in fresh salmon. Our first conclusion is that these prices are not cointegrated with the Norwegian export price of fresh salmon since the latter is found to be nonstationary. In other words, the six series are integrated of order 0, while the export price is integrated of order 1.

The remaining 14 retail price series are all found to contain one unit root and thus qualify for inclusion into the cointegration analyses with the Norwegian export price. The empirical strategy is to run bivariate tests of price transmission between export and retail prices.

The results from the cointegration analysis are presented in Table 2.<sup>8</sup>

<sup>8</sup> The reported test has no trend in the short-run dynamics. We conducted the cointegration tests also with a trend in the short-run dynamics, and this did not impact the conclusions from any of the tests. This is as expected given that lack of trends in the price series as shown in Figure 3.



**Table 2**  
Results johansen cointegration test.

Product	Market	Lags	TRACE		Trace rank	Full price transmission	Weak exogeneity	
			$K = 0$	$K = 1$			Retail price	Export price
Fresh Fillets	France	2	23.99	5.52	1	1.04	9.10**	4.52*
Fresh Steak/Fish Meat	France	2	27.28	3.09	1	7.86**	19.02**	4.07*
Prepared Ready Main Meal	France	1	10.46	1.74	0			
Fresh Fillets	Germany	1	18.03	4.16	1	0.14	4.9885*	2.409
Smoked Fresh Other	Germany	2	10.50	2.93	0			
Frozen Fillets	Germany	2	26.66	6.14	1	14.25**	12.316**	1.944
Smoked Fresh Sliced/Filet	Germany	1	15.12	2.45	0			
Fresh Fillets	UK	2	21.46	0.98	1	1.49	11.726**	8.579**
Fresh Fish Meat	UK	2	36.54	5.81	1	3.16	7.986**	0.086
Smoked Fresh	UK	2	15.44	7.06	1	0.62	6.718**	0.361
Fresh Fillets	Spain	1	26.31	7.34	1	7.72**	11.621**	0.326
Fresh Steak	Spain	1	18.79	3.06	1	10.34**	12.794**	0.135
Fresh Whole	Spain	2	18.66	5.42	1	0.01	15.791**	0.389
Smoked Fresh	Spain	1	10.32	1.04	0			

\*indicates significant at a 5% level and \*\* indicates significant at a 1% level.

To make results easier to read, all retail prices found cointegrated with the Norwegian salmon export price are highlighted with a grey background. For these prices, the trace test rejected the null of 0 cointegrating vectors but not of 1. As the table shows, 10 out of 14 retail prices are cointegrated with the export price.

The product forms that are not cointegrated with the export price are prepared ready main meal (FR), smoked fresh other (DE), smoked fresh sliced/fillet (DE), and smoked fresh (ES). Like stationary price series, a characteristic of the retail prices not cointegrated with the export price is that they are prices for relatively highly processed products. This makes sense as processing and value-added create a larger wedge between the export price of the fresh salmon and the retail price of the final consumer product. All the costs associated with processing, marketing, and distributing a value-added product diminish the cost share of the basic salmon raw material.

With two exceptions, all the retail products' price series cointegrated with the export price are fresh products. The exceptions are frozen fillets in Germany and smoked fresh in the UK. However, the test of full price transmission is rejected for frozen fillets. This means a long-term relationship exists between frozen fillet and fresh exported salmon prices, but this is not a one-to-one relationship. Surprisingly, the full price transmission hypothesis is not rejected for the fresh smoked price in the UK. This suggests that the retail price of smoked fresh in the UK has a strong relationship with the Norwegian export price, unlike all the other prices of smoked salmon products in the three other national markets.

For three of the fresh natural prices cointegrated with the export price, the full price transmission hypothesis is rejected. For five of the fresh products the hypothesis is not rejected, indicating a strong long-term relationship. The fresh products where the full price transmission hypothesis was not rejected are either fresh fillet or fresh whole products. The fresh categories where it was rejected are a combination of fresh steak, fresh fillet, and fresh meat products, leaning slightly more heavily towards processed products compared to the group more tightly linked to the export price.

The tests of weak exogeneity exhibit a general pattern with a few exceptions. The pattern rejects the hypothesis of weak exogeneity of the retail price while failing to reject the hypothesis for the export price. This means that the evidence overwhelmingly supports that shocks primarily are transmitted downstream from the export price to the retail prices, not vice versa. Exceptions from this pattern are fresh fillet and fresh steak/fish meat in France, where the hypothesis of the export price being weakly exogenous is also rejected. The sheer size of the French market for fresh salmon products may make the causality of price transmission less clear in this market. Since the fresh market in France is large, shocks in retail demand for these products may also influence prices upstream. Fresh fillets in the UK is the other product where the

direction of price transmission bidirectional.

For products not cointegrated with the export price, conducting hypothesis tests of full price transmission or weak exogeneity makes no sense since there are no long-run relationships. This explains why no results are reported for these pairs of products.

## 5. Discussion and conclusions

Global aquaculture production continues its rapid increase (Garlock et al., 2020) and contributes to increased seafood consumption (Belton et al., 2018; Garlock et al., 2022). The main explanation for this growth is innovations and technology adaption that increase the industry's competitiveness (Asche, 2008; Kumar and Engle, 2016; Afewerki et al., 2023; Garlock et al., 2023). Furthermore, competitiveness is enhanced by improved logistics and product development that increase demand (Asche et al., 2018; Brækkan et al., 2018; Gizaw and Brækkan, 2021). This is important, as Asche and Bjørndal (2011) note that for a species like salmon, where there is a strong development in the product forms being offered, production growth is much stronger than for a species like sea bass, where most of the sales are limited to one product form. The greater offering of product forms and varieties allows market penetration into new customer segments, resulting in a positive shift in demand.

This paper shows that the range of product forms in which salmon is sold varies significantly by country when comparing sales in Europe's four largest salmon-consuming countries. Spain is a country where sales of salmon are still quite traditional, as unprocessed fresh products still dominate the market and resembles how Asche and Bjørndal (2011) described all salmon sales until the turn of the century. While fresh products with a low degree of processing are important also in France, Germany and the UK, other product forms are becoming more important, and most of these are more processed products. Such products will tend to increase demand as they are suitable for other consumption settings (Torrissen and Onozaka, 2017; Asche et al., 2018). This is important for total consumption. For instance, Asche et al. (2018) show that for U.S. chicken, the consumption of whole birds in the 2000s is as high as in the 1960s despite total U.S. chicken consumption more than quadrupling. Hence, all the demand growth for chicken has been in more processed product forms. A similar process seems to be on its way in some salmon markets, while it has barely started in others, like Spain.

Landazuri-Tveteraas et al. (2018) noted that the degree of price transmission in France differed by product form and tended to be lower for more processed products and zero for the most processed products. This is not surprising as the salmon's cost share is reduced as more processing and packaging takes place. Moreover, more processed products are typically sold in contract with price clauses rather than spot markets, also reducing the degree of price transmission. We find that this

is also the case in Germany, Spain and the U.K. This is important as the low degree of price transmission will insulate the retail price from volatile producer prices.<sup>9</sup> The demand elasticity for salmon is negative (Zhang et al., 2023), so increased prices reduce the quantity demanded. For unprocessed product forms where the price transmission elasticity is high, price volatility at the producer level will strongly impact retail prices and, thereby, salmon consumption. However, for the more processed products where the price transmission elasticity is zero, price volatility at the producer level will not impact retail prices and consumption. As such, aggregate demand for salmon is more stable in Germany than in Spain.

The increasing market share of more processed products helps explain the extraordinary profitability of the industry in recent years (Sikveland et al., 2022; Sánchez et al., 2023; Zitti and Guttormsen, 2023), as the low degree of price transmission for these products helps sustain demand even at high prices. It is also positive from a public health perspective as it helps maintain consumption despite high producer prices (Love et al., 2022b) and it reduces food waste (Love et al., 2023b). This effect is stronger in markets with a lower degree of price transmission due to a higher share of more processed products, as in the U.K., than in markets where a higher share of the consumption is in the form of less processed products, as in Spain. It also helps explain the very limited impact the Covid-19 shock had on salmon exports and prices (Straume et al., 2022; Yang et al., 2022; Asche et al., 2022d).

#### CRedit authorship contribution statement

**Hans-Martin Straume:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Frank Asche:** Writing – review & editing, Writing – original draft, Validation, Investigation, Conceptualization. **Ursula Landazuri-Iveteraas:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bård Misund:** Writing – review & editing, Writing – original draft, Validation, Investigation, Formal analysis, Conceptualization. **Ingrid Kristine Pettersen:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Dengjun Zhang:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.

#### Declaration of competing interest

The authors declare no conflict of interests related to this article.

#### Data availability

The data that has been used is confidential.

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<sup>9</sup> Salmon prices at the producer and export levels are highly volatile (Dahl and Oglend, 2014; Asche et al., 2017).

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