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THE ARCTIC
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Analysis of demand for cod in EU mainland

An investigation of the demand for different product forms of cod

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Foreword

With this thesis, I complete my master in Economics, at School of Business and Economics, University in Tromsø.

I have conducted research on this topic since January. I have experienced this period as interesting and instructive. At the beginning, I had little knowledge of demand systems and how to apply them. However, I have been able to achieve a result I am very satisfied with. I would like to thank my supervisor from the University of Tromsø, Eivind Hestvik Brækkan and assistant supervisor Sverre Braathen Thyholt. Their valuable insights, directions, knowledge and availability has been priceless to complete the research and write the thesis.

In addition, I would like to thank my family and friends for their assistance during the research. The greatest acknowledgement goes to my wonderful girlfriend for her positivity and encouragement through this hectic period.

Abstract

This study is a demand analysis for the European Union mainland's import of the different product forms of cod. A system of demand equations are specified with a Linearized Almost Ideal Demand System (LA-AIDS) to analyze the demand for fresh, frozen, clip, salt and dried cod using a data set from 1988-2014. The time series properties are explored and found to be non-stationary but they cointegrate. To avoid the problem of spurious results due to non-stationarity the variables have been written in first difference form. The competition between these product forms has received little attention in the literature. There could be some important substitution effects between the commodities. All the different product forms considered come from the same raw material, cod. The processing industry has the opportunity to produce all of the different product forms under consideration: fresh, frozen, salt, clip and dried cod. It is important for this industry to enhance its knowledge about the demand for these different product forms. Harmonic variables are included in the model to account for seasonal fluctuations. The result show that almost all of the product forms are substitutes with each other except for fresh and dried cod, which are complements. Papers that investigate the different product forms of cod are either rare or non-existent. Hence, this paper should provide a unique insight into on how the different product forms of cod operate in the European market.

Keywords: European Union, demand analysis, cod, Linearized Almost Ideal Demand System, elasticities

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1. Introduction

This paper investigates the relationship between the EU mainland's import of different product forms of cod. This is done by estimating the demand for fresh, frozen, clip, salt and dried cod. In the last two decades, the demand for cod has been studied but not as thoroughly as the demand for salmon. These studies have covered different markets and used different demand specifications. Another characteristic of these studies is that they mostly look at the white fish market instead of specific species. Gordon and Hannesson (Gordon & Hannesson, 1996) consider the price linkage between cod in the US market and the EU market. However, they only look at two product forms of cod, fresh cod and frozen fillets. Asche, Gordon and Hannesson consider different product forms of the species of white fish, cod, saithe, haddock, and redfish in the European market. The purpose of their study is to define market boundaries for white fish species and product forms within the EU (Gordon, Daniel, Asche, Frank, Hannesson, 2003).

This thesis considers the demand for fresh, frozen, clip, salt and dried cod in the European Union mainland (excluding UK). The European market is of great importance regarding consumption of seafood. It is one of the largest markets in the world. The supply of cod in EU has been dominated by third countries (Non-members of EU) for many years. Overall, the import of cod was stable throughout the 90's, before increasing from 2008. However, from figure 1 we see that imports of frozen cod to the European Union increased vastly since 1988, while import of salt cod has declined since 1996. Clip has been stable throughout the time series. Fresh cod has had an increasing trend the last seven years. While dried has also been stable except for some spikes in 1992 and 2007.

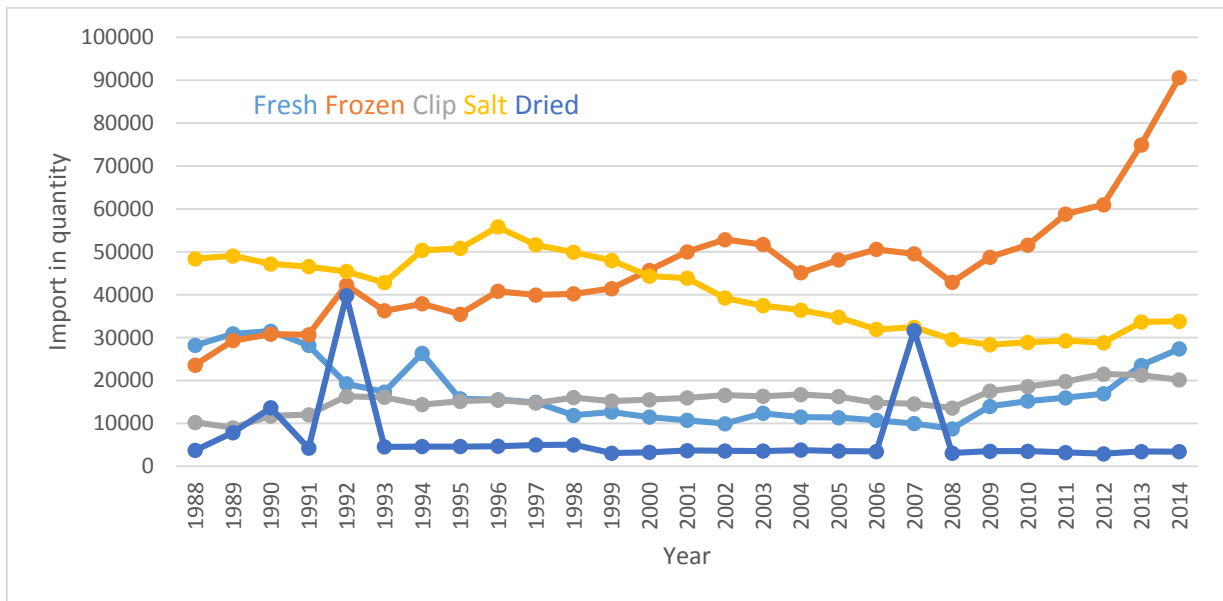


Figure 1 Yearly import of cod

The European white fish seafood processing industry relies on a consistent and sustainable supply of raw materials in order to satisfy the increasing demand of consumers for added value seafood products by consumers. The European Union is the world's largest seafood market, where the wild caught white fish species cod is one of the most important goods. For stakeholders in this industry there are many unanswered questions related to the market. A question I will address is the demand relationship between different product types of cod. This paper is organized as follows: First I will look at the EU, market. In the next section I will present two different demand models that are often applied in demand analysis and then give a comparison of the two by looking at different papers. After I have presented the model of choice I will look at some econometric challenges regarding the use of time series, and how cointegration works. Then I describe how elasticities are derived from the AIDS model and what the interpretation of them are. In the following section the data are described. Then I represent my econometric model. Empirical results are then reported and concluding remarks are given in the final section.

2. Background

Cod is the main commercial white fish species with Norway, Russia, Iceland and the EU as the main catching nations (A.I.P.C.E.-C.E.P, 2013). The white fish stock consists of Pollock, Haddock, Pangasius, Cod and Hake.

Wild caught white fish species are an important commodity in the European market, especially cod (Seafoods, 2012). In 2010, 89% of all cod catches ended up in the EU market. The product forms salt, dried and clip (conventional) mainly come from Norway and Iceland and are sold to markets in Portugal, Spain and Italy. The fishing industry has through the last 25 years gone from being a free access industry to a regulated industry with quotas (Seafoods, 2012)

The EU market relies on imports due to a very low self-sufficiency. Extra EU trade means transactions between EU member countries and non-EU member countries. Cod is one of the most consumed fish species in the EU in volume. Of all the EU member states Spain, France and Italy spent most on import of seafood. (Seafoods, 2012). Groundfish was the most important commodity group imported from extra-EU countries in volume. Almost 70% of extra-EU imports of ground fish originated from China, Norway, the United States and Iceland in 2012. Ground fish are fish that live near the sea floor. Typical groundfish species are cod, flounder and halibut.

The process industry is large in the European Union, but even so it is highly dependent on imported products. In all the member states there is a wide diversity in consumption of both quantity and species which is driven by tradition (Portugal, Spain, Italy) and the introduction of new products that have increased the frequency when fish is eaten. There has been a growing number of different white fish species in the white fish market the last 30 years. In the 1980s it was mostly cod, haddock and pollock. In the 1990`s Alaskan Pollock came to the market followed by hake and hoki in the mid 90`s. In the last ten years, Pangasius has also been introduced to the market (Asche, n.d.rapport). Even though there has been more white fish products introduced to this market cod retains the number one status of preferred whitefish species in the EU. Imports are by far the most dominant supply to this market (A.I.P.C.E.-C.E.P, 2013).

The European white fish seafood processing industry relies on a consistent and sustainable supply of raw materials in order to satisfy the ever-increasing demand of consumers for added value seafood products by consumers, both for domestic and out-of-home consumption.(A.I.P.C.E, 2008)

3. The EU Market for cod

The EU is the largest consumption market of seafood in the world. While the EU produces enough to fulfill its needs concerning small pelagics and flatfish it is highly dependent on import of groundfish (cod, halibut, sole). When looking at how much the EU contributes to the world production of seafood it is only at fifth place, with 3.4% of total production(EUMOFA, 2014). The top four countries are China, Indonesia , India and Peru. However, the EU is easily number one when it comes to expenditure for purchasing fish products. The EU covers the majority of domestic consumption through import. Shrimps, tuna, whitefish and fishmeal are the most imported products measured in quantity. Most of the cod is imported due to a low self-production of this fish type(EUMOFA, 2014).

In 2012 Spain, France and Italy accounted for almost 60 % of the EU expenditure on seafood. In 2011, cod was the second most consumed fish species in the EU. This is one of the reasons why I chose to look at the EU`s demand for cod, since it is an important fish species in EU and many consume it(EUMOFA, 2014). Since the EU cannot catch all of the cod it needs to meet demand, it is dependent on imports. In my data set I have arranged a list containing the top ten contributing third countries (non EU members) regarding the EU`s import of the different product forms of cod, fresh, frozen, salt, clip and dried. My dataset is consistent with what is calculated in a report regarding the EU market (A.I.P.C.E.-C.E.P, 2013) . From figure 2 the main suppliers of fresh cod are Norway, Iceland, Russia and Great Britain. Russia is the biggest supplier of frozen cod followed by Norway Iceland and China. The final processing of frozen H&G (headed and gutted) cod into fillets and portions is now largely carried out in Asia, predominantly, in China. It is this final processing where the greatest changes in yield have occurred and hence in the conversion factors to be used in Europe.

Greenland and Great Britain has a relatively small share of the supply of frozen cod. Salt cod's largest supplier is Iceland, closely followed by Norway. Clip and dried cod is mainly supplied by Norway, but Iceland, Russia and Great Britain has a relatively small share of the dried cod supply as well.

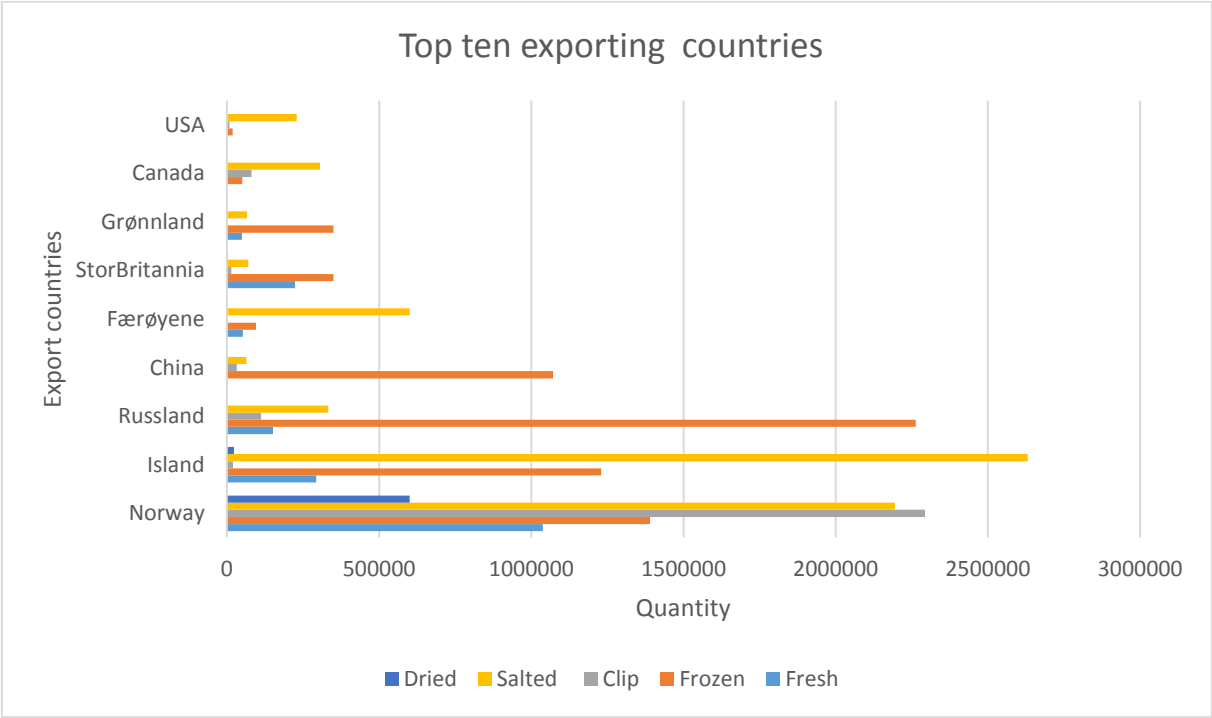


Figure 2 Top ten exporting countries to the European Union mainland

The report concludes that cod is the number one preferred whitefish species in the EU (A.I.P.C.E.-C.E.P, 2013). This is good news for the third country suppliers since the EU has such a low self-production of cod and in addition accounts for almost 70% of global consumption. One thing worth mentioning regarding China is that it is a processing country. Most of the raw material comes from Norway (EUMOFA, 2014)

“Overall the countries of the European Union are forming one of the main fish importing and processing regions in the world. The demand for fish products in the EU is much larger than can be provided by the European fishing fleet. The access to the world market is, therefore, of great importance”(Döring, 2013, page 23)

Countries that use cod as an input factor in their processing industry are Denmark, France, Lithuania, Portugal and Slovenia. An article written by SINTEF (Bedriftsutvikling, 2012) points out that one of the factors for the increase in demand for frozen cod comes from the clip fish industry. The clip fish industry wants to use frozen cod as an input factor to get a

more smooth production throughout the year. Countries that mainly import fresh cod for consumer markets are Germany, Spain, and the Netherlands. Frozen cod is imported by the Netherlands, Portugal and Poland. It would be interesting to see how large the fraction of EU's import are divided between the consumer market and the process industry.

Unfortunately, I have not been able to get a hold of a dataset showing this.

Another interesting thing regarding the EU is the intra trade relationship. It plays an essential role in the whole EU fishery trade. It is similar to the EU's imports from other non member countries. The main exporters are Denmark, Spain, and the Netherlands. The main importers are France, Italy, Germany and Spain. Two other EU member countries act as "trade hubs" for Norwegian exports. These two countries are Denmark and Sweden. Most of the products are not consumed there, but rather re-exported within the EU. When looking at EU as a market we have to take into consideration two groups, namely the consumers through the retailers and the process industry. Some product forms may almost only be demanded by the process industry. The process industry might be less elastic than consumers when looking at price changes in the product forms. This might be reflected in some of the elasticities of the product forms. It would be interesting to see how large the fraction of EU's import are divided between the consumer market and the process industry. Unfortunately, I have not been able to get a hold of a dataset showing this.

The EU consists of several different countries where the consumers in each country might have different preferences regarding the product form of cod. In Germany, frozen whitefish has the highest proportion of sales in the retail distribution while fresh has a much lower share. Spain has a large share of salted and frozen cod. In France, the product forms on the market are mainly fresh and frozen cod, where fresh has the highest market share. In Portugal and Italy, the consumers mainly demand salted and dried cod, but clip is also very popular in Portugal. The conventional products include clip, salt and dried have all been processed before being imported to EU. (Seafoods, 2012)

4. Theory

When performing an analysis of a complete demand system it is common to apply some assumptions regarding the consumers and the goods we are looking at. More cod products exist than have been analyzed here. However, a demand system consisting of several hundred equations would require vast amounts of data that would be challenging to analyze. To avoid this problem we need to make an assumption about the consumer's preferences. I will assume weakly separability (Edgerton, 1997). When making this assumption we can divide commodities into different groups where the preferences within each group are independent of the other groups. In my thesis cod is a group consisting of different product types that are independent of the consumer's consumption of for example salmon, meat or some other products (Deaton & Muellbauer, 1980). In this thesis I will check if frozen, fresh, clip, salt and dried cod are weakly separable from those omitted from the study and hence can be considered a group of commodities. When weakly separability is assumed, another important assumption will then be two stage budgeting. Two stage budgeting means that in the first stage the consumer decides on how much to spend on a group of commodities, which will in my case be the group consisting of the product forms of cod. In the second stage, the consumers decide on how much to spend on each good in the group. It is very common in aquaculture papers to assume weakly separability (Edgerton, 1997). The only problem is that it is difficult to test if weak separability holds. To justify the aggregation of the products I have chosen, into one group of commodities I will choose a different approach. Asche, Bremnes and Wessells argues that if the Law of one price holds then the composite commodity theorem holds (Asche, Bremnes, & Wessells, 1999). Therefore, I will check if the law of one price holds. The definition of law of one price is that given that we have a group of commodities, if their prices move proportionally over time the law of one-price holds.

The Hicks-Leontief composite commodity theorem states that if all prices of several goods move proportionally then the corresponding group of commodities can be treated as a single good. While the theorem requires perfect correlation between prices, this assumption is typically relaxed (Lewbel, 1996). Arthur Lewbel came up with the idea of a generalized composite commodity theorem. This would be easier to apply with empiric data since it relaxes the restriction regarding perfect correlation. It is common to aggregate single goods into groups to make estimation possible, often after performing statistical tests for whether the composite commodity theorem holds. I will check if it is possible to aggregate the

commodities, I have chosen into one group. To test if the generalized composite commodity theorem holds I will check if the law of one price holds. By following Asche, Bremnes and Wessells procedure I can use the product forms I have chosen when the LOP holds.

There exists several different demand systems in today's demand literature. Two popular models are the Rotterdam model and the AIDS model. An important issue when looking at empirical consumption studies is the functional form. An article written by Dameus, Brorsen and Sukhdial (Dameus, Richter, Brorsen, & Sukhdial, 2002) concludes that different functional forms results in different elasticities. In economic theory there are no rules deciding which one of the two models to choose from. There are however assumptions that you should check if the models violates and then make a decision (if for example one of the models violates the law of demand or some other strong prior belief).

4.1 AIDS Model

From Muellbauer we have the base for the Almost Ideal Demand System (AIDS) model (Muellbauer, 1976). The expenditure function have the consumer's preferences on the piglog form. The consumer's choice of consumption is represented through its budget share rather than the quantities or values purchased. Engel curves have budget shares that are linear in log income and this tends to fit data better than quasi-homothetic demands. Preferences having these types of Engel curves are called piglog. The piglog demands are important to assume to make precise aggregation (Lewbel, 1988). The piglog preferences was developed to treat aggregate consumer behavior as if it where the outcome of a single maximizing consumer.

I assume that demand satisfies standard regularity conditions (Stahl, 1983). Let $\mathbf{r} = \mathbf{h}(\mathbf{P}, \mathbf{Y})$ where \mathbf{r} is a vector of budget shares, \mathbf{P} is a vector of logged prices and \mathbf{Y} is the log of total expenditures. To simplify we assume $\mathbf{P} > 0$ and $\mathbf{Y} > 0$. The piglog demands have the following budget share form

$$\mathbf{r} = \mathbf{h}(\mathbf{P}, \mathbf{Y}) = \mathbf{g}(\mathbf{P}) + \mathbf{Y}\mathbf{f}(\mathbf{P})$$

Where \mathbf{g} and \mathbf{f} are vector-valued functions. For piglog demands to come from utility maximization, they must take the form

$$\mathbf{r} = \frac{\partial \mathbf{B}(\mathbf{P})}{\partial \mathbf{P}} + (\mathbf{Y} - \mathbf{B}) \frac{\partial \mathbf{A}(\mathbf{P})}{\partial \mathbf{P}}$$

\mathbf{B} and \mathbf{A} are scalar valued functions. The piglog cost (expenditure) function that yields these demands is in log form $\mathbf{Y} = \ln C(\mathbf{P}, u) = u\mathbf{A}(\mathbf{P}) + \mathbf{B}(\mathbf{P})$. u is utility.

The expenditure function is defined as the minimum expenditure needed to attain a specific utility level at given set of prices. The function is defined as $C(\mathbf{P}, u)$ where \mathbf{P} is a price vector and u is utility. Deaton and Muellbauer (Deaton & Muellbauer, 1980) defines the expenditure function as

$$(1) \log C(\mathbf{P}, u) = (1 - u) \log(a(P)) + u \log(b(P))$$

$a(P)$ and $b(P)$ are regarded as cost of subsistence and happiness. For this cost function to be on a flexible functional form, it must consist of enough parameters so that at any point its

derivatives, $\frac{\partial C}{\partial p_i}, \frac{\partial C}{\partial u}, \frac{\partial^2 C}{\partial p_i \partial p_j}, \frac{\partial^2 C}{\partial u \partial p}, \frac{\partial^2 C}{\partial u^2}$ can be set equal to any type of cost function.

The concept of a flexible demand system is that it is extremely useful for estimating a demand system with many desirable properties. The AIDS model is better in theory, because it is consistent with aggregation over consumers, where we assume rational consumers that minimize expenditure given utility. That is why the AIDS model has been derived from an indirect expenditure function.

We can set $a(P)$ to the following

$$(2) \log a(P) = a_0 + \sum_k a_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j$$

$$(3) \log b(P) = \log a(P) + \beta_0 \prod_k p_k^{\beta_k}$$

From equation 2 and 3 we can write the AIDS cost function

$$(4) \log C(\mathbf{P}, u) = a_0 + \sum_k a_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j + \beta_0 \prod_k p_k^{\beta_k}$$

To find the demand functions from 4 we can apply Shepard's lemma. This means that we have to take the derivative of the expenditure/cost function with respect to the price of the relevant good.

Shepard's lemma $\frac{\partial C(\mathbf{P}, u)}{\partial p_i} = q_i$. Where q_i is demanded quantity for good i ,

$\frac{\partial C(\mathbf{P}, u)}{\partial p_i}$ is the marginal change in the cost function for a change in the price of good i If we

multiply both sides with $\frac{p_i}{C(\mathbf{P}, u)}$ we get

$$(5) \frac{\partial \log C(\mathbf{P}, u)}{\partial \log p_i} = \frac{\partial C(\mathbf{P}, u)}{\partial p_i} \frac{p_i}{C(\mathbf{P}, u)} = q_i \frac{p_i}{C(\mathbf{P}, u)} = r_i$$

If we do a logarithmic differentiation of equation 4, we get the budget shares as a function of prices and utility.

$$(6) r_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i u \beta_0 \prod P_k^{\beta_k} \quad \text{Where } \gamma_{ij} = \frac{1}{2} (\gamma'_{ji} + \gamma'_{ij})$$

Here r_i is the market share of good i , p_j is the price of good j , y is total expenditure of all goods and P is a translog price index.

For a utility maximizing consumer, total cost Y is equal to $C(u,P)$. We can invert this equation to give u as a function of Y and P , which is the indirect utility function. If we do this for 4 and substitute the result into 6 we get the budget shares r_i as a function of Y and P . As a result, we get the AIDS demand functions in budget share forms.

$$(7) r_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i \log(Y/P)$$

P is a price index defined by the following

$$(8) \log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_j \sum_k \gamma_{kj} \log p_k \log p_j$$

This model complies with general demand theory if the following restrictions are satisfied

$$(9) \sum_{i=1}^n \alpha_i = 1 \quad \sum_{i=1}^n \gamma_{ij} = 0 \quad \sum_{i=1}^n \beta_i = 0 \quad \text{Adding up}$$

$$(10) \sum_j \gamma_{ij} = 0 \quad \text{Homogeneity}$$

$$(11) \gamma_{ji} = \gamma_{ij} \quad \text{Symmetry}$$

Given that these restrictions hold, the AIDS model (7) represents a system of demand functions which add up to total expenditure ($r_i = 1$), are homogeneous of degree 0 on all prices and satisfy Slutsky symmetry. The restriction regarding homogeneous of degree 0 simply means that if prices and income increase by the same amount we will have no change in the budget shares. In essence, the real purchasing power remains constant. Impacts of the relative prices are seen through the parameter γ_{ij} , while changes in real expenditure operates through β_i . These add up to 0 and are positive for luxury goods and negative for necessities. The adding up conditions, which are automatically satisfied by the data, imply that the covariance matrix is singular. Asche, Bjørndal and Salvanes solved this problem by deleting one equation from the system (Asche, Bjørndal, & Salvanes, 1998). We find the coefficients to

the omitted equation by using the adding up restriction or simply by estimating the model by changing one of the goods with the deleted good.

AIDS model may be difficult to estimate due to the price index, which makes the parameters estimated nonlinear. To solve this issue we can implement the Linear AIDS (LA AIDS) model.

It follows from equation 8 that the price index ($\ln P$) creates estimation difficulties due to the nonlinearity of parameters. Deaton and Muellbauer (Deaton & Muellbauer, 1980) suggested a linear approximation of the nonlinear AIDS model. By doing this approximation it is possible to perform the estimation using ISUR (Iterated Seemingly unrelated regression). If prices are closely collinear, it is sufficient to approximate P to some known index P' . We will use the Stone price index. By using equation 12, the LA AIDS treats the index as exogenously.

$$(12) \log P' = \sum_{k=1}^n r_k \log p_k$$

The LA AIDS model with stone price index:

$$(13) r_i = \alpha_i^* + \sum_j \gamma_{ij} * \ln(p_j) + \beta_i * \ln\left(\frac{y}{P'}\right)$$

4.2 Rotterdam model

The Rotterdam model introduced by Theil and Barten (A. . Barten, 1968; A. Barten, 1977; Theil, 1965, 1975) is specified with a log functional form.

Hence, I will now derive this model in absolute price

$$(14) w_i \Delta \log q_i = \sum_{j=1}^n \gamma_{ij} \Delta \log p_j + \beta_i DQ$$

The demand equations are in budget share form, where i and j are indexes for goods, q_i is the quantity demanded of the i th good, and p_j is the price of j th good within the group. W_i is the average of w_{it} , and w_{it-1} , budget shares of i th good on time t and $t-1$. Δ denotes the first-difference operator. DQ represents the real income term

When estimating a Rotterdam model there are some restrictions that can be tested for or imposed. These restrictions make the model consistent with demand theory.

The adding up restrictions imply that.

$$(15) \sum_i \beta_i = 1 \quad \sum_i c_{ij} = 0$$

To avoid making the covariance matrix singular you need to delete one equation from the demand system. After you have estimated the parameters, you can use the adding up restrictions to find the coefficients of the deleted equation.

$$(16) \sum_{i=1}^n \gamma_{ij} = 0 \text{ Homogeneity}$$

$$(17) \gamma_{ij} = \gamma_{ji} \text{ Symmetry.}$$

The restrictions homogeneity and symmetry can be used to test whether the data support a theoretically consistent specification of the Rotterdam system or be imposed to secure that the estimated system is consistent with theory.

Calculated elasticities in the Rotterdam model are compensated Hicksian elasticities. When looking at the compensated elasticities we assume constant utility where we want to minimize expenditure. This means explicitly that we do not get a change in the expenditure (real change).

$$(18) E_{ii}^* = \frac{\alpha_{ii}}{D_i} \text{ Hicksian own price elasticity.}$$

$$(19) E_{ij}^* = \frac{\alpha_{ij}}{D_i} \text{ Hicksian cross price elasticity}$$

$$(20) A_i = \frac{\mu_i}{R_i} \text{ Hicksian income elasticity.}$$

4.3 Rotterdam versus the LA/AIDS model

Among the many demand specifications in the literature, the Rotterdam model and the Almost Ideal Demand System (AIDS) have particularly long histories, have been highly developed, and are often applied in consumer demand systems modeling (Arnade, Pick, & Gehlhar, 2005; Asche, 1996; M. H. Duffy, 1987; M. Duffy, 1995; Eales & Unnevehr, 1988a)

Estimation of demand functions consistent with economic theory has been a highly published area the last forty years. Popular models are the Rotterdam model (Theil, 1965, 1975; Barten, 1964, 1968, 1977) and the AIDS model (Deaton & Muellbauer, 1980). In applied

microeconomics both the Rotterdam and AIDS models are frequently used, since each can be estimated in linearized form with theoretical restrictions easily imposed and tested.

Several studies have been conducted on which of the demand models gives the best goodness of fit. One such study is that performed by (Taljaard, van Schalkwyk, & Alemu, 2006). In this article, a non-nested test selects the best model based on the estimated results of these two models. The conclusion is that the non-nested test favors the Rotterdam model. This also coincides with another study done by (Jung & Won, 2002). They also were interested in which of the two models best fits the data best. They use the compound model approach Alston and Chalfant (Alston & Chalfant, 1993) to decide which model is the best to use. After estimating both the models, they find out that the LA/AIDS model fits the data best.

Asche (Asche, 1996) has published an article about the demand for salmon in the European Union. He considers three different product forms of salmon, fresh, smoked and frozen. He uses the LA AIDS model to estimate the parameters and then the elasticities. His results are somewhat coherent with theory.

It is difficult to assume that other demand systems could have explained the data better, without applying other models. One suggestion for further investigation is to apply the inverse AIDS model developed by Eales and Unnevehr (Eales & Unnevehr, 1994). If we would want to apply this model, we would have to assume that quotas decide everything and that quantity is exogenous. Hence, this could be done for further research.

There is disagreement regarding which model that is best to use among econometricians. The AIDS model is used a lot in demand studies of fish (Asche & Zhang, 2013; Dey, 2000; Jung & Won, 2002; Xie & Myrland, 2011), hence I will apply the Almost Ideal Demand System (AIDS) to my thesis since I look at the fish species, cod.

5. Econometric challenges

When analyzing relationships between prices, cointegration has become an important tool to apply due to the tendency of prices series to be non-stationary (Asche et al., 1999). It is common that there are some econometric challenges when working with time series data. The data series might have some issues. One of these issues is the one regarding non-stationarity (Engle & Granger, 1987).

5.1 Cointegration

Given two price variables p_1 and p_2 that are non-stationary. These two variables can be made stationary by writing them on first difference form. This implies that they are integrated of order 1. (Hill, Griffiths and Lim, 2012). The first difference means the change in the variable from period $t-1$ to t .

$$(21) \Delta p_{1t} = p_{1t} - p_{1t-1} = v_t$$

$$(22) \Delta p_{2t} = p_{2t} - p_{2t-1} = \mu_t$$

If you estimate a model with non-stationary variables, you will get spurious regression. The reason for this is that if you actually do use non-stationary time series data your result may falsely indicate a significant relationship, when in fact there is none.

An assumption in a linear regression model is that the observations are collected as a stochastic process. When dealing with time series data this assumption is most likely to be violated since the observations are connected in some ways connected. A stationary process is defined as a random error term with constant mean and constant variance (Engle and Granger, 1987). Time should not have any meaning when dealing with a stationary process. Any variable with a long-term trend is non-stationary. You have to test each variable for characteristics regarding if it is stationary or not. When dealing with non-stationary series it is important how many times you difference the variable to make it stationary. There exists different tests for this. One test I will take advantage of in my thesis is the Augmented Dickey Fuller test. If the variables are integrated of order 1, I can write them on first difference form

to make them stationary and avoid issues with spurious regression. As a result, I will get a first difference LA AIDS model.

5.2 The Johansen test

The procedure developed by Søren Johansen (Johansen, 1991) is used to determine if there exists a cointegrating relationship between the different product forms fresh, frozen, clip, salt and dried. Johansen suggests two tests to find out how many cointegrating vectors there are in the system. The first test is the maximum eigenvalue test. Here the null hypothesis is that there are r -cointegrating vectors while the alternative hypothesis is that there exists $r + 1$ cointegrating vectors. The second test is the trace test. The null hypothesis in the trace test is the same as for maximum eigenvalue test while the alternative hypothesis is that there exists more r cointegrating vectors. In the Johansen framework, the null hypothesis involves only variables that are integrated of order 0 (stationary), which is something my variables will be when written on first difference. Asche, Bremnes and Wessel use the Johansen (Asche et al., 1999) procedure to check if the law of one price holds and product aggregation can be made. Hence, I will perform the same procedure with the product forms fresh, frozen, clip, salt. If the group of goods I look at operate in the same market, the prices must be pairwise cointegrated. This implies that in a system with n prices there must be $n-1$ cointegrating vectors. In my case n will be equal to five.

6. Harmonic variables

It is well known that the purchases of agricultural products are exposed to seasonal changes in production (Arnade et al., 2005). If we omit relevant variables, we may get biased results. An example of such relevant variables are variables that measure seasonal effects. When there are seasonal effects where the change in purchase is not explained by prices alone, the seasonal component can be captured by using dummy variables in a demand model. One can for example create dummies for each month in a year and see if there are some months, that increase or decrease demand. However to get a more accurate estimate of the demand you can implement a seasonal component. Seasonality in data has received a lot of attention in macroeconomic context (Franses & Box, 1991; Franses, Philip Hans, Paap, 1995; Hylleberg, Engle, Granger, & Yoo, 1990)

The most common approach to incorporate dummies has been to use monthly or quarterly dummies (Piggott et al., 1996). Critics against the use of dummies (Arnade & Pick, 1998; Fraser & Moosa, 2002) points out the risk of biased estimates when pre-determined dummies are used to account for seasonality. Having the flexibility for a model to determine the existence and location of the season and the changes that the season might experience over time is important in a market in which seasonal demand shifts of season is likely.

To represent seasonal effects in an AIDS model, seasonal trigonometric variables are included in each share equation:

$$(23) r_i = \sum_{m=1}^M \beta_{im} \ln(P_m) + \gamma_i \ln\left(\frac{Y}{P}\right) + \sum_{u=1}^6 \alpha_{1iu} f_u + \sum_{v=1}^6 \alpha_{2iv} g_v$$

The functions f_u and g_v are the seasonal functions. They are defined as followed:

$$(24) f_u = \cos\left(\left(\frac{u}{z}\right) \pi t\right)$$

$$(25) g_u = \sin\left(\left(\frac{v}{z}\right) \pi t\right)$$

The variables u and v says something about how many different seasonal frequencies there are of the data. If u and v are equal to 4 there are 4 seasonal cycles in a year. $z = \frac{s}{2}$ Where s

equals the frequency of the data ($s=12$, for monthly data). The seasonal coefficients α_{1iu} and α_{2iv} measure the contribution of each seasonal cycle to the model. I will choose to include the harmonic variables that are significant when estimating the parameters. The range of seasonal cycles will be from 2-12.

7. Elasticities

Generally, if the price of something goes down we buy more of it (law of demand). This is due to two effects:

Income effect: When the good becomes less expensive, our purchasing power increases (real income increase) because we do not have to spend as much on the same number of quantity. This effect may also lead to a reduction in demand if the good is inferior.

Substitution effect: Elasticities are defined as the relative change in consumption for a change in price. The AIDS model expresses utility through prices and income. As a result, the calculated income elasticities and price elasticities are uncompensated (Marshallian elasticities)

The reason why we use elasticities is that they are unit less. Marshallian elasticities can be calculated by using equation 25. This is the Slutsky equation. For a derivation of the Slutsky equation check the appendix.

$$(25) E_{ij} = E_{ij}^* - R_j * A_i$$

Here E_{ij} is the price elasticity of Marshallian demand on good i with respect to a price change in good j . E_{ij}^* is the price elasticity of Hicksian demand. R_j is the market share of good j while A_i is the income elasticity of demand for good i . A price change in good j on the left side of the equation is decomposed into a substitution effect, which is the first term on the right hand side, and we get an income effect due to the change in price of good j , which is what the last term shows us.

First term on the right hand side of equation 25 gives us the rate of change in the Hicksian demand, the pure substitution effect. This effect is captured by assuming a constant utility

where we want to minimize expenditure. Hicksian demand therefore only shows the pure substitution effect which means that demand only varies with price because other goods become more attractive. When we deal with normal goods the Hicksian demand will have a smaller response to a price change (less elastic) than the Marshallian demand looking at own price. The last term in the equation is the income effect. If price of x_j goes down we get an increase in the purchasing power (real income.)

From Green and Alston (Green & Alston, 1990) we get the general definition of the uncompensated elasticities of demand from LA/AIDS model.

$$(26) E_{ij} = \frac{\partial \log Q_i}{\partial \log p_j} = -\delta_{ij} + \frac{\partial \log r_i}{\partial \log p_j} = -\delta_{ij} + \frac{\gamma_{ij} - \beta_i \frac{\partial \log P}{\partial \log p_j}}{r_i}$$

These type of elasticities represent allocations within a group holding constant expenditure (Y) and all other prices ($p_k, k \neq j$), δ_{ij} is the kroencker delta ($\delta_{ij} = 1$ for $i=j$, $\delta_{ij} = 0$ for $i \neq j$) and we use P' (stone price index). There are many different ways of calculating these elasticities in the literature. A common approach is to use equations on the following form (Chalfant, 1987; Fujii, Khaled, Mak, Journal, & May, 1985).

$$(27) E_{ij} = -\delta_{ij} + \frac{(\gamma_{ij} - \beta_i r_i)}{r_i}$$

Equation 27 is obtained when $\frac{\partial \log P'}{\partial \log p_j} = r_i$ from equation 26.

The AIDS model expresses utility through prices and income, as a result of this the price elasticities and income elasticities are uncompensated elasticities (Marshallian). The budget share is expressed through the following equation.

$$(28) q_i \frac{P_i}{C(P,u)} = r_i = \frac{p_i q_i}{Y}$$

From equation 28, $r_i = \frac{p_i q_i}{Y}$, if we derivate this with respect to p_j we will get the general expression for the cross price elasticity.

$$(29) E_{ij} = \frac{\partial \log r_i}{\partial \log p_j} = \frac{\partial r_i}{\partial \log p_j} \frac{1}{r_i} \quad \text{From (7) we get}$$

$\frac{\partial \log r_i}{\partial \log p_j} = \gamma_{ij} - \beta_i r_i$ Looking at these two formulas, we can derive the cross price elasticity.

(30) $E_{ij} = \frac{\gamma_{ij}}{r_i} - \beta_i$ Which can be rewritten as

(31) $E_{ij} = (\gamma_{ij} - \beta_i r_i) \frac{1}{r_i}$ Cross price elasticity

A price change in a good will cause an effect on the goods purchased within the group, given an unchanged group expenditure.

If $E_{ij} > 0$ then the goods are substitutes

If $E_{ij} < 0$ the goods are complements

If $E_{ij} = 0$ the goods are independent (no relationship)

Looking at equation 24 we can easily find the own price elasticity. When $p_i = p_j$ the kroenecker delta is equal to one.

(32) $E_{ii} = -1 + \frac{\gamma_{ii}}{r_i} - \beta_i \frac{r_i}{r_i} = -1 + \frac{\gamma_{ii}}{r_i} - \beta_i$ Own price elasticity

If $E_{ii} < -1$ elastic demand

If $E_{ii} > -1$ inelastic demand

If $E_{ii} = -1$ unitary elastic demand

The general expression for income elasticity A_i

(33) $A_i = \frac{\partial \log q_i}{\partial \log Y} = 1 + \frac{\partial r_i}{\partial \log Y} \frac{1}{r_i}$ Where $\frac{\partial r_i}{\partial \log Y} = \beta_i$

From equation 7 we can write the expression for income elasticity in the following matter:

(34) $A_i = 1 + \frac{\beta_i}{r_i}$ Income elasticity.

If $A_i > 1$ a luxury good and normal good

If $0 < A_i < 1$ a necessity and a normal good

If $A_i < 0$ Inferior good

One thing worth noticing is that the parameters in the AIDS model actually determine whether the good is a necessity or a luxury good. If $\beta_i > 0$ then market share will increase when Y increases, so the good is then a luxury good. In the same way if $\beta_i < 0$ it is a necessity (Deaton and Muellbauer, 1980)

The general restrictions for Marshall Demand are listed underneath.

Engel aggregation shows the relation between the income elasticity between different goods. It must sum up to 1.

$$(35) \sum_i r_i A_i = 1$$

Cournot aggregation gives us the relation between own and cross price effects.

$$(36) \sum_i r_i E_{ij} = -r_j$$

Symmetry

$$(37) E_{ij} = \frac{r_i}{r_j} E_{ji} + r_j (A_j - A_i)$$

Homogeneity

$$(38) \sum_j E_{ij} = -A_i$$

These restrictions will hold globally for a standard AIDS model, while when we use the LA AIDS model it will only satisfy the restrictions from demand theory locally (Asche & Wessells, 2014)

7.1 Price flexibility

Price flexibility can be interpreted in a similar way as elasticities. When we have price elasticities we see how much change there is in demand when prices increase or decrease. When dealing with price flexibility, look at what happens to prices when quantities increase or decrease. This means that we get the percentage change in price for a 1% change in quantity. Quotas control the wild fish industry so this might give a good indication to what will happen with prices if these quotas are increased or decreased. Since I am just measuring the EU market, it does not necessarily mean that an increase in the quota will result in the price changes that my result might show. This is since some of the increase in the quota will go to other markets. Nevertheless, the EU is an important market so it will still be interesting to investigate. The result must be interpreted with this in mind. Price flexibilities are inflexible if the own price flexibility is less than 1 in absolute terms (Thong, 2012). We calculate an approximation of the price flexibility by taking the inverse of the elasticity of demand.

$$(39)E_{Pf} = \frac{1}{E_{ij}}$$

8. Data

In my thesis, I am looking at the EU mainland's import of cod. Great Britain is the largest fishing nation in EU regarding the white fish species cod. The country has a very high self-production; because of this, I will not include it in my thesis.

Capia provided a data set of the EU mainland's demand for seafood between January 1988 and December 2014. The EU's import data are adjusted for internal trade, so that processing in the EU and re-export to other EU markets are omitted. This is done so we do not count the same fish several times. The UK has been omitted due to a high own production and I have only had access to import data. Since I have time series data it is important to test the characteristics, whether it is stationary or not. When a series is non-stationary, the number of times it must be differenced in order to make the series stationary is important (Schalkwyk, Van, Taljaard, PR, Alemu, 2004). As mentioned in the theory part I will use the Augmented Dickey Fuller test to check for stationarity. The price variables are written in first difference form to make them stationary so we can use them in the LA AIDS model. As a result, I will get a first difference LA AIDS model.

We have monthly data on different product forms of cod, namely fresh, frozen, salted, clip and dried. There is a total of 324 months. The original data set consists of value and quantity data. Quantity is in live weight equivalents. This means that the mass of different cod products have been converted to the mass of the cod as it was taken from the sea (whole fish). Prices were determined by dividing value by quantity. All prices are in Euro. Asche, Salvanes and Steen points out some problems when having import data ((Asche, Salvanes, & Steen, 1997). The first problem is the use of the AIDS model. This is a consumer demand model while the import data we use implies that it is a derived demand system. A problem with this is that the consumer's preferences are not the same as the intermediaries' demand. They argue that the AIDS model is used when estimating international trade models, which makes it possible to interpret the result as import demand. Another problem they point out is that the intermediaries production technology may cause their demand for commodities do be different from the consumers. This is due to substitution possibilities when there is changes in the relative prices. In my case the commodities are the main factor in the intermediaries production process. As a result the intermediaries elasticities will resemble the consumers

elasticities, which implies that the intermediaries demand will mirror the consumers demand. A common problem when dealing with import data is if they reflect the market size. Of the countries in the EU, only the UK has a large production of cod. Therefore, I have excluded this country from my analysis, only looking at the EU mainland's import from third countries, since the EU has a very low domestic production of this type of fish. A third issue is the problem of auto correlation since we are working with time series. All the variables will be integrated of order 1 (see result) which means that the model will be run in first difference form. This implies that first order auto correlation is removed.

There are five product forms of cod in the data set. Table 1 lists the names of the different product forms and their average price, average monthly quantity and average market share. Frozen and salted cod are the two largest commodities having a market share of 32% and 36% respectively. Frozen is the cheapest commodity (1.79 euro) while dried cod is the most expensive commodity (3.13 euro). The export countries are shown in figure 2 earlier in the paper. I have aggregated EU imports from all third countries (non EU members and the UK). This is done to prevent any spurious results, since some of the EU member countries export to other EU member countries (intra-trade).

	Average price Euro/kg	Average monthly quantity	Average market share
Fresh	2.52	17145	0.14
Frozen	1.79	46348	0.32
Clip	2.24	15786	0.13
Salted	2.4	40715	0.36
Dried	3.13	6711	0.05

Table 1 Average price/kg, average quantity and average market share for fresh, frozen, clip, salted and clip. 1988-2014

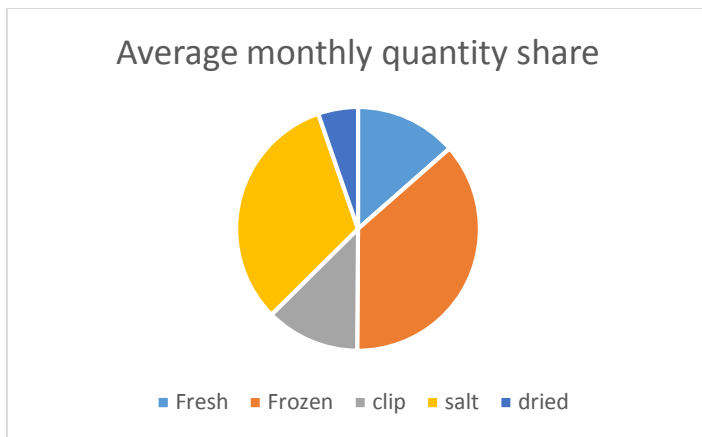


Figure 3 Average monthly quantity share

Figure 4 illustrates the yearly development in the import prices for the different cod product forms in the EU from 1988 to 2014 in Euro. The prices seem to have a similar pattern. Dried cod has been very volatile throughout the time series. It peaked in 2008 at almost 4 euros before declining to the same price it had in 1988, 3 euros. Fresh cod has experienced an upward trend from the beginning until 2008, where it had a price of 4 euros, before declining in 2009 to 3.2 euros. Cod catching is regulated through quotas so this may affect the price, where an increase in quotas might decrease the price. Frozen shares a similar trend as fresh until 1998. From 1998 until 2008 it has an increasing trend, though not by far as large as fresh. From 2008-2014 frozen cod decreases from its peak at 2.5 euros to 1.8 euros in 2014. Both clip and salt have almost identical price curves. They show very similar trends. Both had an upward trend until 2008 before a substantial decline. All of the product forms experience a substantial price decrease in 2008.

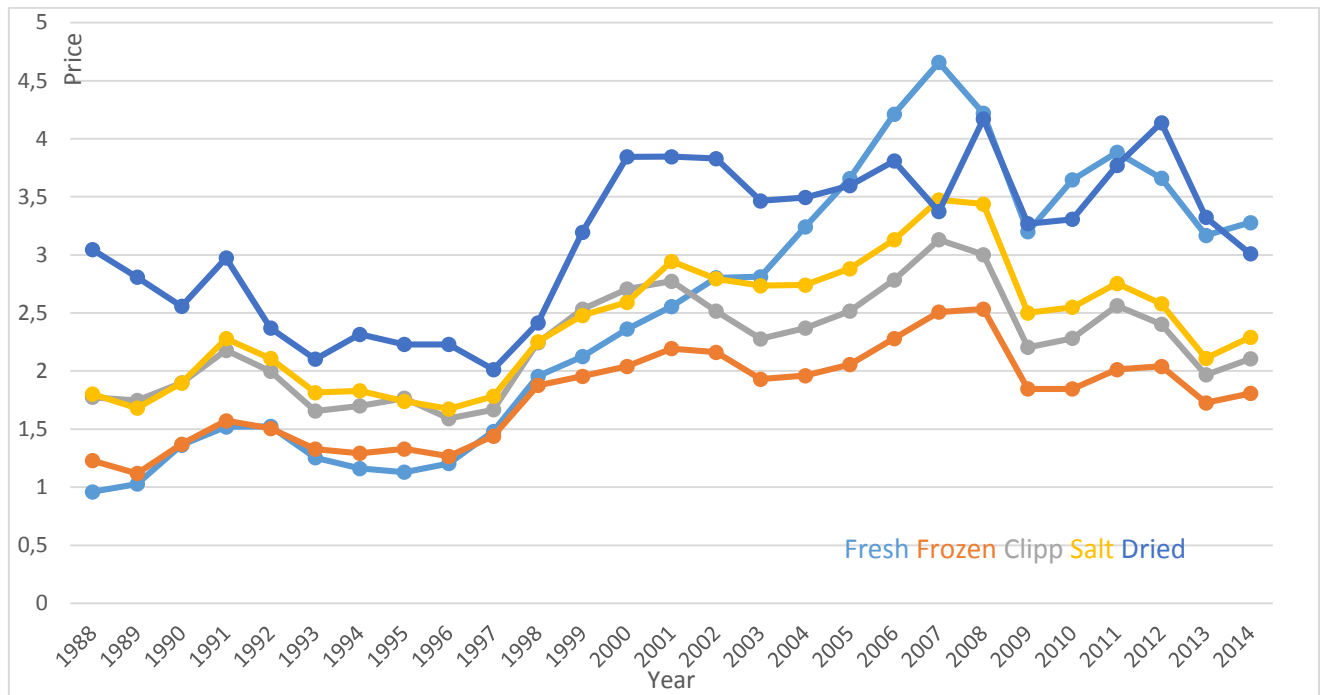


Figure 4 Yearly development in the import prices for cod product forms in the EU market

Frozen cod has the highest average monthly quantity 46 348 tonne, while dried has the smallest average monthly quantity with 6711 tonne. This is probably because dried cod is more of a niche product than frozen cod. Figure 5 shows the yearly market share. Salted cod has the largest market share from the late 1980's and onwards until around 2005. From year 2005, frozen cod increased its market shares. It seems that there is a decreasing trend for salted cod and an upward trend for frozen cod. Clip has had a relative stable level of market share throughout my dataset. Dried cod has the smallest market share, but it is also relatively stable.

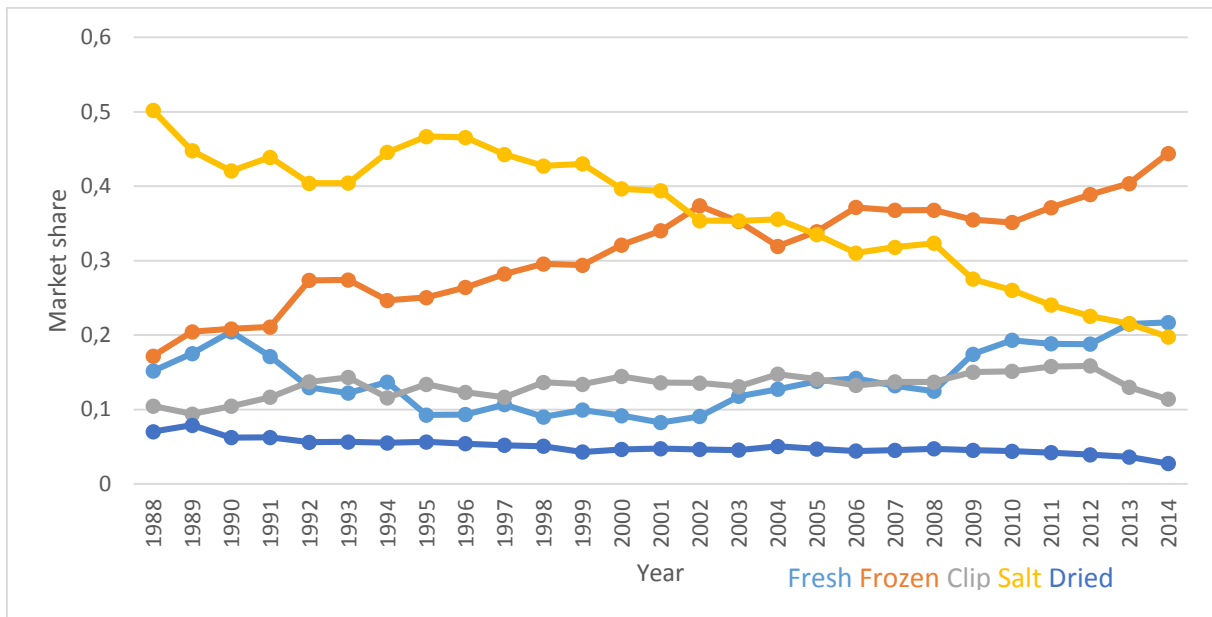


Figure 5 Average yearly market share

In figure 5 you will see the average market share per month. This shows how seasonal fluctuations affect the market share throughout the year. Fresh cod has its peak during the months of February until May. The lowest market share is through the summer months and autumn. Frozen cod has the lowest market share during the months that fresh has its highest and the highest market share in the summer months. All the conventional product forms (dried, clip and salt) seem to all have the highest market share from September to November. In May and June, dried cod has almost no market share. This indicates that there is seasonal pattern in the data.

Since the model of choice is the LA AIDS model, we would prefer to use four commodities instead of five. This is due to the complexity of the model when having more than four commodities. From figure 4 we can see clearly that the two product forms clip and salt prices seems to develop in a similar manner. I will perform a test to see if it is possible to merge these two product forms later.

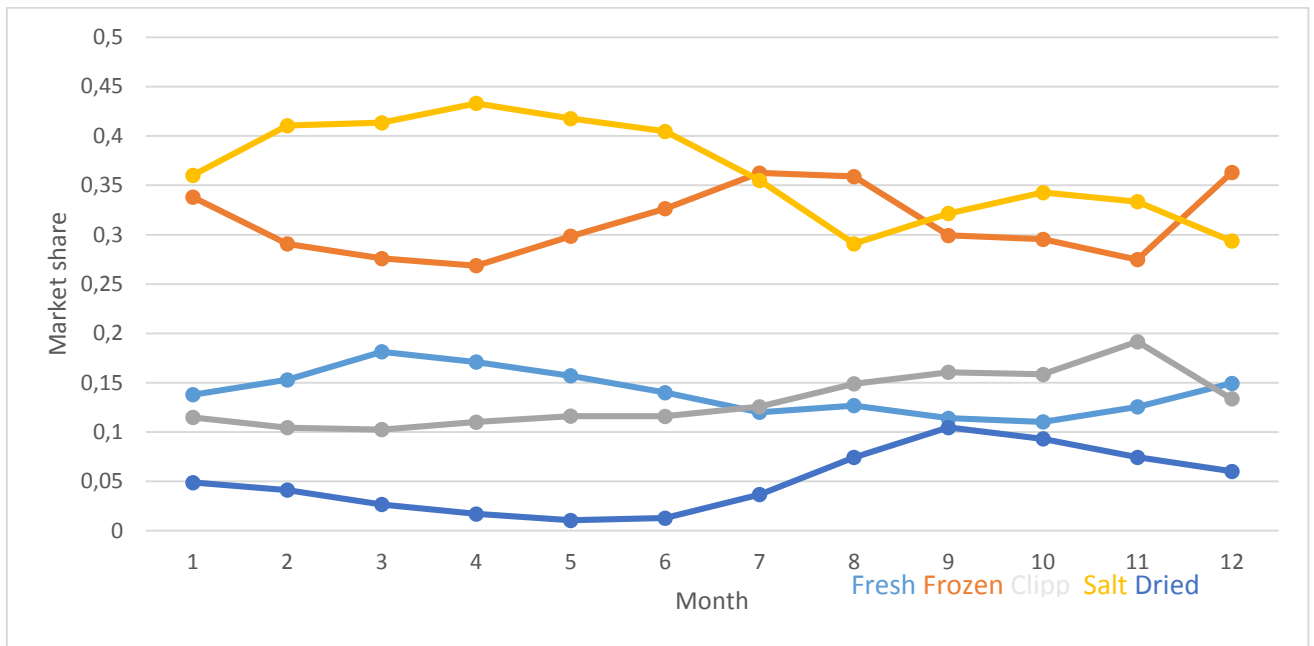


Figure 6 Seasonal fluctuations in the average market share. 1-12 are months in a year

One issue that might arise is regarding whether the prices or the quantity is exogenous. If quantity decided everything, then quantity would be exogenous. Asche and Zhang (Asche & Zhang, 2013) argue that if quantity is exogenous one would need to use the inverse AIDS model. Norges sjømatråd (Sjømatråd, 2015) shows in his market report that EU is not the only market for cod. Since the market for cod is a global market it is reasonable to assume that prices are decided globally and quantity to the EU is the endogenous variable.

9. The econometric model

Before I can start to analyze the elasticities, the system must be tested for misspecification. When working with time series a general problem is non-stationarity with the data. In demand system analysis a common tool when testing for non stationarity is the Augmented Dickey fuller test.

First I perform the ADF (Augmented Dickey Fuller) test to see if the prices are stationary. We cannot use the variables in the model if they are non-stationary.

$H_0 = \text{Unit root (non-stationary)}$ $H_1 = \text{Stationary}$

If the absolute value of the test statistic is larger than critical value than the variable is stationary. From table 2 we see that all the price variables are non-stationary

z(t)	Test statistic	1% Critical value	5% Critical value	10% Critical value	
p1	-1,87	-3,454	-2,877	-2,57	Non-stationary
p2	-2,235	-3,454	-2,877	-2,57	Non-stationary
p2	-3,269	-3,454	-2,877	-2,57	Non-stationary
p4	-2,394	-3,454	-2,877	-2,57	Non-stationary
p5	-3,187	-3,454	-2,877	-2,57	Non-stationary

Table 2 Augmented Dickey Fuller test

To deal with the non-stationary problem we take first difference of the variables and check if they are stationary. By taking first difference, the variables are now integrated of order 0.

$z(t)$	Test statistic	1% Critical value	5% Critical value	10% Critical value	
dlnp1	-21,545	-3,454	-2,877	-2,57	stationary
dlnp2	-25,964	-3,454	-2,877	-2,57	stationary
dlnp3	-22,11	-3,454	-2,877	-2,57	stationary
dlnp4	-24,017	-3,454	-2,877	-2,57	stationary
dlnp5	-31,065	-3,454	-2,877	-2,57	stationary

Table 3 Augmented Dickey Fuller test with first difference variables.

In table 3 we see that when we have taken the first difference of the prices they are stationary, which means we can use them in our LA AIDS model.

Following the Hicks-Leontief composite commodity theorem we would like to check if all the product forms can be aggregated into one group. First, we estimate how many lags to use in the vector error correction model. I will use a varsoc model on the log of all prices. The varsoc model is a selection of criteria model. Following Lütkepohl, the maximum amount of lags I choose is 12, this is because we have monthly data (Lütkepohl, 2004). The result from the varsoc model is presented in table 4

lag	AIC	HQIC	SBIC
0	-2.84341	-2.81944	-2.78343
1	-8.60633	-8.4629*	-8.2443*
2	-8.68707	-8.42336	-8.02725
3	-8.82616	-8.44258	-7.86642
4	-8.8148	-8.31135	-7.55513
5	-8.8459*	-8.22267	-7.28641
6	-8.82328	-8.08009	-6.96377
7	8.84337	-7.98032	-6.68395
8	-8.78965	-7.80673	-6.33031
9	-8.80041	-7.69762	-6.04115
10	-8.70564	-7.48297	-5.64645
11	-8.78272	-7.44019	-5.42361
12	-8.79224	-7.32984	-5.13322

Table 4 Selection of information criteria

Choosing information criteria is effective when choosing a statistical model. When dealing with time series data there are three criteria that are often used. They are in all likelihood based on, and consists of, two elements. The first element looks at the goodness of fit while the second element penalizes complicated models. In the table above Akaike's information criterion (AIC) gives a lag length of 12, Hannan-Quinn (HQIC) gives a lag length of 3 and Schwarz Bayesian (SBIC) gives a lag length of 1. Tsay (Tsay, 2013) argues that you should always choose the simplest model, which in my case is lag 1.

The error correction model's purpose is to estimate the speed at which the dependent price variable returns to equilibrium after a change in the independent variable, time. Now that I have estimated the number of lags to apply in the vector error correction model, I can check if the prices cointegrate, which implies that the law of one price holds. By having $n = 5$ I should get 4 cointegrating ranks. By applying the Johansen test I can check if the prices are cointegrated. The result is presented in table 5 and table 6.

Maximum rank	parms	Trace statistic	5% critical value
0	5	425.2176	68.52
1	14	196.4024	47.21
2	21	98.0881	29.68
3	26	26.6887	15.41
4	29	2.4041*	3.76

Table 5 Trace test

Maximum rank	parms	Max statistic	5% critical value
0	5	228.8151	33.46
1	14	98.3143	27.07
2	21	71.3994	20.97
3	26	24.2846	14.07
4	29	2.4041	3.76

Table 6 Max test

I get 4 cointegrated ranks which means that the prices of all the product forms are cointegrated. This implies that there exists a long-term relationship between them. Because of this the law of one price is satisfied which means that the general composite theorem is satisfied.

Since the law of one price and the general composite theorem are satisfied the five product forms fresh, frozen, clip, salt and dried can be aggregated into one group. I am also interested to see if some of the product forms can be combined into one single good. This is so we can reduce the number of equations in the LA AIDS model. I will perform similar tests but this time only use prices for salted and clip, due to similar price patterns and product form (conventional). In table 7, 8 and 9 underneath you see my result. The number of lags chosen is 1.

Lag	LL	LR	df	SBIC	AIC	HQIC
0	-176.79			1.14099	1.11744	1.12684
1	355.762	1065.1	4	-2.11536*	-2.18601	-2.1578
2	365.046	18.568	4	-2.10128	-2.21904	-2.17201*
3	369.809	9.5265	4	-2.05894	-2.22381*	-2.15797
4	372.319	5.020	4	2.00253	-2.2145	-2.12985

Table 7 Selection of model criterion

Now that we know how many lags to use in the vector error correction model, we can estimate the Johansen test.

Maximum rank	parms	Trace statistic	5% critical value
0	10	90.1296	15.41
1	13	3.6048	3.76
2	14		

Table 8 Trace test

Maximum rank	parms	Max statistic	5% critical value
0	10	85.6800	14.07
1	13	3.6048	3.76 *
2	14		

Table 9 Max test

The null hypothesis says that there is no cointegration when rank is equal to the number in the column. Trace and lambda max statistic are both larger than critical value implying that we cannot reject the null hypothesis when $r = 1$. There is a long run relationship between salt and clip, which indicates that they cointegrate. As a result, we can merge clip and salt into the

product type clip/salt, hence when estimating the LA-AIDS model and testing different restrictions we will have four product forms that are fresh, frozen, clip/salt and dried.

When choosing the LA AIDS model we also need to ask what variables are likely to influence the market share (dependent variable). Omission of a relevant variable may lead to an estimator that is biased.

From figure 4, we clearly see that the price development from 1988 until 2014 contains a seasonal pattern. I considered using monthly dummy variables but due to the risk of biased estimated I decided to use the approach from Arnade, Pick and Gehlhar (Arnade et al., 2005) when choosing harmonic variables.

We use equation (7) which is the LA AIDS model and add the harmonic variables as describes in section five. This gives the following model.

$$(40) d.r_{it} = \vartheta_{it} + \sum_j \gamma_{ij} d.log p_{jt} + \beta_i d.log(Y_t/P_t) + \alpha_{1i} \cos\left(\left(\frac{1}{12}\right)\pi t\right) + \alpha_{2i} \sin\left(\left(\frac{1}{12}\right)\pi t\right) + \alpha_{3i} \cos\left(\left(\frac{2}{12}\right)\pi t\right) + \alpha_{4i} \sin\left(\left(\frac{2}{12}\right)\pi t\right) + \alpha_{5i} \cos\left(\left(\frac{3}{12}\right)\pi t\right) + \alpha_{6i} \sin\left(\left(\frac{3}{12}\right)\pi t\right) + \alpha_{7i} \cos\left(\left(\frac{4}{12}\right)\pi t\right) + \alpha_{8i} \sin\left(\left(\frac{4}{12}\right)\pi t\right) \epsilon_{it}$$

The parameter r_i is the budget share, where $i = 1, 2, 3, 4, 5$ is respectively fresh, frozen, salted/clip combined and dried cod, ϵ_i is a random residual. Our demand system will consist of eight harmonic variables. The harmonic variables that are supposed to capture seasonal trends are:

$$\alpha_{1i} \cos\left(\left(\frac{1}{12}\right)\pi t\right), \alpha_{2i} \sin\left(\left(\frac{1}{12}\right)\pi t\right), \alpha_{3i} \cos\left(\left(\frac{2}{12}\right)\pi t\right), \alpha_{4i} \sin\left(\left(\frac{2}{12}\right)\pi t\right), \alpha_{5i} \cos\left(\left(\frac{3}{12}\right)\pi t\right), \alpha_{6i} \sin\left(\left(\frac{3}{12}\right)\pi t\right), \alpha_{7i} \cos\left(\left(\frac{4}{12}\right)\pi t\right) \text{ and } \alpha_{8i} \sin\left(\left(\frac{4}{12}\right)\pi t\right)$$

The different parameters that will be estimated are α_i which is the constant term, γ_{ij} which represent the change in product form i 's budget share with regards to the price of product form j given that all the other variables are constant. ϑ is a constant that represents the time trend. β_i shows the change in product form i 's budget share with regards to the real expenditure for cod (Y/P) given that all the other variables are constants. d means that the variables are written on first difference form. The seasonal coefficients $\alpha_{1i}, \alpha_{2i}, \alpha_{3i}, \alpha_{4i}, \alpha_{5i}, \alpha_{6i}, \alpha_{7i}$ and α_{8i} measure the contribution of each seasonal cycle to the model. The estimated

model will only include significant trend variables. Due to stationarity the model will be written in first difference form. Eales and Unnevehr (Eales & Unnevehr, 1988b) recommends using lags when calculating the Stone price index, this is to avoid simultaneity problems.

The model is estimated using ISUR (iterate seemingly unrelated regression) method. This model was proposed by Arnold Zellner (Zellner, 1962) in 1962. It's a generalization of a linear regression model that consists of different regression equations. Each equation has its own dependent variable and is linked to exogenous explanatory variables (harmonic variables). Seemingly unrelated means that each equation uses a valid linear regression on its own and can be estimated separately. I have to delete one equation, the deleted equation is the one for dried cod and the reason for doing this is to avoid singularity in the variance/covariance matrix. Adding up and the homogeneity restrictions will be applied to find the coefficients that are deleted from the system (dried).

10. Empirical results

The LA AIDS model was estimated using equation 40. Here I found out which of the harmonic variables were significant and could be included when testing for homogeneity and symmetry.

Likelihood Ratio test was applied to test if the homogeneity and symmetry restrictions are compatible with the data.

The null hypothesis says that there is no difference between the models with and without restrictions imposed. This indicates that the restrictions are valid. In table 10 we see that the model with both homogeneity and symmetry restrictions has a likelihood ratio larger than the critical value. In this case, we will reject the null hypothesis. When we use the restriction regarding homogeneity or symmetry, we do not reject the null hypothesis. This means that we should not include both symmetry and homogeneity. However a paper by Cozzarin and Gilmour (Cozzarin & Gilmour, 1998) that investigates several articles regarding demand systems, finds out that the symmetry restriction was tested 36% of the time and rejected 51% of the time. Homogeneity was tested 29% of the time and rejected in 57% of the cases. The likelihood ratio test does reject the null hypothesis when both the restrictions are incorporated. Rejecting homogeneity or symmetry does not mean that the theory is wrong, but instead it might be that the data and model combined does not support the theory because of the data or the model specification (Asche & Gordon, 2005). For the model to be in accordance with demand theory I will impose both symmetry and homogeneity when estimating the model.

Restrictions	Degrees of freedom	LR	Critical value χ^2 5% significant level
Homogeneity	3	4,57	7,814
Symmetry	3	6,85	7,814
Homogeneity and symmetry	6	17,68	12,591

Table 10 Log Likelihood Ratio test

		Fresh	Frozen	Clip and salted	Dried
Constant term	ϑ_i	-0.0166 (0.0144)	0.0011 (0.0030)	-0.0014 (0.0036)	0.000 (0.0010)
Prices	γ_{1j}	-0.0166 (0.0144)	0.0283 (0.0185)	0.0001 (0.0210)	-0.0118 (0.0022)*
	γ_{2j}	0.0283 (0.0185)	0.0865 (0.0458)	-0.1076 (0.0455)*	-0.0072 (0.0039)
	γ_{34j}	0.0001 (0.0210)	-0.1076 (0.0455)*	0.0905 (0.0532)	0.0169 (0.0045)*
	γ_{5j}	-0.0118 (0.0022)*	-0.0072 (0.0039)	0.0169 (0.0045)*	0.0021 (0.0014)
Income	β_i	-0.0983 (0.0077)*	-0.1022 (0.0137)*	0.2268 (0.0161)*	-0.0262 (0.0049)*
Seasonal trend	α_{1i}	0.0044 (0.0024)		0.0110* (0.0028)	-0.0155 (0.0015)*
	α_{2i}	0.0162 (0.0025)*		-0.0032 (0.0029)	-0.0130 (0.0015)*
	α_{3i}	0.0034 (0.0024)	-0.0019 (0.0043)	-0.0150 (0.0051)*	0.0135 (0.0015)*
	α_{4i}	-0.0151 (0.0026)*	0.0244 (0.0046)*	0.0001 (0.0055)	-0.0094 (0.0016)*

R²		0.3817	0.3113	0.4256	0.4868
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Table 11 Values in parenthesis is the standard error. * indicates significant at 5%.

Table 11 represents the parameter values that are estimated from our model with both the homogeneity and symmetry restriction imposed. Among the 16 price parameters, 6 is statistically significant which might indicate that not all the cod product forms affect the demand for other product forms of cod with statistical significance.

β_i is positive for the combination of salted and clip. This indicates that the income elasticity for clip/salted is above 1 and for fresh and frozen it should be below 1. We will see if this is correct when the elasticities are estimated. The values for R^2 varies between 0.3113 for frozen cod and 0.4868 for dried.

Uncompensated and compensated elasticities are presented in table 12. These are elasticities measured by the average expenditure shares. The uncompensated elasticities were estimated in accordance with equation 31, 32 and 34. To find the compensated elasticities I applied the Slutsky equation.

	Prices				Income
Quantity	Fresh	Frozen	Clip/salt	Dried	
Marshall					
Fresh	-1.020	0.420	0.348	-0.049	0.299
	(0.000)*	(0.002)*	(0.022)*	(0.001)*	(0.000)*
Frozen	0.136	-0.620	-0.181	-0.006	0.673
	(0.022)*	(0.000)*	(0.218)	(0.572)	(0.000)*
Clip/Salt	-0.063	-0.359	-1.044	0.011	1.456
	(0.134)	(0.000)*	(0.000)*	(0.200)	(0.000)*
Dried	-0.162	0.019	0.599	-0.931	0.475

	(0.000)*	(0.820)	(0.000)*	(0.000)*	(0.000)*
Hicksian					
Fresh	-0.977	0.514	0.497	-0.034	
	(0.000)*	(0.000)*	(0.001)*	(0.030)*	
Frozen	0.231	-0.410	0.152	0.026	
	(0.000)*	(0.005)*	(0.295)	(0.032)*	
Clip/Salt	0.140	0.095	-0.321	0.084	
	(0.001)*	(0.295)	(0.003)*	(0.000)*	
Dried	-0.095	0.168	0.835	-0.907	
	(0.030)*	(0.032)*	(0.000)*	(0.000)*	

Table 12 The number in parenthesis are the p-values. *significant at a 5% critical level.

Most of the demand studies look at salmon or the white fish market. I have yet to find a study that focuses on different product forms of cod. Hence, this paper is unique of its kind.

10.1 Own price elasticity

All of the uncompensated own price elasticities are statistically significant at a 5% critical level. The own price elasticity of fresh (-1.02), frozen (-0.620), clip/salt (-1.044) and dried (-0.907) are all negative, which is coherent with theory. For fresh and clip/salt the price is elastic, while for frozen and dried it is inelastic. This indicates that frozen and dried are necessities. For frozen this might be because it is so cheap compared with the other product forms. Frozen cod is also mostly used in processing and this might be one of the reasons for this product form being more inelastic. Average elasticities does not necessarily give a good picture of the market, if there are large changes in the period for which I have data. Due to this, I have chosen to present the elasticities over time, to get a better picture of the market. In figure7 underneath the development of the own price elasticities are drawn by using expenditure shares per year Frozen cod has been inelastic and stable throughout the period. This is also the cheapest product form of cod. Even though the market share of frozen cod has increased substantially the last 5 years it has not affected the own price elasticity much, probably because it is a necessity. Fresh own price elasticity has been more volatile. It has been elastic from the beginning to the end, but the magnitude has fluctuated. It was most

elastic during the period from 1995-2002. This was the period with the lowest market share. This is coherent with equation 32. Since the own price coefficient is negative, a decrease in the market share will make demand more elastic. From 2002-2014 market share increased and the own price elasticity became less elastic. Both frozen and clip/salt are substitutes with fresh cod (table 12). These product forms might have acted as substitutes due to the high prices of fresh cod. Dried cod has also been stable right underneath -1 throughout the period, except for a gap between 1998-2001 where it was more inelastic. Clip/salted started with the approximately same own price elasticity as frozen in 1988 but clip/salt has decreased almost ever since. There has been a relatively steep decreasing trend in the market share for salt and clip from around 2001. This reduction in market share has made salt/clip more inelastic.

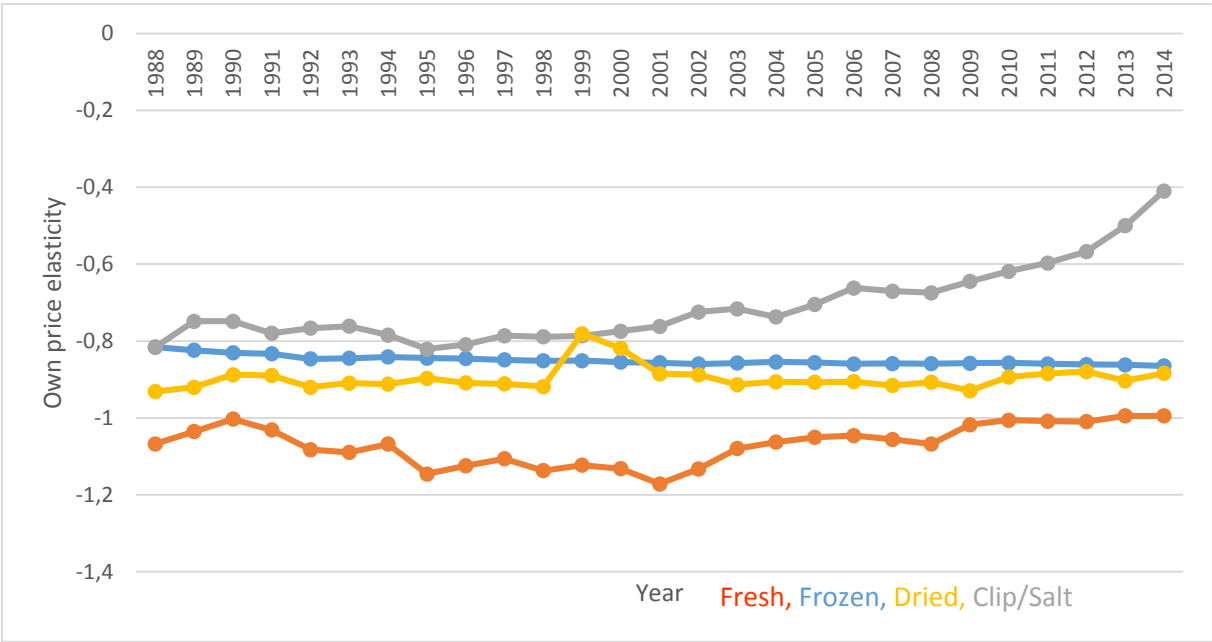


Figure 7 Yearly development in own price elasticity from 1988-2014

Cod is subject to seasonal fluctuations. Figure 8 shows how the own price elasticities on average change throughout a year. Dried cod has the largest volatilities. From figure 6 we see that during the second quarter of the year dried cod has its lowest market share. Since dried cod is a necessity, the own price elasticity drops due to a reduction in market share. As we approach the late summer months, market share increases and dried cod becomes less inelastic. Frozen cod is relatively stable and inelastic throughout the year. This commodity is the cheapest of the product forms and is used a lot in process industry. Since it is frozen, it is possible to stock the cod and provide the market throughout the year, which might mitigate the effect from seasonal fluctuations. Both fresh and salt/clip are elastic and stable in a year. From figure 8 we see that fresh cod is less elastic through the months of March, April and

May. This is the spawning season for cod, which means that the biggest catches are done during these months. This implies that fresh cod has its largest market shares, which makes it less elastic. Clip/salt is more elastic through the months fresh is less elastic. This is because during these months the market share of clip/salt is the smallest, making it more elastic. During the months where the market share is larger, clip/salt becomes less elastic. Clip/salt is more elastic through the spawning months since the fish first needs to be caught and then the process of making it salt or clip begins.

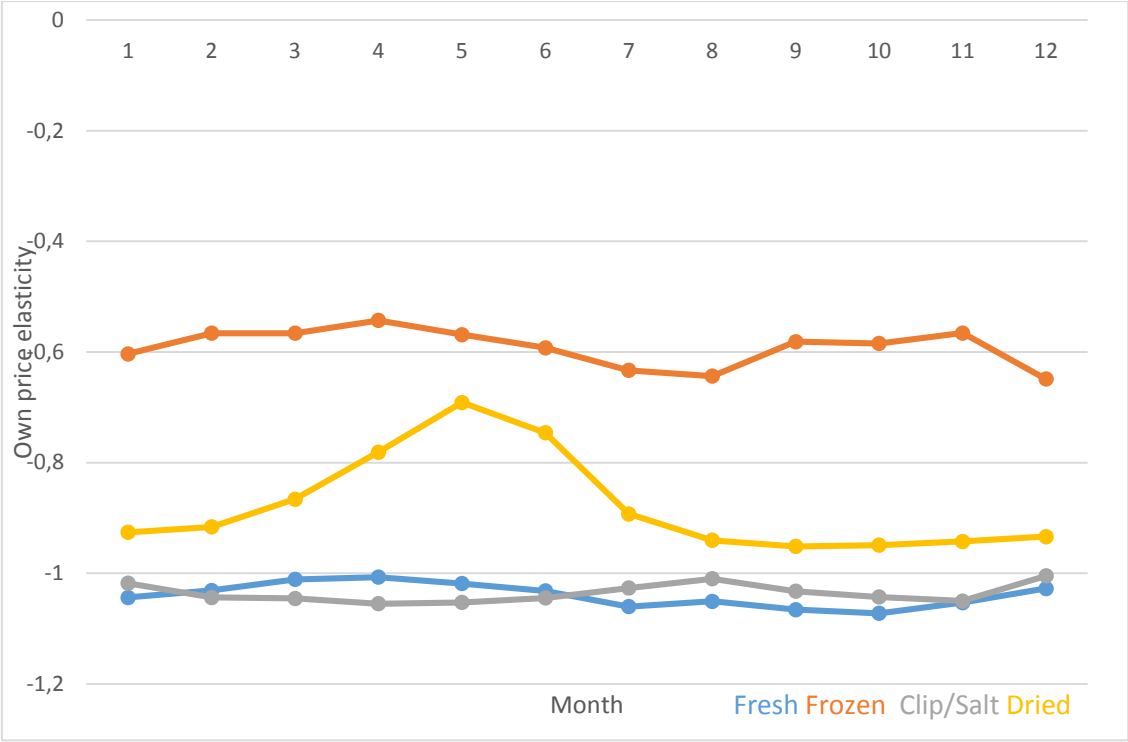


Figure 8 Average development in own price elasticity through a year

10.2 Cross price elasticities

Seven of the twelve uncompensated (Marshallian) cross price elasticities are statistically significant at a 5% level. Deaton and Muellbauer (Deaton and Muellbauer, 1980) point out that it is difficult to estimate the cross price elasticities with precision. I would still like to comment on the cross price elasticities even though five of the twelve are not significant.

10.2.1 Fresh cod

The cross price elasticity between fresh and frozen, and fresh and clip/salt are positive, indicating that fresh cod is a substitute for both frozen and clip/salt. The cross price effect between fresh cod and dried cod is negative. This indicates that the two product forms are complements. Looking at the value of the elasticity, we see that it is very low (weak complements), so a price increase in dried cod reduces demand for fresh cod by very little. The magnitude of this elasticity is very low, indicating that the relationship between dried and fresh cod is close to zero. All the elasticities are significant.

10.2.2 Frozen cod

The cross price elasticity between frozen and fresh is positive, indicating that fresh and frozen are substitutes (significant). If the price of fresh cod increases, then the demand for frozen will increase. What is interesting here is that fresh cod can be interpreted as a stronger substitute for frozen than the other way around. The cross price elasticity between salt/clip and frozen is negative. This indicates that they are complements. Still this relationship is not significant. Dried and frozen cod have a negative elasticity, but this elasticity is very low so a price change in dried cod has almost no impact on the demand for frozen cod. This relationship is not significant. This seems reasonable since frozen and dried cod are two differentiated products. Frozen has a large function as an input factor in process industry while dried cod is more directly targeted at consumers.

10.2.3 Clip/Salted cod

The cross price elasticity between clip/salted with fresh and frozen cod are both negative indicating that they are complements. It is only the elasticity with frozen that is significant. There is a small positive elasticity between dried and salt/clip but this is not significant. It is difficult for me to say anything more about this given my data set.

10.2.4 Dried cod

Two of the three cross price elasticities are significant. The cross price elasticity between clip/salted and dried cod is positive and relatively large. This indicates that dried cod is a substitute for clip/salt cod. This makes sense since those three product forms go under the name conventional products (Bedriftsutvikling, 2012). Fresh has a negative cross price elasticity indicating that it is a complement with dried cod. There is a relatively small positive

elasticity between frozen and dried. This indicates that they might be substitutes, but it is not significant.

Not all the goods are found to be substitutes. Fresh and dried are complements, but the magnitude is so low that they are approximately independent of each other. This indicates that a price increase on dried or fresh will not affect the demand for either one of them. Clip/salt and frozen seems to be substitutes for all the product forms. This must be interpreted cautiously since the cross price elasticities are not very precise. It might seem a bit odd that dried cod is a substitute for frozen cod, since dried cod is a more conventional product while frozen is not. Looking at how small the magnitude is (0.026) the significance of this is minimal. Clip/salt is a much stronger substitute for dried cod than the other way around. We know that the markets for clip/salt and dried are mainly Portugal, Spain and Italy. Since dried cod has such a small market share it might be that, the consumers are more indifferent between the two product forms. Fresh and frozen are both substitutes.

10.3 Expenditure elasticity

An interesting feature is the expenditure elasticities. Clip/salt is the only product form that is expenditure elastic, while fresh, frozen and salt are necessities. All the income elasticities are significant at a 5% level. Salt/clip cod is the most sensitive when looking at changes in income. Fresh is the least sensitive if there are changes in income. Of the four product forms we have, it seems that salt/clip is looked upon as more exclusive than fresh, frozen and dried cod. The income elasticities are in accordance with the β values. Since I have a data set that goes over a long time period, it would be interesting to check if there are some large changes over time and not only look at the elasticities measured by the average expenditure share. To investigate these elasticities further I have computed the expenditure elasticities for each year in figure 9. We see here that clip/salt has had an increasing trend. This is not surprising since the market share of salt has decreased over time. Clip/salt is a luxury good and when the market share decreases, this will make the expenditure elasticity more elastic. From 1994-1997 there is an increase in the market share for clip/salt. From figure 9 we see that the expenditure elasticity is a little bit less elastic through this period This is reasonable since a

good cannot always be expenditure elastic (Asche et al., 1998). Almost all the clip and salt fish is imported by Portugal and Spain. They have long traditions with conventional products. When the import of these products declines, it is not unreasonable that people are willing to buy more when they have an increase in income. The other three products are income inelastic (<1). Fresh has the least elastic expenditure. This might be due to the strong expansion in the import of frozen cod. We see that frozen cods expenditure elasticity also increases over time even though the import rate has increased, this is due to this product form being a necessity. The expenditure elasticity for fresh cod has been more volatile. From the end of 1993 until the end of 2002 it was an inferior good (negative expenditure elasticity). During this period, fresh cod had its lowest market share, while frozen cod had a strong growth. The magnitude of the elasticity for fresh cod is declining throughout the period. Fresh cod is a normal good the first seven years. However, following the growth of frozen salmon and the decrease in market share for fresh from figure 1, it seems to become an inferior good. The magnitude of the elasticity is decreasing in the period from 1995-2001. This seems reasonable and may be explained by the increase in the import of frozen cod giving fresh cod a smaller market share in an increasing market. From 2003 onwards fresh cod has had an increase in the market share. This is also reflected in the increase of the expenditure elasticity since it is a necessity. This is interesting. Since income growth has more importance for the demand for fresh cod now than earlier. The same applies to frozen and clip/salt, but the largest change is for fresh cod. This might give an indication that the process industry should try to pivot away from dried cod and towards the other product forms in the future. Dried cod has by far the most volatile expenditure elasticity. It is an inferior goods in many periods from 1988-2014. Frozen cod has been relatively stable through the period, but the last five years there is an increasing trend in the expenditure elasticity. This is due to the increase in the market share of frozen cod. There is no doubt that there has been a shift in the import of product forms. Salt cod has had the largest market share form 1988 until 2005 before frozen cod got the largest market share.

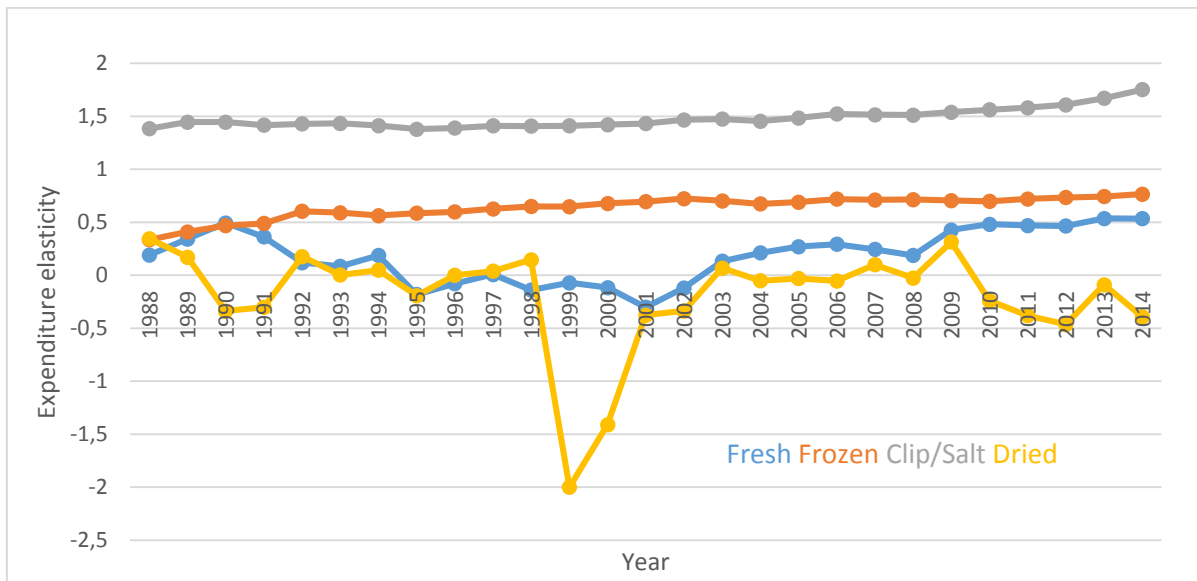


Figure 9 Expenditure elasticity over time

10.4 Compensated elasticities

When looking at the compensated elasticities also known as the Hicksian elasticities we assume constant utility where we want to minimize expenditure. The consumer is compensated for the income effect of a price change. This implies that the Hicksian elasticity represents the substitution effect. The compensated cross price elasticities indicate that almost all of the product forms are substitutes except for fresh and dried cod. Not all of these elasticities are significant. The clip/salt is a substitute for frozen, but this is not significant, the same applies the other way around. The effects of changes in the price clip/salt on fresh (0.497) and dried (0.835) together with the effects of changes in the price of frozen on fresh (0.514) are the strongest effects in the system. Hence, an increase in the price of clip/salt will significantly increase the demand for fresh and dried cod. If the price increases for frozen, the demand for fresh will significantly increase. The price of fresh (0.231) cod on the demand for frozen cod is also significant and important, but the effect is smaller than the other way around. A price change in dried cod gives the smallest substitution effects overall. This might indicate that dried cod is looked upon as a niche product, which makes it more differentiated from the other product forms. The uncompensated elasticities interpreted above are more ambiguous, but we can clearly see in table 13 that the expenditure effects play a major part.

Compensated price elasticities are nevertheless the most appropriate to look at when you want information about the substitution effects.

10.5 Price flexibility

Using the equation (39) I have calculated the different price flexibilities using the Marshallian own price elasticities. The result is given in table 13 underneath, measured at means of expenditure share throughout the period. This might be useful for producers to form price expectations from changes in supply due to quotas. The own price flexibility for fresh and clip/salt cod are less than one in absolute terms. This indicates that demand for these product forms is inflexible. For example, a 1% increase in the quantity of fresh cod is associated with a 0.98% decrease in price for fresh cod. The own price flexibility for frozen and dried cod have values larger than one in absolute terms which indicates that the demand for dried and frozen are flexible. A 1% increase in quantum for frozen cod is associated with a 1.61% decrease in price. This is good news for the process industry if supply is expanding, since frozen cod is common to use as an input factor. Since 2008, the import of frozen cod has increased substantially and as a result, the price has decreased a lot as well. This seems reasonable given the estimated price flexibility. In figure 4 we see that the prices dropped when the import increased of frozen cod. If the flexibilities are on approximately the same level globally then a 10% increase in quotas will lead to a 10% decrease in prices (with a flexibility near one). This implies that an increase in quotas will not give an increase in revenues for the fishermen. This is a very important implication and needs to be further researched.

	Fresh	Frozen	Clip/Salt	Dried
E_{pf}	-0.98	-1.61	-.95	-1.07

Table 13 Pice flexibility

11. Concluding remarks

I have yet to find any papers that resemble my results. This is because there has not been conducted any research on all the different cod species before. Hence, this thesis will therefore be an important contribution to the area of demand analysis regarding cod.

The goal of this thesis was to investigate the import of different product forms of cod from EU mainland. By using monthly data from Capia, the demand for fresh, frozen, clip/salt and dried cod was specified and estimated using the Linearized Almost Ideal Demand system developed by Deaton and Muellbauer. Both symmetry and homogeneity restrictions are imposed to the model. To avoid the problem of spurious results due to non-stationary I have written the variables on first difference form. Since the data set shows some seasonality, harmonic variables have been included to account for this.

The expenditure elasticities are interesting, as it seems that income growth are of greater importance for the demand after fresh cod now than it was earlier. This also applies to frozen and clip/salt, but the biggest change in expenditure has been for fresh cod looking back over the last 15 years. This have implications for future demand growth, where an increase in income affects the demand for fresh cod, while dried cod gets a reduction in demand for an increase in income.. This might be an indication for the process industry that they should revolve away from dried cod and more towards the other product forms in the future.

Not all goods are found to be substitutes. This applies to fresh and dried cod. This is important, as it implies that the demand for fresh cod is not dependent on the price of dried cod and vice versa. Dried cod is the product form with the smallest substitution effect. As mentioned earlier, this might be because it is looked upon as a niche good. This is good news for Norway since it is the only country supplying dried cod to EU mainland. Hence, Norwegian producers of dried cod might have some degree of stronger market power.

Throughout the timeline of my data set, we see that frozen cod has become the commodity with the largest market share in EU. This is reflected through a less elastic own price elasticity and more elastic expenditure elasticity.

One of the issues when looking at the data set is that in EU there exists the consumer market and the process industry. These two might have different demand for the different product

forms. The process industry uses mostly frozen cod as an input factor. While consumers are more spread in between the product forms. For further research, one should get a dataset that reflect this matter. Looking at the price flexibility, we see that frozen is price flexible. This is good news for the process industry if supply is expanding. Quota expansion might not increase the revenues of fishermen, since an increase in quantities is off-set by a corresponding decrease in price.

With this master thesis, I have filled a gap in knowledge and contributed to increased knowledge about demand for different product forms of cod in the main market (EU). The results have implications for quota setting, the process industry and for further research on cod.

Appendix

Deriving of Slutsky equation.

We have the following relationship between Hicksian(compensated) and Marshallian(uncompensated) demand.

$$(1) x_i^h(p,u) \equiv x_i(p, e(p, u))$$

If I differentiate both sides with regards to p_j . Expenditure $e(p,u)$ can change in whatever way to keep the utility constant.

$$(2) \frac{\partial x_i^h(p,u)}{\partial p_j} = \frac{\partial x_i(p,e(p,u))}{\partial p_j} + \frac{\partial x_i(p,e(p,u))}{\partial I} * \frac{\partial e(p,u)}{\partial p_j}$$

Then I use the identity called Shepards lemma

$$(3) \frac{\partial e(p,u)}{\partial p_j} = x_j^h(p, u)$$

$$(4) x_j^h(p, u) \equiv x_j(p, e(p, u)) \text{ and } e(p,u) \equiv I$$

I substitute $x_j(p, I) = \frac{\partial e(p,u)}{\partial p_j}$ and I for $e(p,u)$

$$(5) \frac{\partial x_i^h(p,u)}{\partial p_j} = \frac{\partial x_i(p,I)}{\partial p_j} + \frac{\partial x_i(p,I)}{\partial I} * x_j \text{ where } i,j = 1,2,3,,n$$

If I rearrange this, I will get the Marshallian demand in terms of the derivative of the Hicksian demand, which gives us Slutsky equation.

$$(6) \frac{\partial x_i(p,I)}{\partial p_j} = \frac{\partial x_i^h(p,u)}{\partial p_j} - \frac{\partial x_i(p,I)}{\partial I} * x_j$$

Marshallian elasticities can be divided between gross substitutes and gross complements.

If $\frac{\partial x_i(p,I)}{\partial p_j} > 0$ *gross substitutes*

If $\frac{\partial x_i(p,I)}{\partial p_j} < 0$ *gross complements*

The Hicksian elasticities can be divided in a similar way.

If $\frac{\partial x_i^h(p,u)}{\partial p_j} > 0$ *net substitutes*

If $\frac{\partial x_i^h(p,u)}{\partial p_j} < 0$ *net complements*

Interpretation of the different terms in the Slutsky equation

$$(7) \frac{\partial x_i(p,I)}{\partial p_j} = \frac{\partial x_i^h(p,u)}{\partial p_j} - \frac{\partial x_i(p,I)}{\partial I} * x_j \quad \text{Slutsky equation}$$

Here the term on the left side is the total change in Marshallian demand. Given Marshallian demand you want to maximize utility given a budget. This means that the nominal income/expenditure is constant but the real income/expenditure will vary with prices. Hence we will have both a substitution effect and an income effect.

First term on the right hand side gives us the rate of change in the Hicksian demand, the pure substitution effect. This effect is captured by assuming a constant utility where we want to minimize expenditure. We are not satisfied if we do not obtain equal purchasing power. Hicksian demand therefore only shows the pure substitution effect which means that demand only varies with price because other goods become more attractive. When we deal with normal goods the Hicksian demand will have a smaller response to a price change (less elastic) than the Marshallian demand looking at own price. The last term in the equation is the income effect. If price of x_j goes down we get an increase in the purchasing power (real income.)

We can derive the Marshallian elasticities by using the Slutsky equation. I multiply both sides with $\frac{p_j}{x_i}$

$$(8) \frac{\partial x_i(p,I)}{\partial p_j} * \frac{p_j}{x_i} = \frac{\partial x_i^h(p,u)}{\partial p_j} * \frac{p_j}{x_i} - \frac{\partial x_i(p,I)}{\partial I} * x_j * \frac{p_j}{x_i}$$

I rewrite it:

$$(9) \frac{\partial x_i(p, I)}{\partial p_j} * \frac{p_j}{x_i} = \frac{\partial x_i^h(p, u)}{\partial p_j} * \frac{p_j}{x_i} - \frac{\partial x_i(p, I)}{\partial I} * \frac{I}{x_i} * \frac{p_j x_j}{I}$$

Looking at each term one can see that they are written in elastic form. Then use the following notation:

$$(10) E_{ij} = E_{ij}^* - R_j * A_i$$

Reference list

- A.I.P.C.E. (2008). *White fish study 2008* (pp. 1–27).
- A.I.P.C.E.-C.E.P. (2013). *Finfish Study 2013* (pp. 1–71).
- Alston, J. M., & Chalfant, J. a. (1993). The Silence Almost of the Models of the Ideal Lambdas : Test Rotterdam. *American Journal of Agricultural Economics*, 75(2), 304–313.
- Arnade, C., & Pick, D. (1998). Seasonality and unit roots: The demand for fruits. *Agricultural Economics*, 18, 53–62.
- Arnade, C., Pick, D., & Gehlhar, M. (2005). Testing and incorporating seasonal structures into demand models for fruit. *Agricultural Economics*, 33, 527–532.
- Asche, F. (1996). A system approach to the demand for salmon in the European Union. *Applied Economics*, 28, 97–101.
- Asche, F. (2014). *EU-markedet for fisk (og norsk torskeeksport)* (pp. 1–30).
- Asche, F., Bjørndal, T., & Salvanes, K. G. (1998). The demand for salmon in the European Union: the importance of product form and origin. *Canadian Journal of Agricultural Economics*, 46, 69–81.
- Asche, F., Bremnes, H., & Wessells, C. R. (1999). Product Aggregation, Market Integration, and Relationships between Prices: An Application to World Salmon Markets. *American Journal of Agricultural Economics*, 81, 568–581.
- Asche, F., & Gordon, D. V. (2005). Demand structure for fish. *Research in Economics*, (37), 1–44.
- Asche, F., Salvanes, K. G., & Steen, F. (1997). Market delineation and demand structure. *American Journal of Agricultural Economics*, 79(February), 139–150.
- Asche, F., & Wessells, C. R. (2014). On System, 79(4), 1182–1185.
- Asche, F., & Zhang, D. (2013). Testing Structural Changes in the U . S . White ish Import Market : An Inverse Demand System Approach. *Agricultural and Resource Economics Review*, 3(December), 453–470.
- Barten, A. (1977). The Systems of Consumer Demand Functions Approach : A Review. *Econometrica*, 45(1), 23–50.
- Barten, A. . (1968). Estimating Demand Equations. *Econometrica*, 36(2), 213–251.

- Bedriftsutvikling, S. (2012). *NORD-ATLANTISK FERSK TORSK I EUROPA – MULIGHETER OG UTFORDRINGER* (pp. 1–85).
- Chalfant, J. a. (1987). Globally Flexible , System Almost Demand. *Journal of Business & Economic Statistics*, 5(2), 233–242.
- Cozzarin, B. P., & Gilmour, B. W. (1998). A Methodological Evaluation of Empirical Demand Systems Research, 46(July), 297–316.
- Dameus, A., Richter, F. G. C., Brorsen, B. W., & Sukhdial, K. P. (2002). AIDS versus the Rotterdam demand system: A Cox test with parametric bootstrap. *Journal of Agricultural and Resource Economics*, 27(2), 335–347.
- Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, 70(3), 312–326.
- Deaton, A. and Muellbauer, J. (1980). *Economics and consumer behavior*. Cambridge: Cambridge University Press.
- Dey, M. M. (2000). Analysis of demand for fish in Bangladesh. *Aquaculture Economics & Management*, 4(May 2015), 63–81.
- Duffy, M. (1995). Advertising in demand systems for alcoholic drinks and tobacco: A comparative study. *Journal of Policy Modeling*, 17(January), 557–577.
- Duffy, M. H. (1987). ADVERTISING AND THE INTER-PRODUCT DISTRIBUTION OF DEMAND A Rotterdam Model Approach, 31, 1051–1070.
- Döring, Ralf, Borrello, A. (2013). *The Economic Performance of the EU Fish Processing Industry Scientific , Technical and Economic Committee for Fisheries (STECF) Edited by* (pp. 1–223).
- Eales, J. S., & Unnevehr, L. J. (1988a). Products : Separability and Structural Change. *Aids*, 70(3), 521–532.
- Eales, J. S., & Unnevehr, L. J. (1988b). Products : Separability and Structural Change. *American Journal of Agricultural Economics*, 70(3), 521–532.
- Eales, J. S., & Unnevehr, L. J. (1994). The inverse almost ideal demand system. *European Economic Review*, 38(358), 101–115.
- Edgerton, D. L. (1997). Weak separability and the estimation of elasticities in multistage demand systems. *American Journal of Agricultural Economics*, 79(1), 62–79.
- Engle, R. F., & Granger, C. W. J. (1987). Co-Integration and Error Correction : Representation , Estimation , and Testing. *Econometrica*, 55(2), 251–276.
- EUMOFA. (2014). The EU Fish Market. *The EU Fish Market*, 1–52.

- Franses, P. H., & Box, P. O. (1991). and the Forecasting of Monthly. *International Journal*, 7, 199–208.
- Franses, Philip Hans, Paap, R. (1995). Seasonality and Stochastic Trends in German consumption and income. *Empirical Economics*, 109–132.
- Fraser, I., & Moosa, I. (2002). Demand Estimation in the Presence of Stochastic Trend and Seasonality: The Case of Meat Demand in the United Kingdom, 84(1), 83–89.
- Fujii, E. T., Khaled, M., Mak, J., Journal, S., & May, N. (1985). Journal of transport economics and policy. *Transportation Research*, 4(2), 161–171.
- Gordon, D. V., & Hannesson, R. (1996). On Prices of Fresh and Frozen Cod Fish in European and U . S . Markets The University of Calgary. *Marine Resource Economics*, 11, 223–238.
- Gordon, Daniel , Asche, Frank, Hannesson, R. (2003). Searching For Price Parity in the, (51), 1–24.
- Green, R., & Alston, J. M. (1990). Elasticities in AIDS Models. *American Journal of Agricultural Economics*, 72(2), 442–445.
- Hill, R., Griffiths, W. and Lim, G. (2012). *Principles of econometrics*. Hoboken, N.J.: John Wiley & Sons.
- Hylleberg, S., Engle, R. F., Granger, C. W. J., & Yoo, B. S. (1990). Seasonal integration and cointegration. *Journal of Econometrics*, 44, 215–238.
- Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models. *Econometrica*, 59, 1551–1580.
- Jung, J., & Won, W. K. (2002). Demand for meat and fish products in Korea. *Journal of Rural Development*, 25(439), 133–154.
- Lewbel, A. (1988). A Path-independent Divisia-like Inde for PIGLOG Preferences.
- Lütkepohl, H. 2004. "Univariate Time Series Analysis." In *Applied Time Series Econometrics*, ed. H. Lütkepohl and M. Krätzig, 8–86. 1st ed. New York: Cambridge University Press.
- Muellbauer, J. (1976). Community Preferences and the Representative Consumer. *Econometrica*, 44(5), 979–999.
- Piggott, N. E., Chalfant, J. A., Alston, J. M., Griffith, G. R., Piggott, N. E., Chalfant, J. A., ... Griffith, G. R. (1996). Demand Response to Advertising in the Australian Meat Industry. *American Journal of Agricultural Economics*, 78(2), 268–279.
- Schalkwyk, Van, Taljaard, PR, Alemu, Z. (2004). THE DEMAND FOR MEAT IN SOUTH AFRICA : AN ALMOST IDEAL ESTIMATION. *Agrekon*, 43(4), 430–443.

- Seafoods, A. (2012). *Industry handbook The White fish industry 2012. Processing* (pp. 1–65).
- Sjømatråd, N. (2015). *Markedsrapport Hvitfisk og konvensjonell* (pp. 1–53).
- Stahl, D. O. (1983). Quasi-homothetic Preferences , the Generalized Divisia Quantity Index , and Aggregation, *50*(197), 87–93.
- Taljaard, P. R., van Schalkwyk, H. D., & Alemu, Z. G. (2006). Choosing between the AIDS and Rotterdam models: A meat demand analysis case study. *Agrekon*, *45*, 158–172.
- Theil, H. (1965). The Information Approach to Demand Analysis Author(s): H. Theil Source: *Econometrica*, *33*(1), 67–87.
- Theil, H. (1975). The theory of rational random behaviour and its application to demand analysis. *European Economic Review*, *6*, 217–226.
- Thong, N. T. (2012). An Inverse Almost Ideal Demand System for Mussels in Europe. *Marine Resource Economics*, *27*(2), 149–164.
- Xie, J., & Myrland, Ø. (2011). Consistent Aggregation in Fish Demand: A Study of French Salmon Demand. *Marine Resource Economics*, *26*(4), 267–280.
- Zellner, A. (1962). An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *Journal of the American Statistical Association*, *57*(298),

