Satisfying Norwegian Appetites: Decoding Regional Demand for Shrimp

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Abstract

This study investigates the regional demand for shrimp in Norway by employing the linear approximated Almost Ideal Demand System (LA/AIDS) framework. Shrimp consumption has grown significantly globally, with Norway being no exception. The LA/AIDS model allows us to examine the demand of shrimp across different regions in Norway. We utilize comprehensive data on regional shrimp consumption, prices, and household expenditures to estimate and analyze demand patterns. Moreover, we can distinguish between farmed (freshwater) and wild (coldwater) shrimp. Our findings reveal consistent patterns across regions, with fresh coldwater shrimp emerging as a dominant product form, often substituting for other shrimp species. Furthermore, regional variations in substitution relationships highlight the nuanced nature of the markets, with differences in the intensity of competition and the extent of substitution effects. We also provide the theoretical relationship between regional demand and the aggregate demand at the national level.

Keywords: Almost Ideal Demand System, Demand Index, Price elasticity, Regional demand, Seafood demand, Scanner data

JEL Classification Codes : D12, Q11, Q22

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Introduction

The production and demand for seafood in general and shrimp in particular, has witnessed remarkable growth worldwide, and shrimp have historically been some of the most heavily traded aquatic commodities (Kidane and Brækkan, 2021; FAO, 2022). This is largely due to a rapid expansion of shrimp aquaculture, and shrimp is now the largest aquaculture species globally measured in production value (Asche et al., 2022a; Garlock et al., 2023). However, wild shrimp production also remains important in many regions and markets (Ankamah-Yeboah et al., 2017; Asche et al., 2022b). The demand for shrimp might vary across regional markets, influenced by many factors including pricing, availability, and consumer preferences. The interplay between the different types of shrimp, comprising fresh and frozen varieties, often shapes the dynamics of the market, leading to intricate patterns of competition and substitution (Bronnmann et al., 2016). In the context of Norway, the demand for shrimp is of particular interest given significant domestic fisheries of small coldwater shrimp with several highly regionalized fisheries, given the significant expansion in global production of farmed shrimp.

Understanding the dynamics of regional shrimp consumption in Norway is essential for the seafood industry to optimize production, marketing, and distribution strategies. This knowledge can help industry players align their offerings with consumer preferences, potentially increasing profitability, and market share. Moreover, insight into shrimp consumption patterns and the balance between wild and farmed shrimp can inform policymakers and environmentalists. Effective policymaking can ensure sustainable fishing practices, protect marine ecosystems, and support the livelihoods of local fishing communities. Thus, we aim to investigate how regional variations in consumer demand for shrimp within Norway affect the competition and substitution dynamics between wild-caught and farmed shrimp.

Numerous studies have estimated demand systems for seafood products in different markets, with examples including Xie, Kinnucan, and Myrland (2008, 2009), Dey, Alam, and Paraguas (2011), Xie and Myrland (2011), Chidmi, Hanson, and Nguyen (2012), and Thong (2012). Bronnmann et al. (2016) estimated a QUAIDS demand system for different seafood species in the German market and reveal that farmed and wild shrimp are close substitutes. Other approaches have also been undertaken to study the market for shrimp. Ankamah-Yeboah &

Bronnmann (2018) found evidence of market integration between warmwater and coldwater shrimp markets at the retail level, but not with lobster. Smith et al. (2017), and Asche et al. (2012) use market integration analysis to show that U.S. wild shrimp competes in the same market as imported farmed shrimp. Hukom et al. (2020) find that while the Danish market traditionally has been supplied by coldwater shrimp there is a price premium for imported warmwater shrimp in Danish retail. Ankamah-Yeboah et al. (2017) also found that the markets for coldwater and warmwater shrimp are integrated in several different European countries. Hossain et al. (2024) studies the choice between shrimp and prawn in Bangladesh and found that price, size, and perception of safety, among others explain why they chose prawns over shrimp produced locally.

Some studies have investigated differences in regional demands for other food products. Abdulai et al. (1999) uses the LA/AIDS model to estimate difference in household demand for different food products, among others, between regions while Asche (1996) estimate import demand for different product forms of salmon. Capps & Havlicek (1984) investigate regional and national demand patterns in the US for different products (meats and seafood, other food, and non-food items), but they found regional differences to be less important. Inácio et al. (2020) was looking at the regional demand for wild seafood in Lithuania and found regional differences, for instances that the coastal region is a hot spot for wild seafood consumption which they attribute to the numbers of tourists, a link that is found in other studies (Garcia Rodrigues & Villasante, 2016; González-Mon et al., 2019; Wabnitz et al., 2018), but they also link it to supply and capture. Wessells & Wilen (1994) estimated the regional household demand for seafood in Japan. They find that demand elasticities vary during the year and across regions.

To the best of our knowledge there are no previous studies on regional demand for shrimp within a country. In this study we make use of a large retail scanner dataset for Norwegian purchases of shrimp provided by Nielsen Scantrack. Using the LA/AIDS model, we find competition dynamics within the market. Fresh coldwater shrimp, which is mainly wild caught shrimp, emerges as a strong competitor across all regions, especially in the northern areas. Substitution effects are pronounced, showcasing regional variations that significantly impact demand when prices fluctuate. This underscores the sensitivity of consumer choices to changes in pricing.

The Norwegian shrimp market and Data

Historically, the Norwegian, as well as the European market, was predominantly supplied by coldwater shrimp (*pandalus borealis*) caught in the north Atlantic Ocean. However, during recent decades the imports of warmwater shrimp, mostly from aquaculture, has increased to the European market and has made this the largest shrimp product (Ankamah-Yeboah et al., 2017). A similar development can be observed in the U.S. where shrimp is now the most consumed seafood product (Samshak et al., 2019; Love et al., 2022). Imports of warmwater shrimp has also increased in Norway according to the official import statistics (Norwegian seafood Council, 2023). Norway's seafood production was estimated to be around 4.2 million tons (FAO, 2020), where 90-95 % is being exported (Straume et al., 2024), making Norway the world third largest exporter of seafood in terms of quantity (FAO, 2022). Yet, Norway is among the top seafood consumers with around 50 kg/capita, which is far more than the global average of 20.2 kg/capita in 2020 (FAO, 2022).

The Norwegian retail market for shrimp was estimated to be around 10.8 thousand tons in 2020 (Flesland, 2023), and consist of both locally produced and imported products. There is a substantial import of shrimp, between 12.5 thousand to 16.8 thousand tons product weight per year from 2016 to 2022. Except from 2022, more than half of this were specified to be coldwater shrimp, 11-18 % warmwater, and the rest are not specified and thus a mix of coldwater and warmwater shrimp[1]. The imported coldwater shrimp are wild caught supplies to the Norwegian shrimp industry which produces for both the domestic and the international market. The major source of imported warmwater shrimp for consumption in Norway is aquaculture, with a significant portion being sourced from countries such as Vietnam, Bangladesh, and India. China is also an important producer of farmed shrimp, however primarily for the domestic market (Asche et al., 2022c).

The coldwater shrimp are caught in coastal areas, the North Sea and the Barents Sea, where the latter is dominated by large trawlers that freeze onboard and machine peeled in factories (Rødde et al., 2008), and in the coastal and North Sea fisheries the shrimp are caught by smaller trawlers. The cold water shrimp is one of the most important shellfish species in the north Atlantic and primarily caught by trawlers (Gardner et al., 2021). This is also true for

[1] Including *Pandalus borealis*, *Pandalus montagui* and *Pleoticus muelleri*. The imports do not separate between species, but based on country of origin we can assume that the majority is *Pandalus borealis*.

Norway (Søvik, n.d.). Between 2016 and 2022 there has been a huge increase in Norwegian catch of coldwater shrimp, from 18.6 thousand tons in 2016 to 41.3 thousand tons in 2022 (Norwegian Directorate of Fisheries, 2024). Most of the frozen shrimp are delivered for further processing (pealed), while the fresh partly goes to the industry, and partly is for direct consumption.

The fishing takes place all year round and the landings vary between regions. Nearly all the frozen shrimp is landed in the north, while the largest quantities of fresh shrimp are landed in the south, followed by the east and the north, and the lowest landings are in the mid. This largely follows the pattern of consumption of fresh whole coldwater shrimp, where the mid region has the lowest consumption, and the south by far has the highest consumption. According to the Seafood Consumer Insight (SCI) survey, in 2023 shrimp were consumed less frequently than salmon and other seafood in Norway. However, the survey indicates that 36 percent of seafood consumers in Norway report eating shrimp at least once a month (Norwegian Seafood Council, 2023). When asked of often they buy their seafood in different channels, more than half (53 %) report they often/very often buy from hyper/supermarket and 37 % from their local grocery store. Fewer consumers report that they buy their seafood often or very often from the fishmonger (20 %) or fish market (8 %).

To analyze regional variations in demand, we utilized the Nielsen Scantrack retail scanner dataset, comprising point-of-sale scanning data from the Norwegian grocery sector. This dataset encompasses information from a representative sample of Norwegian grocery outlets, totaling 3,843 stores in 2019. The dataset spans from 2016 to 2022, organized into 4-weekly periods, resulting in 13 periods per year. Facilitated by the Norwegian Seafood Council (NSC), the data includes transaction-level details for products, identified by their European Article Number (EAN) and over-the-counter specifications. Despite the extensive dataset covering approximately 500-700 products annually, the NSC has pre-defined product groups, with the "shrimp" category, for instance, encompassing a total of 26 aggregated products. This robust dataset provides a comprehensive overview of consumer behavior and purchasing patterns across various regions. The data separates only between cold- or warmwater shrimp and provides no information on the scientific names of each product making it impossible for us to split between different species of shrimp.

The different products contain information on level of preparation (whether it is prepared or "natural" (no preparation or curing etc.)), condition (fresh, frozen), type of product (whole or pealed), type of packing (prepacked (EAN-coded) or not prepacked (over the counter), in addition to volumes in tons and value in 1000 Norwegian Kroner (NOK). Moreover, we also have information on whether the shrimp is cold- or warmwater. As Norway has no production of warmwater shrimp, all warmwater shrimp are imported and mostly farmed.

Some of these products are very small, in some years even zero. The largest category is the "natural" with quantity shares varying between 58 to 73 % each year. In terms of preparation, the largest category is fresh, varying between 52 % and 74 %. Whole is the largest type of product (53-70%). Between 87 and 91 % of the shrimp sold are wild caught coldwater shrimp. Packing is only available for a few products and is therefore ignored.

As the interest is in the regional demand for shrimp, and its perceived substitutes we base our analysis on the following three products "Shrimp Natural Fresh Whole Coldwater", "Shrimp Natural Fresh Whole Warmwater", and "Shrimp Natural Frozen Whole Coldwater".

Table 1 descriptive statistics

Region	Metric	Fresh coldwater shrimp	Fresh warmwater shrimp	Frozen coldwater shrimp
Pooled	Price NOK/kg	181.09 (35.96)	223.57(9.17)	94.25(10.07)
	Quantity (tons)	154.35 (49.04)	38.69(12.04)	265.11(209.21)
	Expenditure share	0.449	0.144	0.407
North	Price NOK/kg	153.31(24.07)	223.43(8.83)	74.02(7.66)
	Quantity (tons)	13.78(6.38)	3.26(1.03)	9.14(6.0)
	Expenditure share	0.599	0.209	0.192
South	Price NOK/kg	170.46(36.34)	222.63(8.17)	74.53(10.63)
	Quantity (tons)	38.46(10.78)	1.89(0.64)	8.18(9.12)
	Expenditure share	0.858	0.057	0.085
West	Price NOK/kg	186.41(38.84)	223.28(9.32)	87.17(8.07)
	Quantity (tons)	46.87(18.71)	9.27(2.84)	64.82(48.17)
	Expenditure share	0.520	0.131	0.349
Mid	Price NOK/kg	195.72(43.24)	222.96(8.82)	94.49(11.57)
	Quantity (tons)	3.33(1.84)	3.69(1.18)	19.61(18.11)
	Expenditure share	0.192	0.256	0.256
East	Price NOK/kg	195.13(41.70)	223.93(9.46)	99.55(11.39)
	Quantity (tons)	51.90(19.64)	20.59(6.49)	163.36(130.87)
	Expenditure share	0.321	0.152	0.527

Note: Std. Deviations are in parenthesis

Table 1 presents the descriptive statistics for various products across regions. Table 1 presents mean values (with standard deviations in parentheses) for the price and quantity of different types of shrimp, categorized by geographical regions and whether they are fresh or frozen, and from coldwater (wild caught) or warmwater (farmed) sources. In addition, table 1 displays the expenditure shares for each product within each region.

Across all regions, farmed fresh warmwater shrimp tend to have the highest prices, followed by fresh wild caught coldwater shrimp and frozen coldwater shrimp, respectively. However, quantities (Table 1) vary significantly across regions, with the highest average quantity of fresh coldwater shrimp bought in the East region (51.90 tons) and the lowest in the Mid region (3.33 tons), reflecting regional differences in consumption patterns. Fresh warmwater shrimp shows relatively low quantity purchased across all regions, with the highest being in the East (20.59 tons), indicating it is less competitive compared to coldwater shrimp varieties, especially fresh coldwater shrimp. Fresh coldwater shrimp has the highest expenditure share in the South region (0.854), suggesting that consumers in this region spend a larger portion of their shrimp budget on this variety compared to other regions where expenditure is more evenly distributed among different types of shrimp.

Figure 1 plots the development of the prices over the period of study. Across all regions, frozen coldwater shrimp (blue line) demonstrates the most stable price trend over the observed period, maintaining a relatively constant price around 100 NOK/kg. The price of fresh coldwater shrimp (red line) shows significant volatility across all regions, particularly noticeable in the South and East regions, with prices fluctuating between 150 NOK/kg and 250 NOK/kg. In the North, the price of fresh coldwater shrimp shows the least fluctuation and typically maintains the lowest average price at 153 NOK/kg. All shrimp types show some degree of price increase over the long term, with the most noticeable increases seen in fresh warmwater shrimp, indicating rising demand or cost pressures over the period from February 2016 to December 2022. Figure 1 and Table 1 reveal the pricing details for different products, with fresh items generally commanding higher prices. This aligns with the observations made by Hukom et al. (2020) in Danish retail.

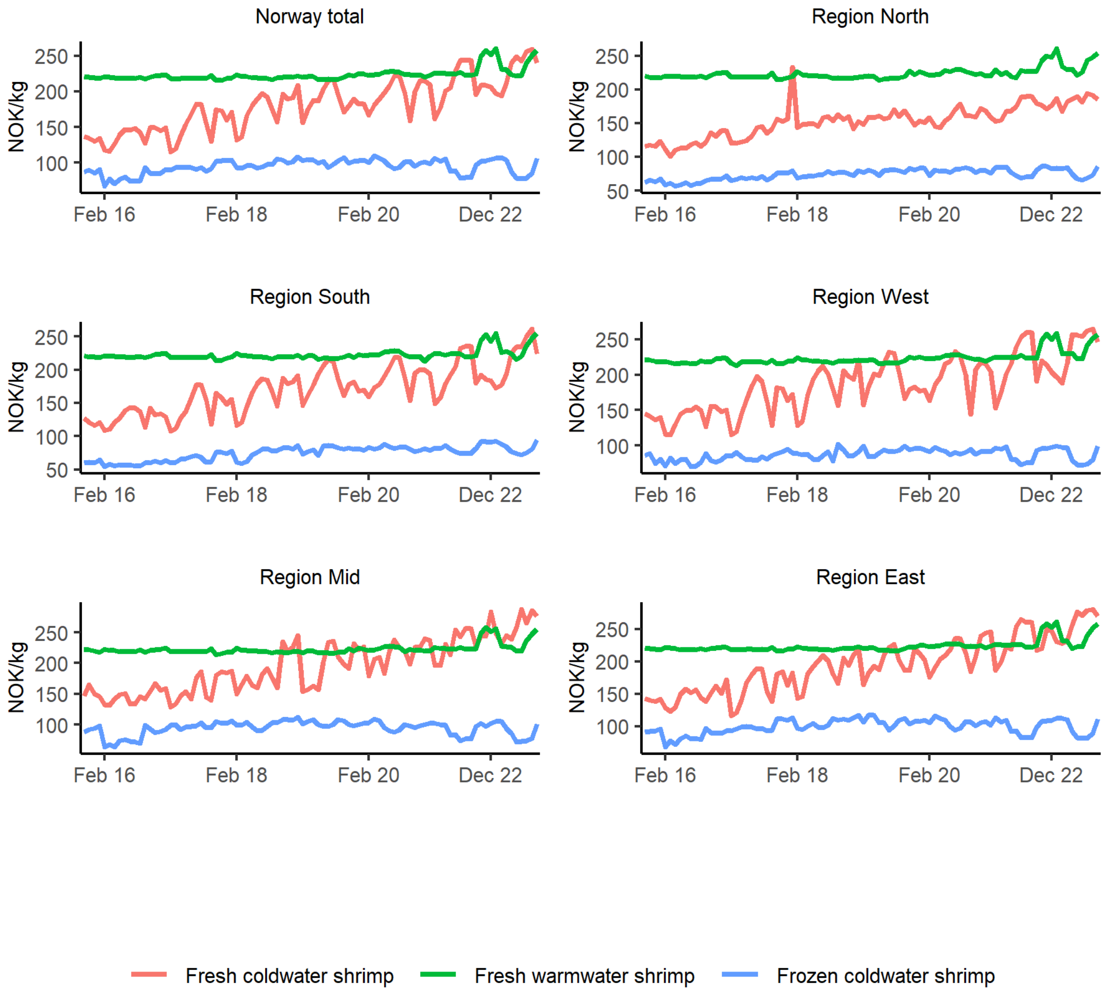

Figure 1 Prices of shrimp by region

Model Specification

The demand equations are estimated using the Almost ideal demand system (Deaton & Muellbauer, 1980). In addition to beginning consistent with demand theory, the model is flexible and easy to interpret (Alston & Chalfant, 1993). It is also commonly used in most seafood demand analysis (Asche et al., 1998; Bronnmann, 2016; Xie & Myrland, 2011 Singh et al., 2012; Nguyen et al., 2013).

Each equation in the AIDS model is given as:

$$w_{it} = \alpha_i + \varphi_i t + \sum_{j=1}^{n} \gamma_{ij}\, ln\, p_{jt} + \beta_i \ln\left(\frac{X_t}{P_t}\right) + \sum_{d=1}^{12} \delta_{id} D_{dt} + u_{it}, \qquad (1)$$

where w_{it} is the expenditure share of the *i*th good, p_{jt} is the price of the *j*th good in period t, X_t is the total expenditure on the n goods in the system, u_{it} is an error term. P_t denotes the price index. The parameters α_i, β_i and γ_{ij} must be estimated, where β_i measures the effect of a real income change to the change in budget share of commodity *i*, γ_{ij} measures the effect of a price change of commodity j on the budget share of *i*. $\varphi_i t$ represents the trend component and $\sum_{d=1}^{12} \delta_{id} D_{dt}$ represents the seasonal dummies, capturing the periodic fluctuations in demand. Seasonality is important in fish demand (Xie & Myrland, 2011), and to account for seasonality, we include four-week period dummies, which is also indicated in prices in figure 1. A likelihood test confirms that the seasonality dummies are significant for all six models. In line with (Bronnmann, 2016) a trend variable (t) is added to the model, as the data covers a period of seven years, and it is thus likely that consumer preferences and behavior has changed. Likelihood ratio tests are used to compare models confirming that that there is a significant difference for the models with and without time trend.

The introduction of the Translog price index renders the demand system nonlinear, leading Deaton and Muelbauer (1980) to propose linearizing it by substituting the price index with the Stone price index. However, the Stone index presents several issues, as pointed out by Moschini (1995). To address these concerns, Moschini (1995) recommended various alternative indices. Among these, we opt for the Laspeyres equivalent. This choice is motivated by the fact that it provides the most straightforward expressions for calculating elasticities (Asche and Wessells, 1997).

The Laspeyres price index is a geometrically weighted average of prices:

$$lnP^L = \sum_i \bar{w}_i lnP_i \quad (2)$$

where $\bar{w}_i$ is the mean budget share.

A total of 6 models were estimated: 1 for all regions aggregated, and 5 different models for the different regions.[2] Economic theory and in particular the assumption of utility maximization implies the following restrictions on the equations system:

Adding up: $\sum_i \alpha_i = 1 , \sum_i \gamma_{ij} = 0 , \sum_i \beta_i = 0$ (3)

Homogeneity: $\sum_{j=1}^{n} \gamma_{ij} = 0$ (4)

Symmetry: $\gamma_{ij} = \gamma_{ji} \quad \forall\, i \neq j$ (5)

The adding up restrictions says that all budget shares will sum to 1, resulting in a singular covariance matrix of the demand system. Thus, one equation must be omitted, and the parameters of the deleted equation may be retrieved using the adding up condition.

Static demand systems assume that consumers immediately adjust demand from price or income changes. This is probably not correct, and several studies have recognized the importance of including dynamic adjustments (Selvanathan et al., 2023). The dynamic nature of the model is captured through the inclusion of an error correction term, which accounts for the long-term equilibrium relationship among the variables. This method ensures that any short-term deviations from the equilibrium are corrected over time.

The dynamic AIDS (Almost Ideal Demand System) model builds upon the static model by incorporating cointegration analysis and the error correction model to address limitations of the static approach. The static AIDS model, which primarily focuses on long-run behavior, does not account for short-run dynamic adjustments influenced by factors such as price fluctuations and policy interventions. Additionally, the static model may be inadequate when

[2] Regions were created by us based on the different counties: South (Agder), East (Innlandet, Oslo, Vestfold og Telemark, and Viken), West (Vestland, Rogaland, and Møre og Romsdal), Mid (Trøndelag), and North (Nordland, and Troms og Finnmark). The counties were aggregated based on the assumption that they are quite similar in terms of access (catch and landings) and consumption, and partly because of few observations in some of the counties.

dealing with nonstationary time series data, potentially invalidating the asymptotic distribution of estimators and failing to evaluate short-run dynamics.

To overcome these limitations, the dynamic AIDS model integrates cointegration concepts and serves as an error correction version of the static AIDS model. The Engle-Granger two-stage cointegration analysis is utilized, as illustrated by Wan et al. (2010). Initially, unit root tests, such as the Augmented Dickey-Fuller test, assess the stationarity of variables. If the variables are integrated of the same order, a cointegration test on the residuals from the static AIDS model is conducted. Stationary residuals indicate a long-run equilibrium and cointegration relationship among the variables, thus validating the static model estimates as long-run equilibrium relations.

Upon confirming cointegration, the residuals (error correction terms) are used to formulate the dynamic AIDS model:

$$\Delta w_{it} = \psi_i \Delta w_{i,t-1} + \lambda_i \hat{u}_{i,t-1} + \beta_i^d \Delta \ln\left(\frac{m_t}{P_t^*}\right) + \sum_{j=1}^{N} \gamma_{ij}^d \Delta \ln p_{jt} + \sum_{k=1}^{K} \varphi_{ik}^d D_{kt} + \xi_{it} \qquad (7)$$

In this equation, Δ represents the first-difference operator; $\hat{u}$ denotes the residual from the static model; and other variables are as previously defined. Parameters ψ, λ, β, γ, and φ are estimated, with ξ being the disturbance term. The superscript d indicates the dynamic (short run) model. Here, ψ measures the effect of consumption habit, and λ indicates the speed of short-run adjustment, expected to be negative.

A key issue in the AIDS model is the potential endogeneity of the expenditure variable, which, if correlated with the error term, can lead to biased and inconsistent estimations. The Durbin-Wu-Hausman test is employed to address this concern. Additionally, model adequacy in both static and dynamic forms is assessed through diagnostic tests such as the Breusch-Godfrey test, Breusch-Pagan test, Ramsey's specification error test, and the Jarque-Bera LM test, as per Wan et al. (2010). The dynamic AIDS model's incorporation of cointegration and error correction mechanisms enhances its ability to capture both long-run equilibrium relationships and short-run dynamics, making it a valuable tool for analyzing demand systems in various economic contexts.

To derive the budget elasticities η_i and price elasticities eu_{ij} and ec_{ij} we follow Asche and Wessells (1997) and Bronnmann (2016) and employ the following calculations:

The expenditure elasticities η_i are given by:

$$\eta_i = 1 + \beta_i/w_i \quad (7)$$

The uncompensated Marshallian price elasticity e_{ij} is given by

$$e_{ij} = \frac{\gamma_{ij}}{w_i} - \delta_{ij} \text{ where: } \begin{cases} 1 \; if \; i = j \\ 0 \; if \; i \neq j \end{cases} \quad (8)$$

The Hicksian (compensated) price elasticities e_{ij}^* (without income effect) is given by the following:

$$e_{ij}^* = \frac{\gamma_{ij} - \beta_i w_j}{w_i} - \delta_{ij} \quad (9)$$

The own, cross-price, and expenditure elasticities are contingent upon the parameter estimates derived from the demand system, along with the expenditure shares. In this study, we opt to compute these elasticities using the sample means of the expenditure shares.

The SUR (seemingly unrelated regression) procedure was used for all models. Frozen whole coldwater shrimp were omitted from the demand system to avoid singularity. For estimation we used the R package 'erer' (Sun, 2022).

National vs. regional demand

When aggregating quantities of a specific commodity across different regional markets into a national market, we denote the quantity of commodity q_1 in the national market simply as q_1, without the use of uppercase or additional subscript notation for clarity. If we consider the quantities of this commodity in five distinct regional markets, where $q_{1,i}$ represents the quantity of commodity 1 in market m (with m ranging from 1 to 5 for the five regional markets), the aggregated national quantity for commodity q_1 can be mathematically expressed as follows:

$$q_1 = \sum_{m=1}^{5} q_{1,m}$$

Here, $q_{1,1}$, $q_{1,2}$, $q_{1,3}$, $q_{1,4}$, and $q_{1,5}$ represent the quantities of commodity 1 in markets 1 through 5, respectively. This formula provides a concise way to calculate the total amount of commodity q_1 available in the national market by summing up the quantities from all regional markets.

Next, we total differentiate the equation for the national quantity of commodity q_1, this results in:

$$dq_1 = \sum_{m=1}^{5} dq_{1,m}$$

Here, dq_1 represents the total change in the national quantity of commodity q_1, and m represents the total change in the quantity of commodity 1 in market m, for i ranging from 1 to 5. This expression captures how changes in the quantities of commodity $q_1$in the regional markets contribute to the overall change in the national quantity of commodity q_1.

Dividing the total differential equation for the national quantity of commodity $q_1$by q_1 throughout, we get:

$$\frac{dq_1}{q_1} = \frac{1}{q_1} \sum_{m=1}^{5} m$$

To further simplify and provide clarity, we multiply each term on the right-hand side by $\frac{q_{1,m}}{q_{1,m}}$ for $m = 5$, and then express it as a fraction of the total national quantity q_1. By introducing notation for the quantity shares of each regional market in the total national market, we denote the proportion of each regional market's quantity relative to the national total as R_i, where $R_m = \frac{q_{1,m}}{q_1}$ for each market m. The condition that $\sum_{m=1}^{5} R_i = 1$ underscores the fact that all regional markets quantities together constitute the total national market quantity, and their shares sum up to unity.

The revised formula, which captures the proportional change in the national quantity of commodity q_1 as a weighted average of the proportional changes in each regional market, can be expressed with the summation notation as follows:

$$\frac{dq_1}{q_1} = \sum_{m=1}^{5} R_i \cdot \frac{dq_{1,m}}{q_{1,m}}$$

Here, $R_i = \frac{q_{1,m}}{q_1}$ represents the quantity share of the mth market in the national market for commodity q_1, and $\frac{dq_{1,m}}{q_{1,m}}$ represents the proportional change in quantity in the ith market. This allows us to calculate the overall proportional change in the national market's quantity as a weighted sum of the proportional changes in each regional market's quantity.

Empirical results

Table 2 shows that the models explanation power is good. The estimated equations show R^2 between 62% and 86%.

Tabel 2: Goodness of fit statistic

	Pooled		North		South		West		Mid		East	
	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2
Fresh whole coldwater shrimp	0.040	0.724	0.042	0.858	0.020	0.679	0.047	0.763	0.032	0.700	0.042	0.607
Fresh whole warmwater shrimp	0.010	0.853	0.021	0.879	0.005	0.803	0.010	0.803	0.025	0.859	0.015	0.843

To provide an economic interpretation of the estimated parameters, we calculate expenditure elasticity, and uncompensated price elasticity. Uncompensated elasticities consider income and substitution effects, while compensated elasticities only account for substitution effects. The results can be found in table 3 for the pooled and regional models, respectively.

Table 3 shows the expenditure and uncompensated price elasticities. Expenditure elasticities quantify how responsive consumers are to changes in their income when purchasing specific shrimp varieties. When looking at table 3 a consistent trend emerges, with positive and significant expenditure elasticities for all three shrimp products. This means that as consumers' income increases, they tend to allocate a larger portion of their budget to purchasing shrimp. Thus, shrimp are normal goods in the Norwegian market. The results reveal, that fresh and frozen whole coldwater shrimp have an expenditure elasticity greater than 1 in most of the regions, indicating that wild caught (coldwater) shrimp can be considered as luxury goods in Norway. For example, in North Norway, fresh coldwater shrimp show a notably higher expenditure elasticity than in the other regions (1.329), indicating that consumers in this region increase their spending on this shrimp as their expenditure rise. A 1% increase in income results in a 1.329% increase in the quantity demanded. In some regions, like Mid Norway, expenditure elasticities are lower, indicating that consumers are less sensitive to income changes when it comes to their shrimp purchases.

When we look at the uncompensated price elasticities (table 3), we see, that the own-price elasticities are all significant negative and greater than one for all models, indicating that when the price of a particular shrimp variety increases, consumers tend to reduce their consumption of that specific shrimp. For the pooled model, which aggregates data across all regions, the uncompensated own-price elasticities reveal that the demand for fresh coldwater shrimp is highly price elastic (-1.602), indicating that a price increase leads to a substantial decrease in quantity demanded. Similarly, frozen coldwater shrimp also exhibit high own-price elasticity (-1.905). Fresh farmed (warmwater) shrimp has a slightly less elastic demand (-1.422), suggesting a somewhat lower sensitivity to price changes compared to wild caught shrimp types.

The own-price elasticity for fresh wild (coldwater) shrimp is highest in the Mid region (-1.875), indicating that consumers there are the most sensitive to price changes. The South region shows the lowest own-price elasticity (-1.206), suggesting that consumers in the South are less sensitive to price changes compared to other regions.

The own-price elasticity for frozen wild (coldwater) shrimp is highest in the South region (-3.092), indicating extreme sensitivity to price changes. The Mid region shows the lowest own-price elasticity (-1.349), suggesting that consumers are less sensitive to price changes there.

The West region exhibits a higher own-price elasticity (-2.188) compared to the pooled data (-1.905), indicating significant sensitivity. The North (-1.897) and East (-1.592) regions show a similar own-price elasticity, with consumers in these areas demonstrating notable but not extreme sensitivity to price changes.

For fresh farmed (warmwater) shrimp, the East region shows the highest own-price elasticity (-1.430), meaning consumers are the most sensitive to price changes in this region. The South region has the lowest own-price elasticity (-0.959), indicating that consumers there are the least sensitive to price changes for farmed shrimp.

The overall finding, that the demand for shrimp in Norway is elastic, is in line with other seafood products in developed countries (Asche et al., 2009; Bronnmann, 2016; Bronnmann et al., 2016) and shrimp own-price elasticity in US retail of -1.585 reported by Nguyen et al (2013). The results also reveal that the demand for farmed shrimp is less elastic than the demand for wild caught shrimp, which is in line with other European countries (Bronnmann et al., 2016). The result indicates that consumers may perceive farmed shrimp as a more reliable or consistent product in terms of availability and quality.

Table 3: Expenditure and Uncompensated Price Elasticities of the regional models

Models		Fresh coldwater shrimp	Fresh warmwater shrimp	Frozen coldwater shrimp
Pooled	Expenditure elasticities	1.012***	0.595***	1.155***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.602*****	0.049	0.541***
	Fresh warmwater shrimp	0.350**	**-1.422*****	0.477***
	Frozen coldwater shrimp	0.636***	0.114	**-1.905*****
North	*Expenditure elasticities*	1.329***	0.372***	0.765***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.572*****	0.023	0.220**
	Fresh warmwater shrimp	0.611***	**-1.168*****	0.185
	Frozen coldwater shrimp	0.996***	0.136	**-1.897*****
South	*Expenditure elasticities*	1.035***	0.455***	1.019***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.206*****	-0.003	0.173***
	Fresh warmwater shrimp	0.465**	**-0.959*****	0.04
	Frozen coldwater shrimp	2.075***	-0.001	**-3.092*****
West	*Expenditure elasticities*	1.005***	0.552***	1.178***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.698*****	0.057	0.637***
	Fresh warmwater shrimp	0.473***	**-1.318*****	0.293**
	Frozen coldwater shrimp	0.972***	0.037	**-2.188*****
Mid	*Expenditure elasticities*	0.976***	0.624***	1.243***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.875*****	0.348**	0.551**
	Fresh warmwater shrimp	0.313***	**-1.121*****	0,184
	Frozen coldwater shrimp	0.179*	-0.073	**-1.349*****
East	*Expenditure elasticities*	0.956***	0.582***	1.186***
	Uncompensated price elasticities			
	Fresh coldwater shrimp	**-1.625*****	0.114	0.556***
	Fresh warmwater shrimp	0.364**	**-1.430*****	0.484**
	Frozen coldwater shrimp	0.334**	0.072	**-1.592*****

***p< 0.01, **p< 0.05, *p< 0.10 (all elasticities are computed at the mean of the data)

The compensated cross-price elasticities are shown in table 4. These values offer insights into the pure substitution effect and provide insights into consumer preferences and substitution patterns in the Norwegian shrimp market. When shrimp species are substitutable in the market for consumers, potential substitutes or complements can be identified by examining the sign of the compensated price elasticities. Positive values suggest a substitution relationship, where consumers switch to a different type of shrimp when the price of one increase. According to the findings presented in the tables, adhering to the LA/AIDS restrictions, the cumulative value of each row in the section pertaining to compensated price elasticities equates to zero. This implies that the compensated own-price elasticity is the inverse of the combined cross-price elasticities within the same category. Our results show substitution relationships between the different shrimp species in the regions.

For the pooled model (first model in table 4) the cross-price elasticity between fresh wild (coldwater) shrimp and fresh farmed (warmwater) shrimp (0.206) suggesting a weak substitution effect. This means that when the price of fresh farmed shrimp increases, the demand for fresh wild shrimp increases slightly, indicating that they are weak substitutes. The cross-price elasticity between fresh wild shrimp and frozen wild (coldwater) shrimp (0.913) is higher, suggesting a stronger substitution effect between these two products.

In the North region, we find significant substitution relationships between all shrimp species. For instance, frozen coldwater shrimp has a high positive cross price elasticity with fresh coldwater shrimp (1.188), implying strong substitutability.

For the South, we find that fresh warmwater shrimp has a slightly higher positive cross price elasticity with fresh wild (coldwater) shrimp (0.860) than in the North, indicating stronger substitutability. Frozen coldwater shrimp exhibits a very high positive cross price elasticity with fresh coldwater shrimp (2.960), much higher than in the North, suggesting a very strong substitutability.

Table 4: Compensated Price Elasticities of the regional models

Models		Fresh coldwater shrimp	Fresh warmwater shrimp	Frozen coldwater shrimp
Pooled	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-1.118*** **	0.206***	0.913***
	Fresh warmwater shrimp	0.635***	**-1.330*** **	0.695***
	Frozen coldwater shrimp	1.188***	0.293***	**-1.481*** **
North	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-0.803*** **	0.331***	0.472***
	Fresh warmwater shrimp	0.826***	**-1.082*** **	0.256
	Frozen coldwater shrimp	1.438***	0.313	**-1.752*** **
South	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-0.306*** **	0.057***	0.249***
	Fresh warmwater shrimp	0.860***	**-0.933*** **	0.073
	Frozen coldwater shrimp	2.960***	0.058	**-3.018*** **
West	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-1.154*** **	0.192***	0.962***
	Fresh warmwater shrimp	0.772***	**-1.243*** **	0.471***
	Frozen coldwater shrimp	1.610***	0.196***	**-1.806*** **
Mid	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-1.671*** **	0.643***	1.028***
	Fresh warmwater shrimp	0.443***	**-0.932*** **	0.489***
	Frozen coldwater shrimp	0.438***	0.303***	**-0.741*** **
East	*Compensated price elasticities*			
	Fresh coldwater shrimp	**-1.287*** **	0.279***	1.008***
	Fresh warmwater shrimp	0.569***	**-1.329*** **	0.759***
	Frozen coldwater shrimp	0.753***	0.278***	**-1.031*** **

***p< 0.01, **p< 0.05, *p< 0.10 (all elasticities are computed at the mean of the data)

Also in the West region, results reveal substitution relationships between all the shrimp species. Fresh warmwater shrimp shows a lower positive cross price elasticity with fresh coldwater shrimp (0.073) than in the North, suggesting weaker substitutability. Frozen wild (coldwater) shrimp has a positive cross price elasticity with fresh wild (coldwater) shrimp like the North, indicating a consistent substitutability.

In the Mid of Norway, fresh farmed (warmwater) shrimp has a lower positive cross price elasticity with fresh (wild) coldwater shrimp (0.443) compared to the North, suggesting weaker substitutability. Frozen coldwater shrimp shows a lower positive cross price elasticity with fresh coldwater shrimp (0.438) than in the North, indicating weaker substitutability.

Results for the East region show that fresh (framed) warmwater shrimp has a higher positive cross price elasticity with fresh coldwater shrimp (0.569) than in the Mid (0.443) but lower than in the South (0.860), indicating moderate substitutability. Frozen coldwater shrimp has a lower positive cross price elasticity with fresh coldwater shrimp than in the South and North, suggesting weaker substitutability.

In summary, the Mid region shows the highest sensitivity to price changes for fresh (wild) coldwater shrimp, while the South region shows the highest sensitivity in substituting fresh wild (coldwater) shrimp with frozen wild (coldwater) shrimp. The North region has balanced magnitudes, indicating a stable market with moderate substitutability between the shrimp types. The East and West regions show very strong negative own price elasticities for fresh (wild) coldwater shrimp, suggesting that demand is highly responsive to price changes for this product in these regions.

Conclusions

This study employs a Linear Approximate Almost Ideal Demand System (LA/AIDS) to investigate substitution effects in the Norwegian shrimp market. The findings reveal significant substitution between different shrimp products nationally, with wild (coldwater) and farmed (warmwater) shrimp competing in the same market. However, there are some interesting regional differences.

When looking at the uncompensated elasticities, the calculation of the national own-price elasticity from regional elasticities reveals several important insights into the dynamics of shrimp demand across different markets. By aggregating regional elasticities using their respective market shares, we obtain a national elasticity that reflects the combined responsiveness of the entire market to price changes. For example, the pooled elasticity for Fresh wild (coldwater) shrimp, calculated by weighting the regional elasticities by their respective shares, is approximately -1.54 (quite aligned with the estimated pooled elasticity of -1.602). The national own price elasticity, computed as a weighted average of the regional elasticities, offers a holistic view of market sensitivity. This approach ensures that regions contributing more significantly to the national quantity have a proportionate influence on the national elasticity.

For instance, when looking at fresh coldwater shrimp the North region, where much of the shrimp is caught, shows a highly elastic own-price elasticity (-1.572) but a small market share (4.1%), limiting its impact on national elasticity (-0.14). Our analysis shows considerable variability in own-price elasticities across regions, driven by factors like income levels, substitutes, cultural preferences, and market conditions. The Mid region has the most elastic demand (-1.875) and the smallest market share (2.8%), indicating high price sensitivity. In contrast, the South region, with a moderate market share (32.7%) and own-price elasticity (-1.206), shows lower price sensitivity, suggesting higher income levels or fewer substitutes. The East and West regions, with the highest shares (44.1% and 39.8%) and close own-price elasticities (-1.625 and -1.698), indicate a stable consumer base, contributing -0.55 and -0.52 to pooled elasticity.

For businesses, understanding that regions like the Mid and North are more elastic can guide pricing strategies to accommodate higher sensitivity to price changes. Regions with high quantity shares but less elastic demand, like the East and West, might be better targets for stable pricing strategies, while regions with more elastic demand might benefit from promotional discounts or dynamic pricing.

The weighted average or pooled elasticity, being closer to the own-price elasticities of regions with larger shares (like East at 44.1% and elasticity of -1.625), suggests that the overall market behavior is more influenced by these dominant regions. Understanding this relationship can help in more accurately predicting national demand responses to price changes.

In summary, the pooled own price elasticity derived from regional elasticities not only enriches our understanding of market behavior but also provides actionable insights for strategic business decisions. This approach allows for a detailed understanding of how regional market dynamics collectively shape national demand.

The substitution between the farmed and wild shrimp can vary regionally, reflecting local preferences and market conditions. For instance, the dominance of wild (coldwater)shrimp in East Norway indicates the significant influence of regional peculiarities on market trends. As the industry navigates these complexities, stakeholders must recognize the multifaceted factors shaping shrimp dynamics, including ecological conditions, consumer preferences, and economic considerations.

Thus, our study underscores the imperative for a nuanced and adaptive approach within the shrimp industry. The dominance of wild (coldwater) shrimp in East Norway serves as a paradigmatic illustration of how regional peculiarities significantly influence market trends.

The details we found in the Norwegian shrimp market reveal distinct competition and substitution effects across various regions. Up north, the popularity of fresh wild (coldwater) shrimp as a strong competitor is probably linked to unique local culinary traditions. People's preferences and cultural subtleties likely play a big role in what consumers prefer. Moreover, disparities in the availability and logistics of different shrimp types within the supply chain may contribute significantly to the observed regional variations. The results highlight the complex nature of the shrimp market, where regional aspects, consumer behavior, and pricing dynamics come together to influence market trends.

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