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Market Information and Fisheries Management

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Introduction

It is well known that the U.S. whitefish market is complex, made up of many species that compete with one another, as well as competing with imports of similar products from other nations. The dominant species sold in the U.S. whitefish market are pollock and Pacific cod. Other groundfish and even farmed catfish are a part of the whitefish market. These species are ultimately sold domestically in a variety of product forms and venues – frozen blocks or portions, fish sticks at fast food restaurants or in the home, and high quality fillets at upscale restaurants. The products are also exported to Asia, in particular Japan, a large importer of pollock as surimi.

In the midst of this complex and very large market for whitefish are the groundfish caught by fishermen in the New England states, including cod, haddock, various flounder species, American plaice, and hake. These products compete at the local level with landings of whitefish from within the New England area, and also nationally in other areas, such as Alaska and the west coast, and with imports. Thus, the forces that determine ex-vessel prices for groundfish in the New England ports are derived from those forces affecting imports and forces affecting markets for other U.S. ground fish, as well as local circumstances affecting other New England markets.

Many reports, journals articles and books have been written about the markets for groundfish, with much of the empirical analysis utilizing simultaneous equation models to evaluate demand and supply. With this approach, researchers have sought to determine price and income elasticities of the various groundfish species. Elasticities are of course important in policy analysis. These models specify a supply equation where exvessel prices are a function of size of landings, and input costs such as labor and fuel. Demand equations are generally specified with quantity as a function of price, prices of substitutes and per capita income.

These models worked reasonably well (Bockstael, 1977; Schrank and Roy, 1991) however, model specification remained a challenge. One specific challenge is to determine those species with which individual groundfish species caught in New England compete. In other words, in the demand equation, which species are close substitutes to haddock? Conventional thought is that all the whitefish species compete with one

another to some extent, but which are the strongest substitutes? Can a group of groundfish be treated as an aggregate commodity? Finally, how do imports of groundfish influence exvessel demand for groundfish?

The purpose of this analysis is to assist NMFS economists in specifying demand for groundfish, allowing them to maintain confidence in the forecasting of changes in consumer surplus as fisheries regulations change in New England groundfisheries.

The report is laid out as follows. First, background on the US whitefish market will be presented. Next, a discussion of the previous literature on groundfish market analysis is presented. Third, the method of testing for cointegration will be presented. Cointegration analysis allows us to investigate the relationship of prices among species over the long run. If there is a long run relationship between prices for different species (prices move together over time) then we can say that those species compete in the same market. Furthermore, we can check exogeneity of prices to determine if there are any dominant species that drive prices for the other species. This discussion is followed by results of cointegration analysis of imported whitefish. Cointegration analysis is then applied to New England groundfish by species and port. Traditional demand analysis is discussed next, with a discussion of potential functional forms used in demand systems analysis. Finally, conclusions will be presented.

The U.S. Market for White Fleshed Fish

Whitefish products are generally defined as products coming from fish with white flesh (muscles). The major difference between the whitefish products and other fish species is that most whitefish species do not contain fat in the fish muscles, but rather collect fat in the liver. Other fish species, such as tuna and salmon collect fat in the muscles. This difference gives the whitefish milder taste than other fish products, such as tuna, herring and salmon.

The whitefish market is not a homogenous market where all whitefish species are considered to be substitutes for each other. There is however considerable substitutability between some whitefish species, and this substitutability has increased over the years, as supply of cod products has declined, while supply of other whitefish products (pollock, hake and catfish) has increased (Asche 1997, Shriver 1994).

The U.S. Trade in Whitefish Products

The United States Department of Commerce trade database is utilized for documenting the U.S. trade in groundfish products. This database contains information on import, export and re-export of all products. The National Marine Fisheries Service republishes all fisheries products within that same database. The data used in this dissertation comes from the NMFS republished fisheries data from their web page.

The total volume of imported whitefish is relatively stable from 1990 to 1998. Figure 1 shows imports by major species, or group of species, including all product forms.

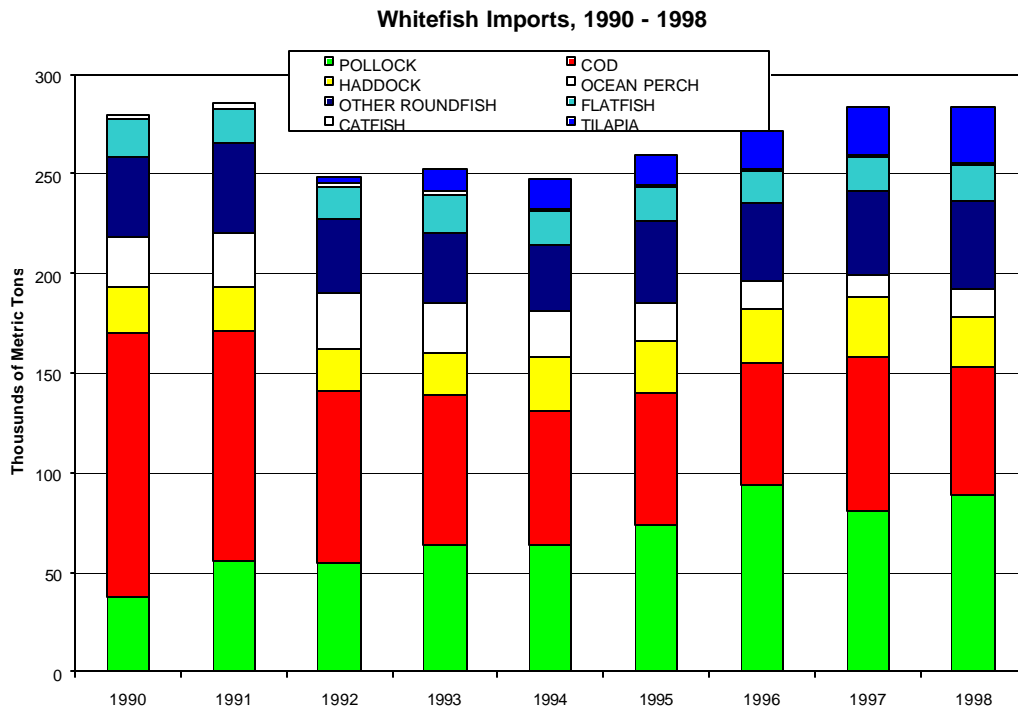


Figure 1: Imports of Whitefish species, processed weight

Source: USDOC, National Marine Fisheries Service, personal communication

The total amount imported in 1998 is about the same as in 1990, or 250,000 metric tons (mt) processed weight. The species composition is different, and relative importance of individual species has changed. Pollock has increased its share from 13% in 1990 to about 36% in 1998. Cod has decreased its share from 44% in 1990 down to 19% in 1998. Other notable changes are tilapia, which is mostly produced by aquaculture, has increased in share from 0% in 1991 to 10% in 1998. This trend is interesting especially when put in the context of increased catfish production in the United States (about 250,000 mt annually, live weight) and the increase in imported farmed Atlantic salmon

Focusing on cod, there are 23 different codes in the United States Department of Commerce trade database for cod products. These codes are split-up into three categories in Table 1. The first category contains fresh or chilled products from cod (4 codes). The second category contains frozen products (9 codes) and the final category is dried, salted and smoked products (total of 10 codes).

Table 1: USDOC Import Codes

USDOC code	Description
Fresh or Chilled	
0302500010	ATLANTIC COD EX FILLETS/LIVERS/ROES, FRESH/CHILLED
0304101044	ATLANTIC COD FILLETS AND OTHER MEAT, FRESH OR CHLD
0304101048	COD NESOI FILLETS AND OTHER MEAT, FRESH/CHILLED
0302500090	COD NESOI, EX FILLETS, LIVERS & ROES, FRESH/CHILLD
Frozen Products	
0303600010	ATLANTIC COD, EXCEPT FILLETS/LIVERS/ROES, FROZEN
0304202011	ATLANTIC COD FILLET, SKINND, BLOCK OV4.5KG, FROZEN
0304203030	ATLANTIC COD FILLETS, NESOI, FROZEN
0304203035	COD (EXCEPT ATLANTIC COD) FILLETS, NESOI, FROZEN
0304901005	COD MEAT MINCED IN BULK OR CONTAINERS OV 6.8KG FRZ
0304901011	COD MEAT MINCED IN BULK OR CONTAINERS OV 6.8KG FRZ
0304901012	COD MEAT NT MINCED IN BULK/CONTAINRS OV 6.8KG FRZN
0304202012	COD NESOI FILLETS, SKINNED, BLOCKS OV4.5KG, FROZEN
0303600090	COD NESOI, EXCEPT FILLETS/LIVERS/ROES, FROZEN
Dried, Salted or Smoked	
0305306030	COD FILLETS, DRIED, SALTED OR IN BRINE
0305620080	COD SALTD NT DRD/SMKD, BRINE, NESOI, MOISTURE <43%
0305620070	COD SALTD NT DRD/SMKD BRINE NESOI MOISTUR >43%<45%
0305620060	COD SALTD NT DRD/SMKD BRINE NESOI MOISTUR >45%<50%
0305620050	COD SALTD NT DRD/SMOKD, BRINE, NESOI MOISTURE >50%
0305620045	COD WHOLE/PROCSD SALTD NT DRD/SMKD MOIST NT OV 43%
0305620030	COD WHOLE/PROCSD SALTD NT DRD/SMK MOISTUR >43%<45%
0305620025	COD WHOLE/PROCSD SALTD NT DRD/SMKD MOIST >45% <50%
0305620010	COD WHOLE/PROCESSD SALTD NT DRD/SMK MOISTURE > 50%
0305510000	COD, DRIED, WHETHER OR NOT SALTED BUT NOT SMOKED

Total import value and volume of cod for the top three countries is shown in Figure 2. All other countries include mainland China, Denmark (including Greenland and Faeroe Islands) Russia and others. Canada has historically been the largest exporter to the United States but since 1995, Canada's and Iceland's shares have been about equal¹. Norway, Denmark and Russia are the next three runners-up. Combined, the top three countries supplied more than 88% in 1990, then declining down to supplying 74% in 1998. The largest increase is in imports of non-specified cod products from China and Russia. However, despite these large increases in imports from China, Russia and Norway, the main suppliers of cod products to the United States are Iceland and Canada.

¹ Both Atlantic and not specified cod products

Imports of Cod Products to the United States

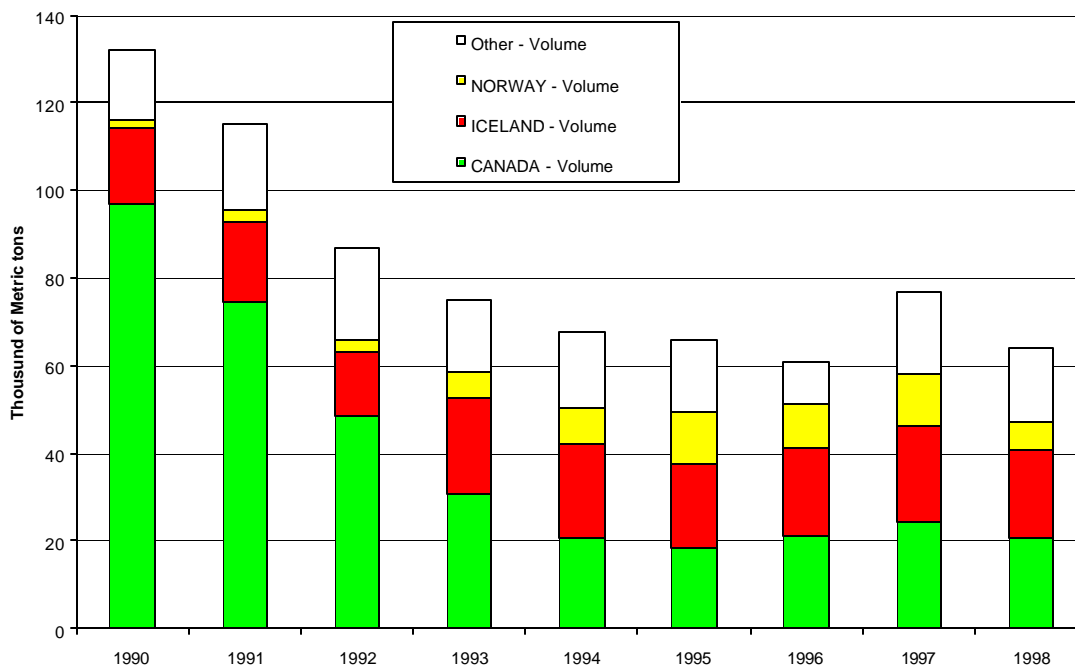


Figure 2: Total Cod Imports by Country

Source: USDOC

Figure 2 shows how cod imports have declined from 135,000 mt in 1990 to 60,000 mt in 1998, about a 50% decrease. This decrease is due to a decrease in imports from Canada. Other countries maintained, or increased, their supply of cod products to the United States. The Canadian supply decreased from over 95,000 mt in 1990, to 20,000 mt in 1998.

Imports by the main three categories are shown in Figure 3.

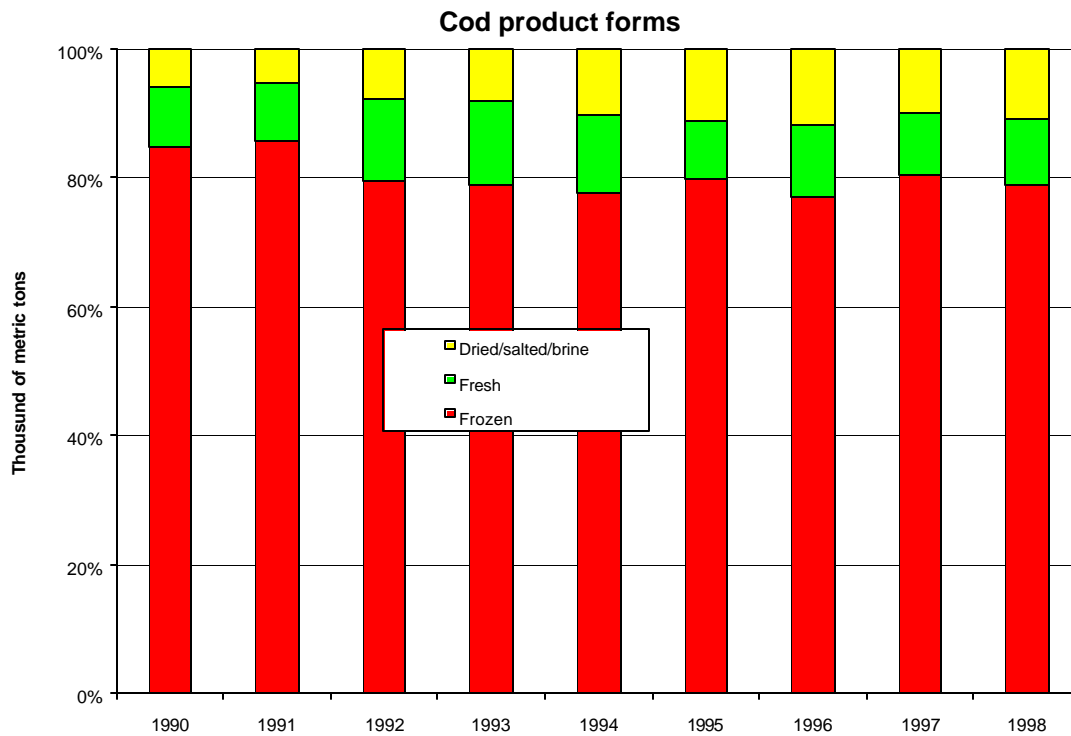


Figure 3: Imports by major categories

Source: USDOC

Fresh or chilled and frozen categories account for 90% of all cod imports into the U.S. Frozen accounts for about 80% of total imports. The increase in the share of dried or salted category from 5% to 10% of total imports from 1990 to 1998 is mainly due to the fact that imported volume of other product forms have declined substantially.

Figure 34 shows the total imports from the frozen categories, by top 10 import codes as of 1998. Historically the most important import code has been Atlantic cod fillets in blocks. This category has decreased from 54,000 mt. in 1990 down to 6,500 mt tons in 1998. This represents clearly the effect from closing down the Canadian Atlantic cod fisheries in 1992 and the change in emphasis on production form after the decline in total allowable catch in the Icelandic cod fishery.

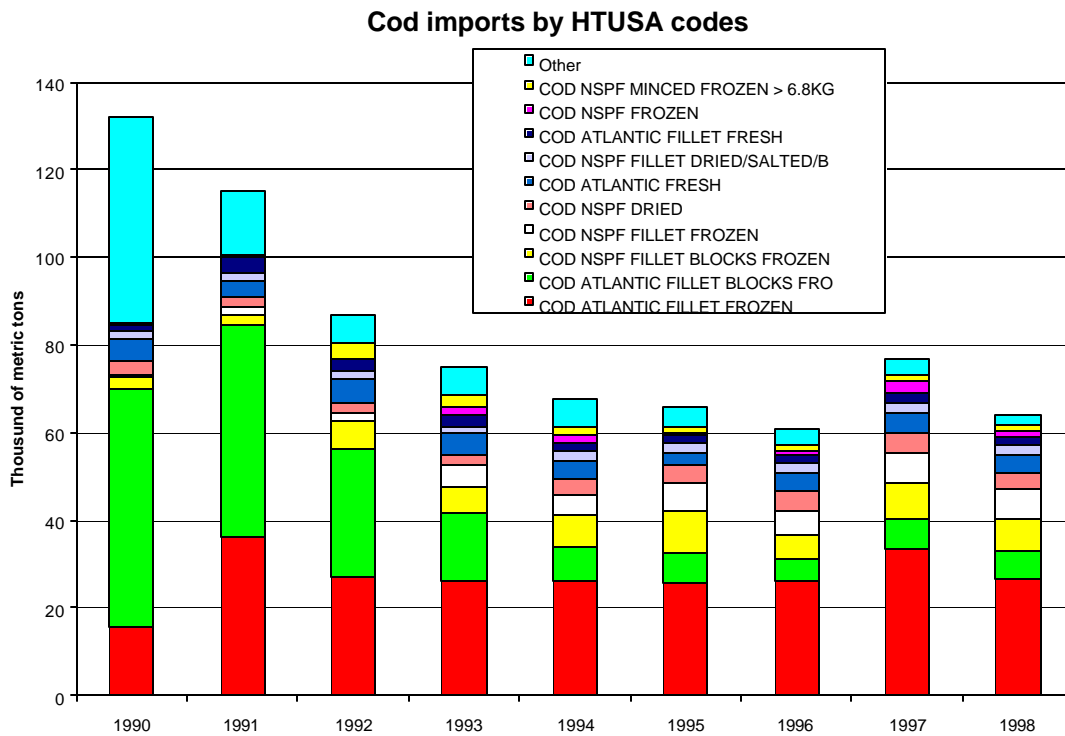


Figure 4: Cod Imports by Product Codes – Frozen

Source: USDOC

In 1998, the largest import code, in volume, is Atlantic cod fillets, with total imports of 27,000 mt. This category has fluctuated between 25,000 mt and 35,000 mt. Other cod product forms are increasing as well, but as an individual share of the total imports their importance is low.

Cod products are distinguished into two groups, Atlantic and Not Elsewhere Specified or Included (NESOI). Atlantic cod is from the North Atlantic Ocean, including Canada, Greenland, Iceland, Faeroe Islands, Norway, Denmark, Russia and the UK. Other cod is mainly Pacific cod from Canada, China and Russia, as well as other countries. These different product forms have different average values, both within each subspecies, as well as between the two subspecies groups. Figure 5 shows average values, on a monthly basis, for the top four product codes (cod fillets, blocks and other, Atlantic and NESOI).

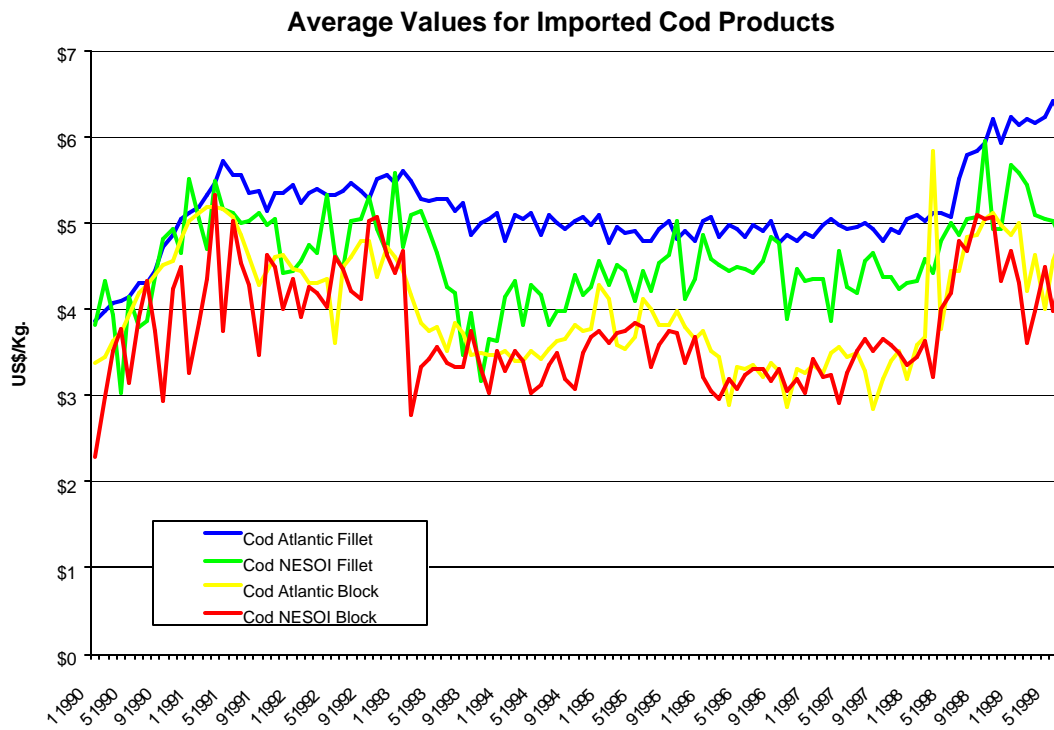


Figure 5: Average values for major cod products code

Source: Own calculations

The Atlantic cod fillet is the most valuable product code in terms of dollars per kg. Non-specified fillets are second, followed by Atlantic block and non-specified blocks. Fillets are more expensive since they are more processed (often individually frozen and pre-cut fillets) and ready for delivery to retail outlets, restaurants and other foodservice establishments. Blocks are usually further processed, where the block is used to produce retail products, such as fish fingers, and other breaded fish products.

Pollock

Pollock accounts for the largest volume of whitefish species imported into the United States. Throughout the last decade the imports have been increasing, while imports of cod, the other main species, has sharply decreased (see Figure 11). The major HTSUSA codes are shown in Table 2.

Table 2: HTSUSA codes for pollock

USDOC code	Description
<i>Fresh or Chilled</i>	
0302630000	POLLOCK ATLANTIC FRESH
0302692023	POLLOCK NSPF FRESH
<i>Frozen Products</i>	
0304202044	POLLOCK ALASKA FILLET BLOCKS FROZEN > 4.5KG
0304203065	POLLOCK ALASKA FILLET FROZEN
0304204065	POLLOCK ALASKA FILLET FROZEN
0303792024	POLLOCK ALASKA FROZEN
0303804050	POLLOCK ALASKA ROE FROZEN
0303730000	POLLOCK ATLANTIC FROZEN
0304202040	POLLOCK NSPF FILLET BLOCKS FROZEN > 4.5KG
0304202048	POLLOCK NSPF FILLET BLOCKS FROZEN > 4.5KG
0304203068	POLLOCK NSPF FILLET FROZEN
0304204063	POLLOCK NSPF FILLET FROZEN
0304204068	POLLOCK NSPF FILLET FROZEN
0304901040	POLLOCK NSPF MEAT FROZEN > 6.8KG
0304901048	POLLOCK NSPF MEAT FROZEN > 6.8KG
0304901044	POLLOCK NSPF MINCED FROZEN > 6.8KG
<i>Dried, Salted or Smoked</i>	
0305691042	POLLOCK NSPF FILLET SALTED
0305691022	POLLOCK NSPF SALTED WHOLE/DRESSED

The most common product form is frozen fillets. Frozen fillets come both as blocks and individually-frozen packed fillets. The pollock is also categorized by regions, coming from Alaska (or the Pacific Ocean), Atlantic or not-specified (NSPF).

The largest product code is frozen Alaska fillet blocks. Figure 6 shows Alaska pollock imports by product codes. Fresh, salted and minced product codes are combined into individual categories.

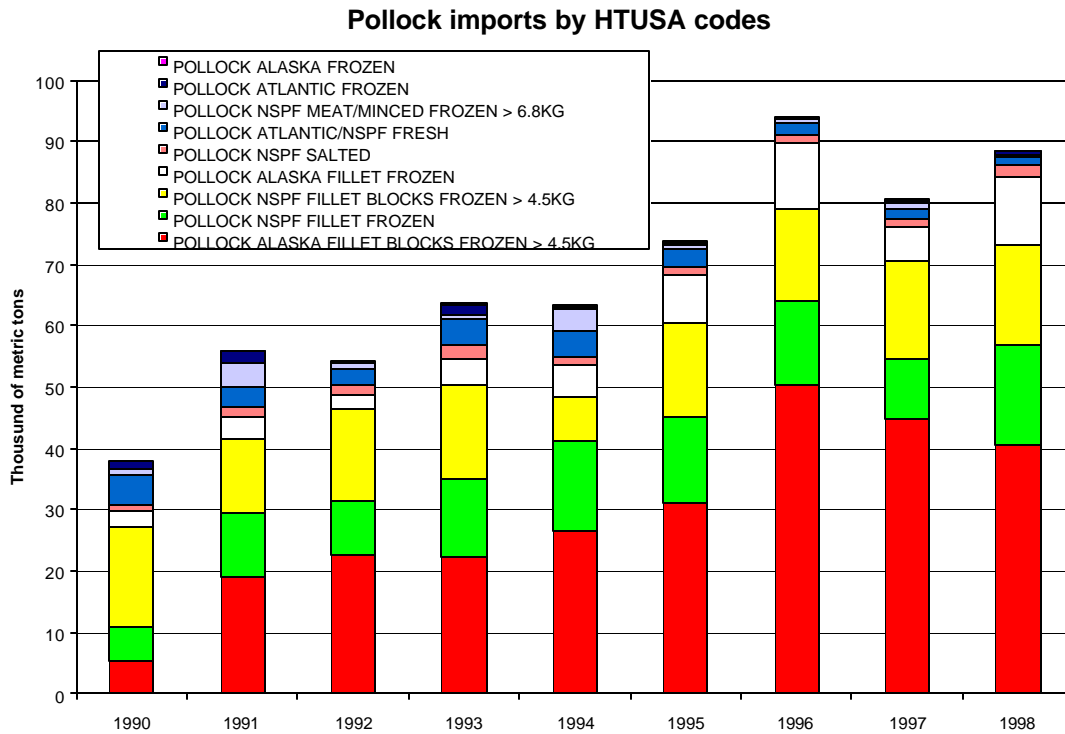


Figure 6: Pollock imports by HTSUSA codes

Source: NMFS, Trade database

The majority of pollock is Alaska pollock, frozen either in blocks or as individually-packed fillets. Total imports increased from 38,000 mt in 1990, to 89,000 mt in 1998. Imports of pollock products reached its peak in 1996, with more than 94,000 mt imported. Since 1991, frozen Alaska block fillets have accounted for approximately 30% to 50% of the total volume of imported pollock. Overall, this trend in pollock imports reflects the general trend in the U.S. market of substitution between cod and pollock, especially for the block products (Shriver 1994).

Pollock imports by country of origin

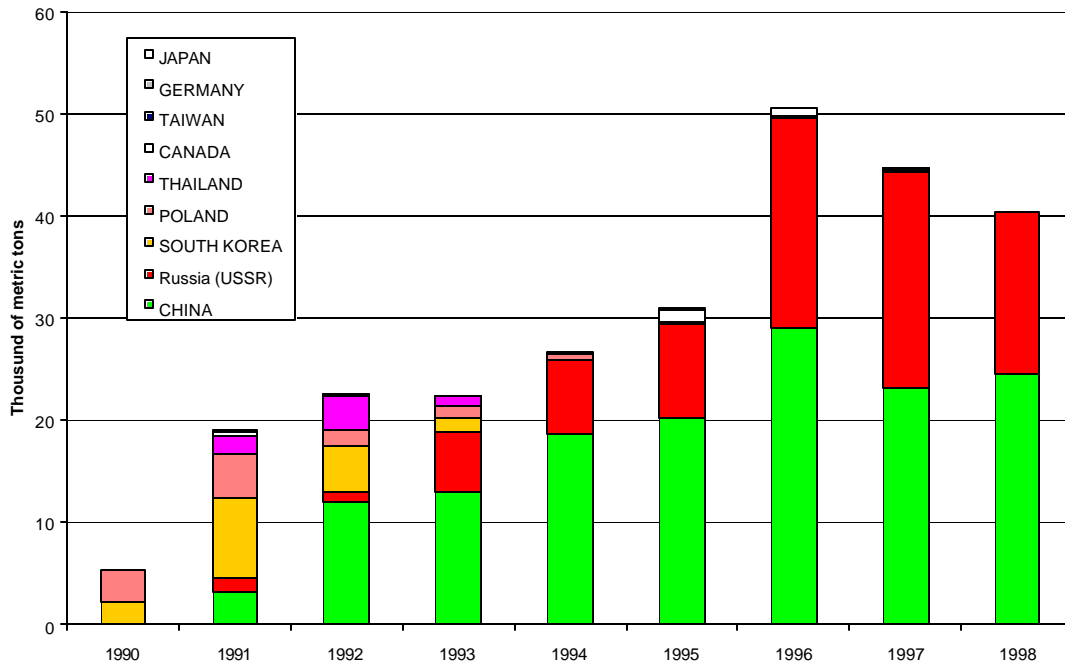


Figure 7: Top ten countries of origin for pollock imports

Source: NMFS, Trade database

The majority of the imported pollock originates from China and Russia. These countries share the Pacific pollock resource with the United States. The trend in pollock imports also reflects the change in world trade.

Some of the imports from China originate in the United States. Lower labor costs make it profitable to export whole, frozen fish to China, from the United States, and then re-export the fillet products to the United States (Shriver 1994)

All other whitefish species.

Cod and pollock are the most important whitefish species imported into the United States. However, there is a great variety of other species imported into the U.S., from all over the world. As we saw in the previous section cod and pollock have accounted for 120,000 - 160,000 mt in the past decade. Other whitefish species imported to the United States have accounted for approximately 100,000 mt on an annual basis. Flatfish, haddock and hake/whiting account for the largest share of other whitefish species, or 70,000 to 80,000 mt on an annual basis. Among other species, monkfish has the greatest imported volume. Though some fluctuations in relative share of individual species groups have occurred, overall composition and importance of each group has not changed over the last decade.

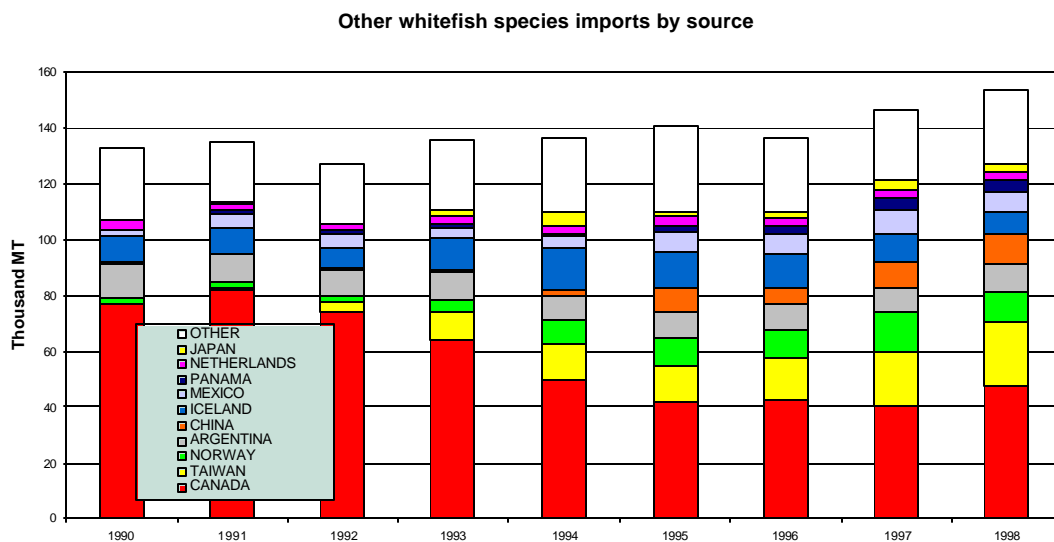


Figure 8: Other whitefish species imports, by source

Source: NMFS, Trade database

The majority of *other species* comes from Canada, Taiwan, Norway, Argentina, China, Iceland and Mexico. From Canada, other whitefish species are haddock, hakes, flatfish (flounder, sole and turbot), and ocean perch. From Taiwan, tilapia is the largest volume imported. Imports from Norway of other whitefish species are mainly haddock. Argentina exports to the United States whitefish species such as flounder, hake and whiting. China exports flatfish species under this same category. Imports from Iceland are haddock and ocean perch (redfish). Imports from Mexico are groupers/snappers.

Aquacultured Whitefish Species

Catfish (*Ictalurus punctatus*) aquaculture has been on the rise in the United States over the past two decades. Channel catfish (from here on referred to simply as catfish) are native to the Mississippi river drainage, but their range has expanded throughout most regions of North America (Lewis and Shelton 1999). Catfish aquaculture on a commercial basis started in the 1950s and 1960s, but did not take off until the late 1970s and early 1980s. Figure 99 shows total annual production of whole catfish from 1970 to 1998.

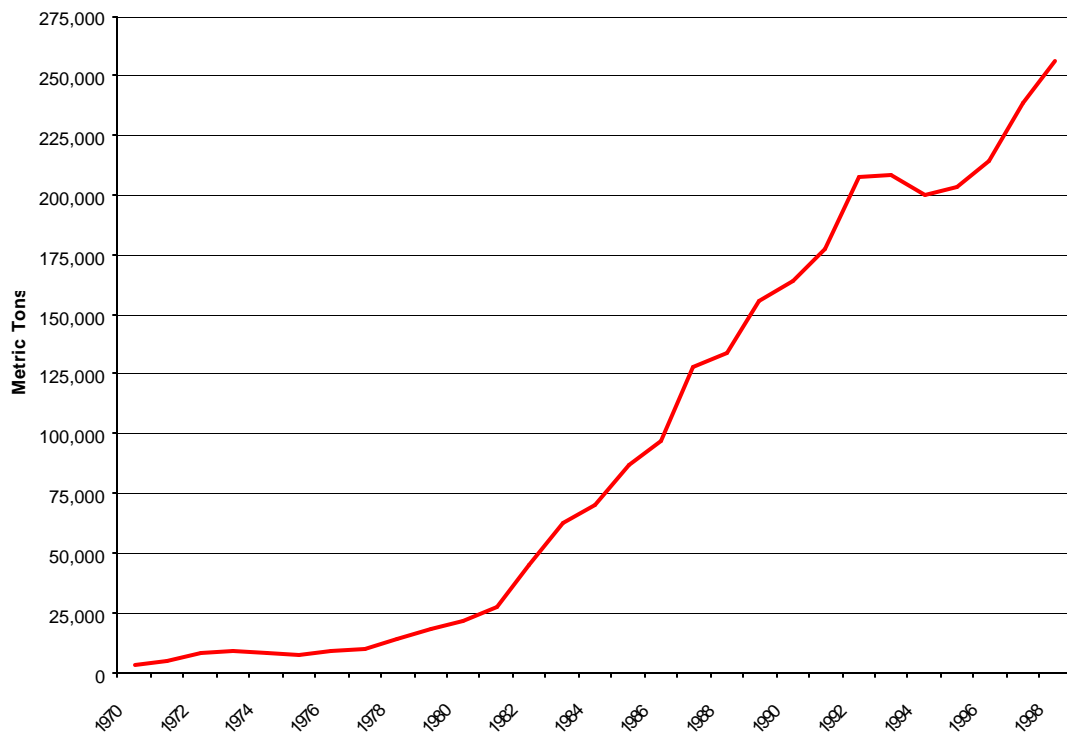


Figure 9: Processed Catfish, round weight in mt

Source: Own calculation based on data from USDA

The average annual increase in processed catfish between 1981 and 1992 was 20.2% per year.

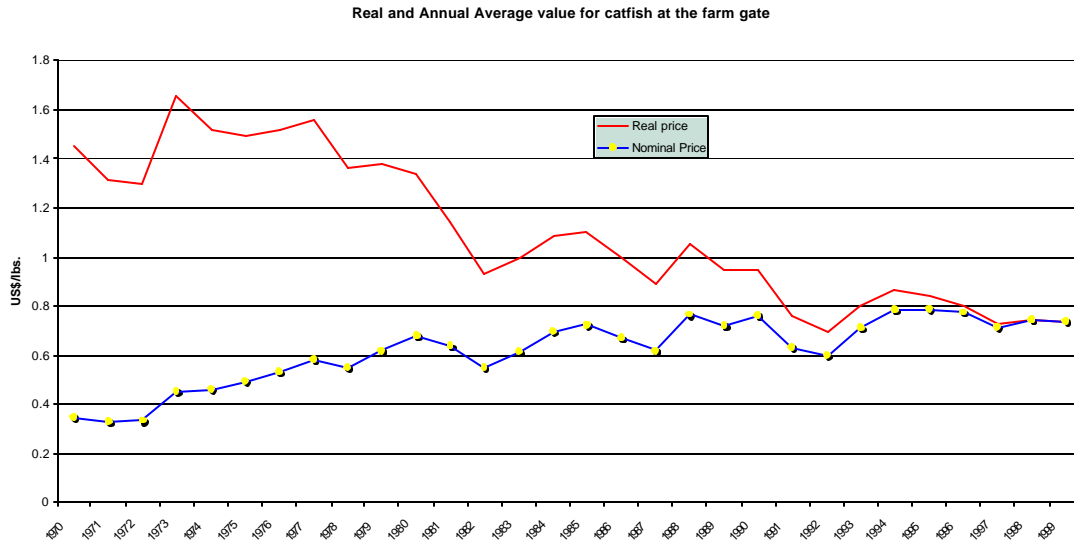


Figure 10: Real and Nominal Annual Average Values

Source: Own calculations based on data from USDA Aquaculture Outlook reports

The real price in Figure 10 is found by inflating the nominal price using the consumer price index with 1998 as the base year. Decreasing real prices, as shown in Figure , do not indicate decreasing profitability in catfish farming over the years. Stocking densities in catfish ponds have increased at least threefold over the period. Improvement in disease control, selection of brood stock and improvements in live-haul fishing have all contributed to maintain profitability in catfish farming.

The catfish industry in the United States is characterized by many small producers, and few, but large, processors. Farmers usually sell their products locally, and directly to the prospective buyers. That is, there is no central auction market for catfish. The structure of the industry has given rise to concerns about monopsony power on behalf of the producers.

Summary of total supply on the U.S. market for whitefish products

Overall, the total supply of whitefish products has increased over the period from 1990 - 1999 on the U.S. market. This is mostly due to an increase in domestic production of channel catfish and due to increased imports of pollock at the time when cod imports have declined sharply. Despite this increase in total supply, overall prices for cod and pollock have increased over the years. This is most likely due to market segmentation between catfish and other whitefish species, but in the past few years catfish has increased its presence in traditional whitefish markets. Hence, one might expect to find some kind of market integration between catfish and other whitefish, as well as integration between wild whitefish species such as cod and pollock, and between the traditional whitefish species, such as cod, haddock, pollock and ocean perch.

Statistical Sources and Selection of Time Series

In applied research, one of the most challenging tasks is to collect *quality* data for statistical analysis and hypothesis testing. Indeed, low quality of data, or lack of data, is often cited as the primary reason for low statistical power of data analysis or for theoretical inconsistencies. Fisheries data is no exception from that (Cross 1991). Fisheries data are collected at an international level, as well as within national boundaries. The Food and Agricultural Organization of the United Nations (FAO) has for several decades collected data on primary fisheries production as well as trade with fisheries products (FAO 1998). These data are only available on an annual basis, and are generally only available with a two-year lag. This constrains timely analysis for seafood products, and since the FAO database is the only international database, it leaves the researcher with national databases to estimate demand and supply relationship in trading between countries. This gives rise to other problems of inconsistencies in data reporting and coding, differences in time period of reporting, due to time spent in transit, etc. As Schrank (1994) describes, there used to be great discrepancies in United States import data and Canadian export data. By the late 1980s, these differences amounted to \$10.2 billion worth on annual basis (Anonymous 1994).

These same discrepancies led the United States and Canadian governments to substitute export statistics with each other's import statistics. This means that from January 1990 Canadian export statistics are substituted by the United States import statistics and the United States export statistics are in reality the Canadian import statistics.

In general, import trade data are believed to be better than export data. This is due to the fact that historically tariffs have been collected based on import data. Governments have therefore put resources into collecting data on imports in order to be able to collect the tax and tariff revenues. This point of view can be found in Cross (1991) and Schrank (1988). Research done by the Quality Assurance branch of the U.S. Census Bureau confirms this point of view (Anonymous 1994).

The International Harmonized System of Commodity Classification (HS)

The United Nations developed their Harmonized System of Commodity Classification (HS) for traded goods in the late 1980s. This system was fully implemented in the United States between 1988 and 1989.

HS codes are 10 digit codes, where each level of digits has specific meaning. There are 99 different chapters under the HS classification system. Fresh, live and frozen fisheries products are found in chapter 3, some processed fisheries products are found in chapter 16. This study deals with fresh and frozen fisheries products. Figure 11 shows the structure of the Harmonized Tariff Schedule for the United States (Anonymous 1998), a 10-digit HS code, abbreviated HTSUSA. Appendix A shows the different trade codes for seafood products and the dates they are in effect.

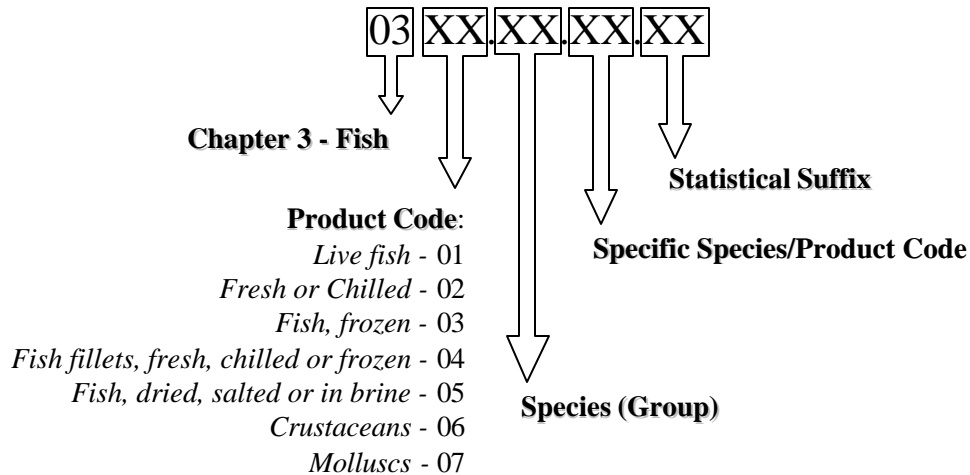


Figure 11: The Structure of the HTSUSA code

The first two numbers of the code indicate the main chapter. The second two numbers indicate the product form. For fisheries products this means live, fresh, chilled or frozen, preserved, processed (including fillets, minced or meat of fish) and finally, crustaceans or mollusks. The third and fourth pair of numbers indicates species, or broad species group and specific species and/or product code. An example is the code 0302.50.00.XX, which is read, fish (03), fresh or chilled (02), cod (50). In this case, cod means several species of cod (*Gadus morhua*, *Gadus ogac*, *Gadus macrocephalus*). The last pair of numbers is a statistical suffix used to further identify different product forms and species. Continuing with the example above, we add the number 10 for Atlantic cod (*Gadus morhua*) and the number 90 for other cod. Hence, the code for fresh or chilled Atlantic cod, excluding fillets, is 0302.50.00.10. It is important to notice that there is no consistency between different product categories and species codes. As an example, the code 0303.50.00.00 is not whole frozen cod, but rather whole frozen herring.

Time Series Selection

The implementation in 1990 of the Harmonized Schedule of Tariff codes means that there are inconsistencies in the reporting of import data reported between 1980 and 1999. Imports of frozen cod products is one example of how the HS codes made the reporting more specific by species and product forms.

This change in the HS code gives a much more detailed description of individual product forms, allowing to specify between Atlantic cod and other cod species, as well as Atlantic salmon from other salmonid products. Hence, the decision was made to use monthly data from 1990 through June 1999, or nine and half years' worth of data. The time series selection is based on the HTSUSA codes and is described in more detail in individual sections to follow.

Whitefish Market Analysis Literature Review

In the 1980s, seafood markets received relatively little attention within the fisheries economic literature (Wessells and Anderson 1992). Early papers on fisheries markets from that era include Bell (1968), Nash and Bell (1969), Gates (1974), and Bockstael (1977). Bockstael's paper was the most comprehensive work on seafood demand analysis at the time. In her work, she estimated demand and supply functions for import of frozen groundfish products by the U.S., U.S. fresh and frozen groundfish products, and U.S. wholesale and retail demand for groundfish products. Her findings concluded that the import demand for frozen groundfish fillets (other than blocks) was affected by import prices, the domestic wholesale price and the inventory status. On the supply side, she found that export prices in the U.S. and Germany affected supply, as well as the world landings variable. Bockstael suggested that U.S. and European markets for groundfish products were related.

Studies in the 1980s that focused on import demand for groundfish products in Europe or the U.S., include Tsoa *et al.* (1982), Crutchfield (1985), Felixson (1986), Schrank *et al.* (1987), Cheng and Capps (1988), Arnason and Felixson (1992) and several papers in a book edited by Schrank and Roy (1991). These papers show that imports of groundfish species play a major role in the price formation of groundfish products on the U.S. market. Import demand for specific products was found to be elastic. Demand for individual product groups, by country of origin, was also found to be more elastic than aggregated demand for all imports. It is frequently mentioned in the papers that data problems (shortage and poor quality of data) constrained the research, and hence the power of statistical tests for individual equations was low (Schrank *et al.* 1990, Cross 1991). In general, the findings were that demand for seafood was relatively little affected by prices of other food proteins, though some substitutability was found between meat and seafood products. The income effect was usually positive and significant, and consumption positively related to increase in per capita income. Most of the data used in these analyses ranged from 1970 through the latter part of the 1980s, and was on a quarterly or monthly basis. These papers used a system of simultaneous supply and demand equations, estimated with least squares methods.

In the 1990s, researchers turned to cointegration analysis in addition to traditional demand and supply analysis of groundfish products. Among cointegration studies on groundfish products are Gordon *et al.* (1993), Hannesson (1994a), Hannesson (1994b), Gordon and Hannesson (1996), Vassdal (1996), Asche and Hannesson (1997a,b), and Asche (1997). Gordon *et al.* (1993) found that price formation for high value species, such as salmon, is independent of groundfish species on the Rungis market in France. They also found that salmon prices were independent of the turbot price, another high value species often used as substitute in salmon demand studies. They suggested using cointegration analysis to construct future market demand models, in order to avoid misspecification errors. Gordon and Hannesson (1996) found a weak long-term relationship between prices of individually frozen cod fillets exported to the U.S. and Europe, by Iceland, Canada and Norway, but no

short-term relationships. They found no cointegration between the European and the U.S. fresh cod market.

Hannesson (1994a,b) and Asche and Hannesson (1997a,b) examined the cointegration among groundfish species in more detail. Hannesson found that block fillets were cointegrated with fillets exported to Europe. Hannesson also found that cointegration between species and products within the U.S. market was only found among block products, nearly homogeneous whitefish products. He confirmed the common notion that there are two markets for groundfish fillets in the U.S., a high-value individual frozen fillet market, and a lower-value block fillet market. Asche and Hannesson (1997b) found stronger evidence of a global market for whitefish products within product groups rather than within species groups. They still found no cointegration between groundfish and salmon.

Statistical Analysis of Time Series

Time-series analysis has developed as an important field within economics, and econometrics, over the past 50 years (Pesaran and Smith 1998). With improved theoretical knowledge, more computing power and constantly growing databases, econometric analysis is better suited to provide information to policy makers and other decision makers in today's information-centered economy.

Over the past twenty years, a new methodology for analyzing and diagnosing time series has been developed. This methodology depends on two statistical test procedures, unit-root tests and cointegration tests. With this new methodology, the researcher can test for direct *economic* relationships between two, or more, time series. This is different from the standard diagnostic tests, which test for deficiencies (autocorrelation, heteroscedasticity, etc.), or misspecification in the *econometric* model itself (McKenzie 1997). The popularity of the new methodology of cointegration testing is hypothesized by McKenzie to be the direct link to economic theory and availability of the tests in today's powerful econometric packages.

One of the problems in estimating a model of the U.S. groundfish market has been model specification, i.e. which products (goods) to include in each equation (Arnason and Felixson 1992, Felixson *et al.* 1987). Cointegration is a tool to assist in the selection of goods to construct an import demand model for the U.S. groundfish market. The objective is to be able to eliminate goods that do not have long-term economic effects within the model, hence being able to minimize the number of variables needed to estimate U.S. demand for any particular species of groundfish.

Cointegration is a useful tool to test if a long-run relationship between prices of products exist. Such a relationship implies that the products are substitutes in the marketplace, or the two products complement each other. If the products are in the same market, the price of each one cannot increase without affecting the other. However, the prices do not need to be the same. A price difference due to quality difference could exist, but price *changes* are the same for the two products.

Market Integration

To provide the intuition behind price-founded definitions of a market, we have in Figure 12 sketched two market equilibriums, where the prices are normalized to be identical initially. Assume then that there is a supply shock in market 1 that shifts the demand schedule to $S1'$. The price is then reduced while the quantity increases. What happens in market 2 depends on the degree of substitution by the consumers. If there is no substitution, price and quantity are not affected. If the goods are perfect substitutes, the demand schedule in market 2 is shifted down to $D2'$, and the relative price between the two markets (goods) remains constant. This is often known as the Law of One Price (LOP). If the goods are imperfect substitutes, the demand schedule in market 2 is shifted somewhat down, and the price and quantity is reduced. The strength of the influence of the shock in market 1 on market 2 is normally measured by the cross-price elasticities.²

However, one can also look at the effect of the supply shock from the price space only. When the supply curve in market 1 shifts, the price changes. This can then have three types of effects for the price of the other good. If there is no substitution effect, the demand schedule does not shift and there is no movement in the price. If there is a substitution effect, the demand schedule shifts down, and the price shifts in the same direction as the price of the first product did. At most, the price of the other product can shift by the same percentage as the price of the first product, making the relative price constant so that the Law of One Price (LOP) holds.³

² Please also note that the same story can be told based on a demand shock, but where it is the producers that potentially adjust their supply.

³ For completeness one should also mention that if the demand schedule in market 2 shifts upwards, the two goods are complements.

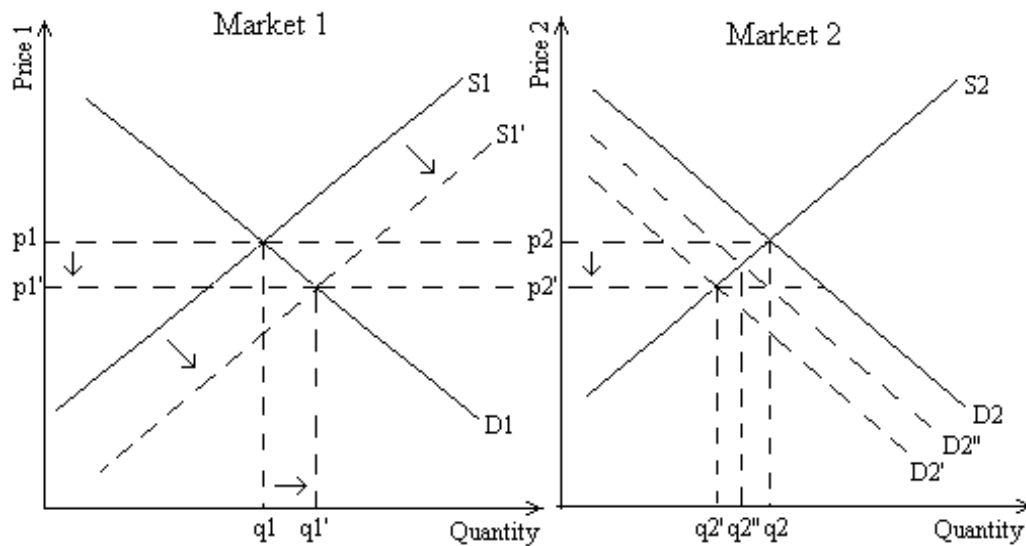


Figure 12. The effects on prices of a positive shift in the demand for Good 1 on the market for Good 2, when the two goods are perfect substitutes.

Our hypothesis then is that if groups of groundfish prices are cointegrated, then they are in the same market. If they are perfectly cointegrated then they are perfect substitutes. Thus, we investigate the cointegration of groundfish products are the import/wholesale market level, and also at the exvessel market level.

Cointegration Analysis: Review of the Theory

"..as an intermediate step a cointegration analysis is a useful tool in the process of gaining understanding of the relation between data and theory, which should help in building a relevant econometric model." Johansen, (1995), page 8

Overview of Theory and Methodology for Cointegration Analysis

It is easy to fall into the trap of spurious regressions when analyzing time series data. Time series tend to increase over time, and regular regressions might indicate relationships between two economic variables, when in fact no relationship exists (see Maddala and Kim 1998, p. 28). Using different functional forms for the regression can circumvent some of the problems. However, when dealing with multivariate regressions, it becomes very difficult to isolate the effects of individual variables (products) in the regression. Cointegration offers a powerful test, yet simple to execute in modern econometric packages, to determine which time series have a long-run relationship.

In order to analyze time series for cointegration, there are two basic steps. First, one must test for non-stationarity in the time series. Second, one must use statistical tests to detect different levels of integration between variables. The time series must be non-stationary in levels in order for cointegration to exist between two, or more, time series.

A process is said to be stationary when the mean, variance and covariance do not change over time. This means that, given any disturbance to the time series, it will tend to adjust to a long-run mean and variance. The original time series is defined as being *at level* implying that the time series is without any difference or lag operators. **Error! Reference source not found.** shows typical stationary processes and non-stationary processes at level. The broken line is non-stationary since it diverts from the mean. The solid line is stationary since it fluctuates around its beginning value.

Figure 13 shows the first difference ($\Delta x_t = x_t - x_{t-1}$) for both time series from **Error! Reference source not found.**¹⁴. Both of these series are stationary in first difference, since the difference values fluctuate around a mean.

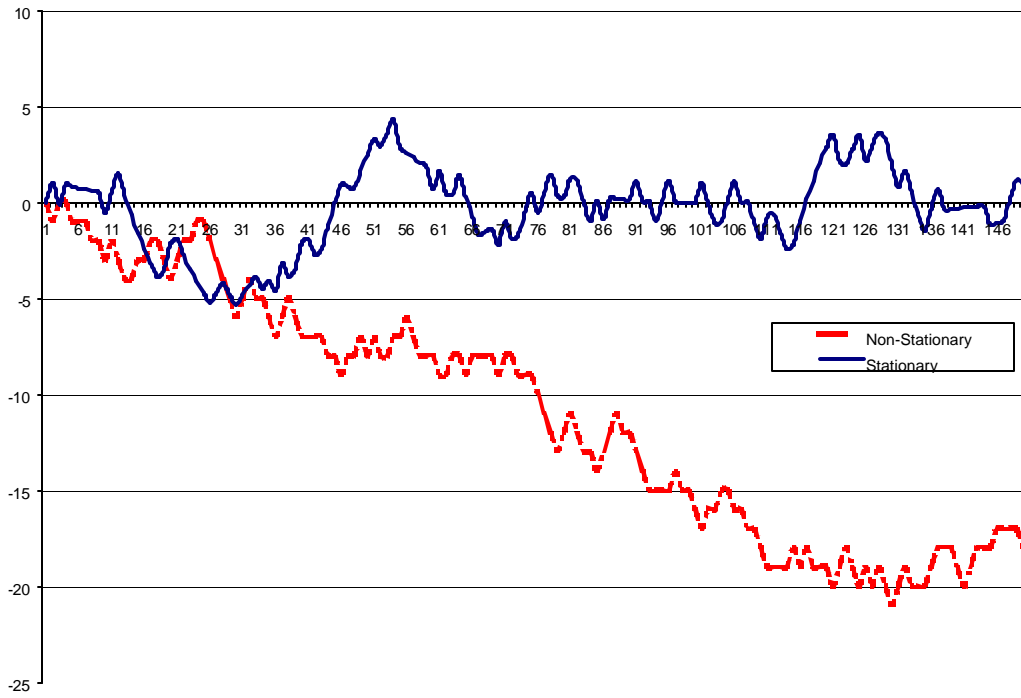


Figure 13: Example of Stationary and Non-Stationary processes

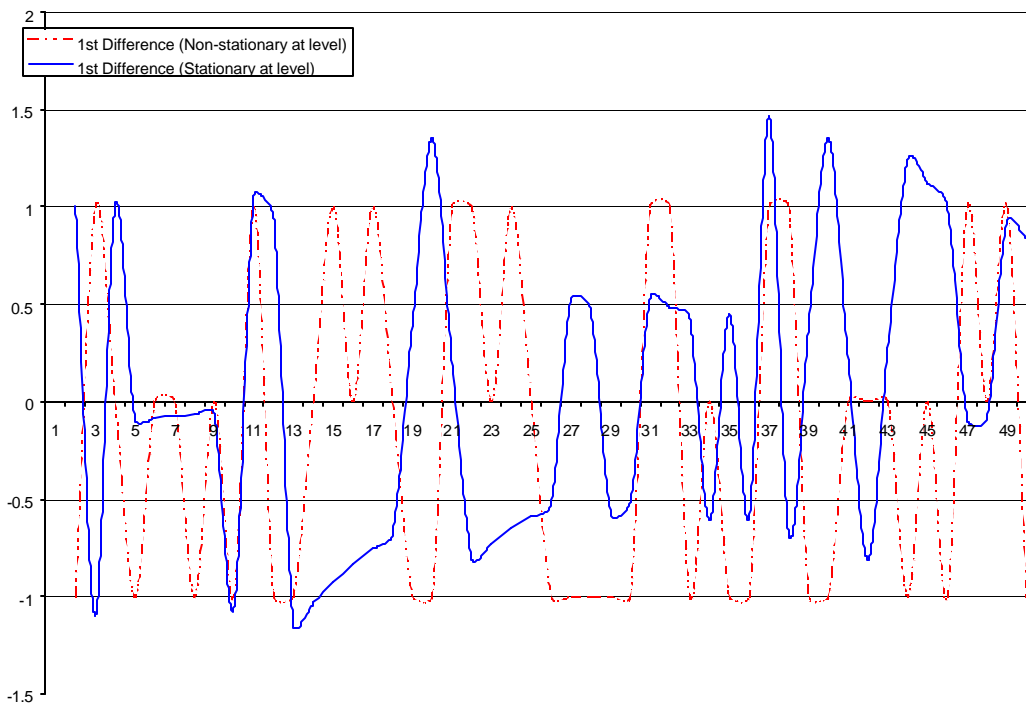


Figure 14: First difference is stationary for both series.

Mathematically the series above are defined as⁴:

$$(1.1.1.1) \quad \begin{array}{ll} x_t = x_{t-1} + e_t & \text{Non-stationary} \\ y_t = \rho \cdot y_{t-1} + u_t \text{ where } \rho < |1| & \text{Stationary} \end{array}$$

where e_t and u_t are pure-white noise disturbance terms, assumed to be independently and identically distributed, x_t and y_t are time series and ρ is the autocorrelation factor. The non-stationary series, x_t , is obviously a special case of y_t , i.e. when $\rho=1$. This special case is also known as the unit root case, or pure random walk. Each observation can be substituted by the initial observation, and the error term, to obtain:

$$(1.1.1.2) \quad \begin{array}{l} x_t = x_{t-1} + e_t = [x_{t-2} + e_{t-1}] + e_t = [x_{t-3} + e_{t-2}] + e_{t-1} + e_t = \dots \\ x_t = x_0 + \sum_{i=0}^{t-1} e_{t-i} \end{array}$$

The time series is then expressed as the initial value plus the sum of all past disturbances. Hence, as $t \rightarrow \infty$, the value of $x_t \rightarrow \pm\infty$. In other words, the value of x_t drifts away from its original value x_0 .

For the stationary time series we obtain, by similar substitution:

$$(1.1.1.3) \quad \begin{array}{l} y_t = \rho y_{t-1} + u_t = \rho[\rho y_{t-2} + u_{t-1}] + u_t = \rho[\rho y_{t-3} + u_{t-2}] + \rho u_{t-1} + u_t = \dots \\ y_t = \rho^t y_0 + \sum_{i=0}^{t-1} \rho^i u_{t-i} \end{array}$$

The importance of ρ is seen by examining equation (1.1.1.3). If $\rho=1$, we have the special case of non-stationary time series. If $-1 < \rho < 1$, then the importance of observations in the past declines by the power of t . Hence, the value of y_t tends to revert towards the original value, and any disturbances, or innovations, and the error term fades away over time, or the time series is stationary. The value of the ρ coefficient tests for non-stationarity.

One way to test for non-stationarity in time series is to use the Augmented Dickey-Fuller (ADF) test (Dickey and Fuller 1981). The ADF test is, in essence, a simple ordinary least squares (OLS) regression. The first difference in the time series is the dependent variable. An intercept, first lagged variable of the same time series and k lagged variables of the first difference are independent variables, or (Dickey and Fuller 1979, Gordon *et al.* 1993):

⁴ This discussion follows Maddala and Kim (1998) closely.

$$(1.1.1.4) \quad \Delta x_{it} = \beta + \rho x_{i,t-1} + \sum_{\gamma=1}^k \alpha_{\gamma} \Delta x_{i,t-\gamma} + \varepsilon_t$$

where $x_{i,t}$ is the i -th time series for the t -th time period, Δ is the difference operator, k is the number of lags, \mathbf{a} , \mathbf{b} , \mathbf{r} are parameters to be estimated, and ε is the error term. The null-hypothesis is that the series is non-stationary, i.e. that $\mathbf{H}_0: \mathbf{r} = 0$, against the alternative that \mathbf{r} is less than zero. Dickey and Fuller (1979, 1981) showed that the \mathbf{r} parameter can be tested using a standard t-statistic of the null hypothesis of non-stationary process versus the alternative hypothesis that the process is stationary. The t-statistic must be compared to a non-standard critical value, tabulated by Dickey and Fuller (1981). The number of lagged variables to be used can be determined by minimizing the Akaike Information Criterion (AIC) from the estimation. The AIC minimizes the following function, for a standard regression equation $\mathbf{Y} = \mathbf{X}\mathbf{b} + \mathbf{e}$:

$$(1.1.1.5) \quad AIC_{(R\beta=0)} = \ln \frac{y' M_1 y}{T} + \frac{2K_1}{T},$$

where y is the endogenous variable, T is number of observations, M is the idempotent matrix $I - X(X'X)^{-1}X'$, R is a matrix that contains imposed restrictions and K is the number of variables (the rank of the X matrix). By adding variables to the model different AIC statistic can be calculated. As the number of variables increases, the AIC criterion increases, but at the same time, the M matrix changes. Hence, the combination of exogenous variables that minimizes the AIC is the one that gives the best tradeoff between parsimony and precision (Judge *et al.* 1988, p. 848).

If two time series are shown to be non-stationary at a base level, but stationary in first differences (i.e. integrated of order one, or $X_t \sim I(1)$), it is possible to proceed and apply the Johansen's test for cointegration among the two time series. If the time series are found to be stationary at their base level, i.e. $X_t \sim I(0)$, cointegration does not exist between $x_{i,t}$ and any other time series, $x_{j,t}$, since any change in the autoregressive time series $x_{i,t}$, fades away over time.

Cointegrated time series do not move apart over time. This means that any innovation in one time series will eventually fade away, and the two time series will move into close proximity to each other. Hence, if time series x_t is $I(1)$, and time series y_t is $I(1)$, the two time series are said to be cointegrated, denoted $CI(1,1)$, if there exists a vector, \mathbf{a} , such that $y_t = \mathbf{a}x_t$, and $y_t = \mathbf{a}x_t$ is integrated of order $d-b$ ($I(d-b)$), where $b > 0$ (Maddala and Kim 1998/p. 26). The objective is to find a co-integrating vector \mathbf{a} which makes the time series x_t stationary.

There may be several co-integrating vectors (linear combinations of lagged variables of x_t) for a variable x_t . This means that α is a matrix rather than a vector. The Johansen cointegration test can be used to test multilevel cointegration. The Johansen test for cointegration was set forth by Johansen (1988) and Johansen and Juselius (1990) and is described more thoroughly by Johansen (1995).

By using the Johansen test for two or more different time series, the hypothesis that the time series move together can be rejected or accepted. Johansen's cointegration test, for a differenced VAR series of order p , starts with the null hypothesis that the time series can be described with the following model:

$$(1.1.1.6) \quad \Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \dots + \Gamma_{p-1} \Delta Y_{t-p+1} - Y_{t-p} \Pi + \Phi D_t + \varepsilon_t$$

where:

$$(1.1.1.7) \quad \begin{aligned} \Gamma_i &= -(I - \Pi_1 - \dots - \Pi_i), \quad (i = 1, \dots, p) \\ \Pi &= (1 - \Pi_1 - \dots - \Pi_k) \end{aligned}$$

Γ is the coefficient matrix for the i th VAR series, D_t is the deterministic trend, Φ is a coefficient to be estimated and Π is the impact matrix (Davidson and Mackinnon 1993). If the first difference of Y_t is stationary, by assumptions, all the other terms which include the first difference must be stationary. Hence, in order for the whole model to be stationary, the series Y_{t-p} must be stationary, or the impact matrix Π contains vectors that will force the term Y_{t-p} to be stationary. Johansen's test estimates the Π matrix in unrestricted form and tests whether the restrictions imposed by the reduced rank of Π can be rejected. Reduced rank of Π implies that there are two matrices of dimension $p \times r$, call them \mathbf{a} and \mathbf{b} , such that $\Pi = \alpha\beta'$, where r is the rank of the impact matrix. The rank of the impact matrix, r , determines the number of cointegration relations among the time series that are being tested. By adding different linear restrictions on the model in (1.1.1.6), there are several possible alternative hypotheses.

Johansen (1995) summarized five alternative hypotheses that can be tested using specific test procedure. The hypotheses are nested from the least restrictive to the most restrictive, in terms of linear restrictions on the cointegration equations. The hypotheses are split into three different categories depending on the assumptions of trend in the data. The first category assumes no deterministic trend in the data. The second category assumes a deterministic trend and the third category assumes a quadratic deterministic trend.

The least restrictive hypothesis assumes a quadratic trend in the time series in question, and that the co-integrating equations within these time series have linear trends and intercepts, as well as a linear trend in the VAR series, or:

$$(1.1.1.8) \quad H(r) : \Pi y_{t-1} + Bx_t = \alpha\beta' y_{t-1} + \alpha\rho_0 + \alpha_{\perp}\gamma_0 + (\alpha\rho_1 + \alpha_{\perp}\gamma_1)t$$

where α and β are the cointegration matrices to be estimated, and $\alpha\beta' y_{t-1}$ is the co-integrating equation. The quadratic trend component is $\alpha_{\perp}\gamma_1 \cdot t$, where γ and ρ are parameters used to decompose the deterministic trend term $D_t = \mu_0 + \mu_1 t$, such that $\mu_t = \alpha\rho_t + \alpha_{\perp}\gamma_t$, $i = 0, 1$. The linear trend component for the equation y_t is $\alpha_{\perp}\gamma_0$. The intercept for the co-integrating equation is $\alpha\rho_0$. If this hypothesis holds then there is a

drift term that allows for the time series to drift apart, over time, but still be considered cointegrated. The time series do not have the same mean.

The second hypothesis is that the data have deterministic linear trends, that both the VAR series and the cointegration equations have linear trends, and that the co-integrating equations have an intercept, or:

$$(1.1.1.9) \quad H^*(r) : \Pi y_{t-1} + Bx_t = \alpha \beta' y_{t-1} + \alpha \rho_0 + \alpha_{\perp} \gamma_0 + \alpha \rho_1 t$$

This hypothesis differs from equation (1.1.1.9) only in the term $\alpha_{\perp} \gamma_1 \cdot t$, the quadratic trend component. Hence, this hypothesis does not allow for the time series to drift apart.

The third hypothesis also assumes a deterministic linear trend in the data, but no linear trend in the co-integrating equations or the VAR series. The co-integrating equations and the VAR are assumed to have a constant, or:

$$(1.1.1.10) \quad H_1(r) : \Pi y_{t-1} + Bx_t = \alpha \beta' y_{t-1} + \alpha \rho_0 + \alpha_{\perp} \gamma_0$$

The fourth hypothesis assumes no deterministic trend, and no trend in the cointegration equation or the VAR series. It does assume a constant term in the cointegration equation, or:

$$(1.1.1.11) \quad H_1(r) : \Pi y_{t-1} + Bx_t = \alpha \beta' y_{t-1} + \alpha \rho_0$$

The fifth, and final hypothesis, is the most restrictive one which assumes no deterministic trend in the data, no trend in either the cointegration equation or the VAR series, and no constant terms, or:

$$(1.1.1.12) \quad H_1(r) : \Pi y_{t-1} + Bx_t = \alpha \beta' y_{t-1}$$

Hence, if cointegration is not rejected under this final hypothesis then there is a relationship between the time series in question, in such a way that a change in each time series will directly influence other time series, by fixed proportions, where the \mathbf{b} vector describes the long run relationship between equations and the \mathbf{a} vector measures the adjustment to past equilibrium errors (Johansen 1995 p. 71).

The null hypothesis is that the number of co-integrating equations is r versus the alternative hypothesis that it is k (i.e. full rank). The restrictions for the five tests are summarized in Table3.

Table 3: Summary of alternative hypotheses and the implied restrictions.

Hypotheses	Deterministic trend in data	Linear trend in CE	Constant in CE	Linear trend in VAR series
$H(r)$	Quadratic	Yes	Yes	Yes
$H^*(r)$	Linear	Yes	Yes	No
$H_1(r)$	Linear	No	Yes	Yes
$H_1^*(r)$	No	No	Yes	No
$H_2(r)$	No	No	No	No

The hypotheses are tested using the trace test (a Likelihood Ratio test statistic):

$$(1.1.1.13) \quad Q_t = -T \sum_{i=t+1}^k \log(1 - \lambda_i)$$

where T is the number of observations, k is the rank of the impact matrix, and λ is the eigenvalue for the i -th data series.

When performing cointegration tests, one can either assume one of the five hypotheses above (based on economic and/or statistical criterion), or test all five by fixing the rank (or the number of cointegration vectors) and test which series have the best statistical outcome.

By comparing the five hypotheses it is possible to find a “weak” or “strong” form of cointegration. Hence, if cointegration is found under hypothesis five, but no cointegration is found under hypothesis one, then it is possible that the time series are cointegrated, but the effect will be relatively low. However, if cointegration is found under hypothesis one, then there is a strong relationship among the time series that are being tested.

"Pitfalls" in Using Cointegration Analysis for Time Series

Since Granger's original introduction of cointegration analysis and the introduction of Johansen's test, cointegration analysis has become popular and is used extensively in economic analysis (McKenzie 1997). During the past two years, increasing criticism has surfaced on the general idea of using cointegration, as well as criticism of the specific test used in cointegration analysis.

Gonzalo and Lee (1998) summarize the shortcomings by defining two types of pitfalls for cointegration analysis. These pitfalls are defined as “...[A Type-A pitfall exists if] the size of a test for the null hypothesis of no cointegration approaches one asymptotically”, and

“.....[A Type-B pitfall exists] if the power of a test for the null hypothesis of no cointegration tends to zero under the alternative of cointegration.”

The degree of integration and number of lags selected is very important in order to avoid pitfalls. To avoid type A pitfalls, Gonzalo and Lee suggest using both Engel-Granger and LR tests. If these tests yield conflicting results, detailed analysis is required. This could include tests for different trends and making corrections to the second level error correction model.

Another method to avoid type-A pitfalls is to use modified critical values, as suggested by Cheung and Lai (1993). Cheung and Lai used response surface analysis to approximate the finite sample properties of Johansen’s cointegration test. Their findings suggest that a scaling factor should be used in order to correct the critical values for the likelihood ratio test in equation (1.1.1.13). The scaling factor is:

$$(1.1.1.14) \quad SF = \frac{T}{T - nk},$$

where T is the number of observations, n is the number of variables in the cointegration equations, and k is the number of lags. As T goes to infinity, the scaling factor moves towards 1.

Singularity or near singularity causes Type-B pitfalls, especially when there is dynamic mis-specification of the model. This type of error is difficult to deal with and requires analysis of the eigenvalues of the covariance matrix of the residuals.

The Law of One Price and Cointegration

Before the profession became concerned with the statistical problems raised by the nonstationarity of prices, the LOP was tested by running the regression

$$\ln p_t^1 = B + A \ln p_t^2 + e_t \quad (4)$$

thus testing whether equation (4) reduces to equation (1) by testing the null hypothesis $H_0: A=1$. However, if the price series are nonstationary, normal inference is not valid on the parameters in equation (4) (Engle and Granger, Ardeni), and therefore, one cannot test the LOP by running this regression.⁵

⁵ One might, however, impose the restriction that $B=0$ and $A=1$, and test the difference of the two prices for stationarity (Baffes). If the strict version of the LOP holds, this difference should be stationary.

However, if the data series are integrated of the same order, equation (4) can be used in Engle and Granger's two-step procedure to test for cointegration.⁶ As the parameter estimates in equation (4) are (super) consistent, equation (4) provides estimates of the long-run relationship, *i.e.*, the parameters in the cointegration vector (1,-A). Cointegration can thus be tested by testing the residuals from equation (4) for stationarity. This is usually done with Dickey-Fuller tests (Dickey and Fuller).

As noted above, normal inference is not valid on the parameters in equation (4) if this is a cointegration relationship. Because the Engle and Granger test has been the main tool in testing whether there is a relationship between nonstationary data series, one has not been able to test the LOP. However, it is well known that many of the problems associated with the Engle and Granger test can be avoided if the Johansen test is used (Johansen). In particular, because the Johansen framework also allows hypothesis testing on the cointegration parameters (Johansen and Juselius, 1990), one can test for the LOP with nonstationary data. A much discussed problem in the LOP literature is the endogeneity problem caused by the fact that prices are simultaneously determined. However, the Johansen test is carried out in a Vector Auto Regressive (VAR) model, which is a reduced form. Hence, a nice feature of the Johansen test in this context is also that this simultaneity problem is avoided. We will comment further upon the Johansen test in the next section.

Because cointegration implies that there is a linear long run relationship between the data series in question, it might be interpreted as a test that the parameter $A \neq 0$. If $A \neq 0$, the price series are cointegrated and there is a long-run relationship between the price series. If both price series are nonstationary and $A=0$, the residuals must also be nonstationary, and the price series are not cointegrated. Hence, cointegration tests for market integration are only tests of whether there is a statistically significant linear relationship between different data series.

At this point one might ask ‘why are we interested in cointegration? What can it do for us?’ Cointegration can tell us quite a lot when it is put into context with the Law of One Price. Analysis of relationships between prices has a long history in economics, and many market definitions are based on the relationship between prices. For instance, in a book first published in 1838 Cournot states: “It is evident that an article capable of transportation must flow from the market where its value is less to the market where its value is greater, until difference in value, from one market to the other, represents no more than the cost of transportation” (Cournot, 1971). While this definition of a market relates to geographical space, similar definitions are used in product space, but where quality differences play the role of transport costs (Stigler and Sherwin, 1985; Sutton, 1991). The main arguments for why this is the case, are either arbitrage or substitution.

*Cointegration Analysis of Imported Seafood Prices*⁷

⁶ Nonstationary data series are labeled after how many times they have to be differenced to become stationary. A data series integrated of order one, denoted $I(1)$, has to be differenced once to become stationary.

⁷ This discussion is taken entirely from Gudmundsson (2002).

The purpose of this section is to provide a statistical analysis of time series on imports of seafood products. Figure 15 shows a graphical overview of the upcoming hypotheses tested. The hypotheses are somewhat nested. Hypothesis A states that all selected fisheries products are in the same market, and as a group compete with other protein. The selected fisheries products are: cod, turbot, pollock, flounder, haddock, shrimp, hake, salmon, whiting, catfish, ocean perch, and sole (all frozen). If this holds true, shrimp, fillets of groundfish, fillets of salmon and fillets of catfish all compete, or complement each other on that market.

Hypothesis B narrows the market down to fillet products of the following finfish species (again frozen fillets): cod, haddock, hake, ocean perch, pollock, whiting, flounder, halibut, sole, turbot. Hypothesis C narrows the market even further down and tests if the market for different products, by roundfish species and then by flatfish species, can be regarded as a separate market segment. The group of frozen groundfish include: frozen cod blocks of fillets, haddock fillets, haddock blocks of fillets, ocean perch fillet, pollock fillets, pollock blocks of fillets. The frozen flatfish species are: flounder blocks of fillets, flounder fillet, halibut, sole blocks of fillets, sole fillet, turbot blocks of fillets, turbot fillet. Finally, Hypothesis D maintains that all individually frozen cod fillets from different import sources compete in the same market, including cod from Canada, Norway, Iceland, and Other. All of these hypotheses are tested for cointegration among the prices of the different products.

Critical values for Johansen's test are scaled using a scaling factor suggested by Cheung and Lai (1993). This is done in order to avoid type-A pitfalls.

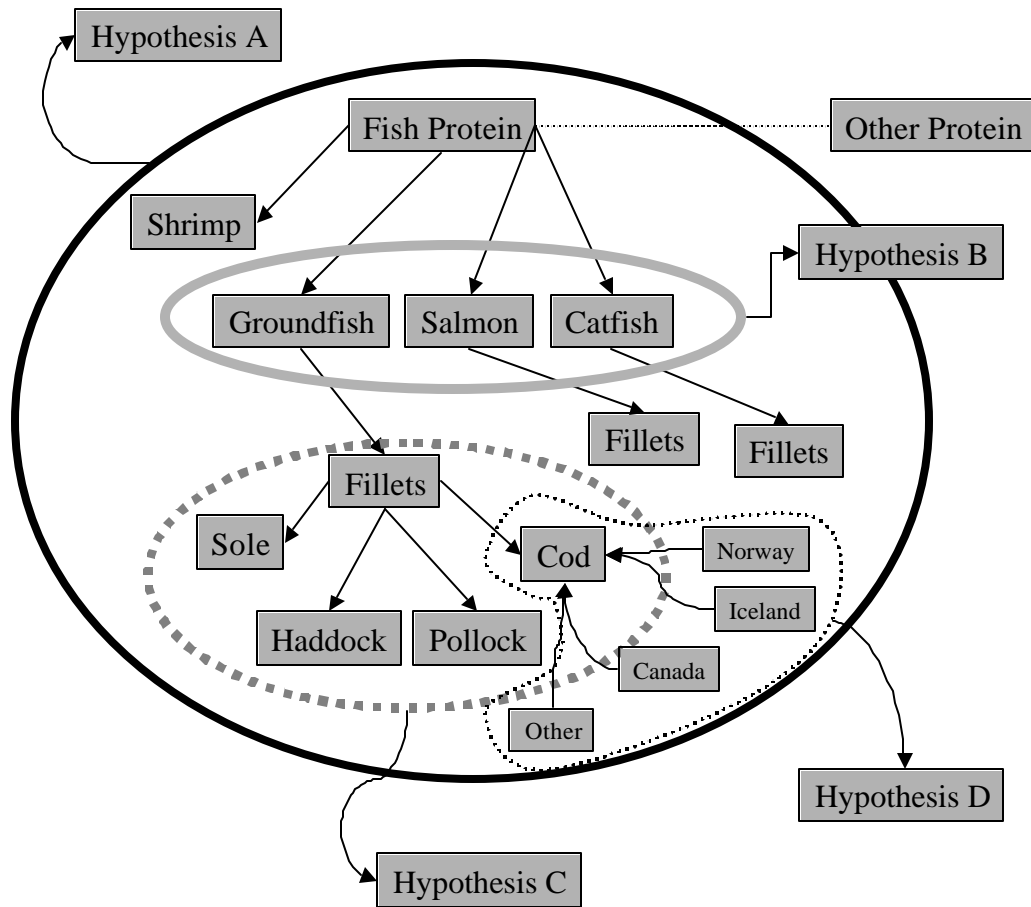


Figure 15: Overview of hypothesis testing

Testing hypothesis A

The first step is to establish a link between the different species imported into the United States. In order to do so several species are aggregated to include major commodities within each group. Groundfish (roundfish and flatfish) products are sold to the retail consumer as frozen fillets or portions, while species like salmon and catfish are sold as whole frozen fish, steaks, or fillets. Finally, the majority of exported whitefish products from Iceland are sold as frozen fillets.

Traditionally, the fisheries marketing literature assumes that shellfish species and/or crustaceans are marketed in a separate market segment from finfish. Preparation methods are also found to be a factor for determining in which market segment the product is sold.

Average values (U.S.\$/kg, from now on simply called price) for whitefish species that have the highest volume in landings and imports, are selected and tested for equality of means, correlation and cointegration. Shrimp is also tested, since it is the most important crustacean. Finally salmon and farmed catfish are included as both have increased their

share of total finfish consumption. The time series start in January 1990 and end in June 1999. If this holds true, shrimp, fillets of groundfish, fillets of salmon and catfish all compete, or supplement each other on the market for fish proteins.

Table 4: Major U.S. species categories by U.S. harvest and imports

Source: NMFS, Fisheries of the United States, 1999.

Species Group	
COD	TURBOT
POLLOCK	FLOUNDER
HADDOCK	SHRIMP
HAKE	SALMON
WHITING	CATFISH
OCEAN PERCH	SOLE

The procedure described above is used to find cointegrating vectors between the different time series to test first hypothesis, hypothesis A, that all of the price series of products from the species in table 4 are products in the same market. This is known as the Law of One Price, where all prices must be equal up to a factor of proportionality, after accounting for transaction costs (Asche *et al.* 1998).

Results of hypothesis A

All time series were found to be non-stationary with a constant and a time trend variable included in the regression equation when using the ADF test. However, the number of lags used for each time series differed. Non-stationarity was rejected when no lags are used. Most of the time series were non-stationary when three lags were used.

Cointegration was tested using 3-month lags for all species above except ocean perch and turbot. Using more than 10 variables in the cointegrating process causes difficulties with many econometric computer packages. Cointegration was found between salmon and most other species. This is not in line with the findings from Gordon and Hannesson (1996), Hannesson (1994a,b) and Asche and Hannesson (1997a, b) for their studies of Europe. However, salmon has been aggressively marketing in the U.S. and is being marketed in fillets and steak forms. With the decline in salmon prices to very low levels, it should not be a complete surprise that prices for salmon and prices for groundfish are competitive.

Otherwise, we reject the cointegration of the prices of the products listed in Table 4, indicating that Hypothesis A is rejected.

Testing hypothesis B

To investigate if there is any cointegration among only the whitefish species, when shrimp, salmon and catfish are excluded, ten time series are tested using Johansen's cointegration test. Hypothesis B narrows the market down to fillet product of finfish species and excludes shrimp.

Results from hypothesis B

As before, non-stationarity was found using different lag lengths. Cointegration was tested with 3-month lag lengths. When adjusted for the critical values, the cointegration tests should that no co-integration can be found; at best.

The bivariate test reveals that cointegration is found among most of the whitefish species, although these test results do not hold among a group of prices. The hypothesis that as a group all whitefish species belong to the same market is rejected at the 95% confidence level. This means that when aggregated over all products and species, the time series do not display a common trend, and demonstrate no, or at most weak, economic relations between the species, as a group. This does not, however, suggest that there are no relationships between individual species, e.g. like cod and haddock.

Testing hypothesis C

Hypothesis C states that different products from the same species are sold on separate markets, *i.e.* there is no long-term economic relation between the different product forms, even if they are from the same species and source of exports. Hypothesis C narrows the market even further down and tests if the market for different fillet products, by groundfish species, can be regarded as a separate market segment.

Results for hypothesis C - Groundfish

The products tested for cointegration are: cod blocks of fillets, cod fillets, haddock blocks of fillets, haddock fillets, ocean perch fillets, pollock fillets, and pollock blocks of fillets (all frozen).

Using three lags in first difference, all the time series except pollock fillets are stationary. Using 4 lags, pollock fillets are stationary as well. Cointegration is found between cod blocks and most other whitefish species, except ocean perch. This is in line with results from Asche and Hannesson (1997a,b) who used data for U.S. import prices between 1992 and 1996. The results for the cointegration are similar, though the data set has been expanded compared to the research done by Asche and Hannesson. It is therefore concluded that the market for whitefish products by species is cointegrated among higher value species, but not between higher and lower valued species. This once again confirms the notion of high and low value markets for whitefish products, and that there is some product differentiation among whitefish species.

Results for hypothesis C - Flatfish

The products tested for cointegration are: flounder blocks of fillets, flounder fillet, halibut, sole blocks of fillets, sole fillet, turbot blocks of fillets, turbot fillet (all frozen).

The null hypothesis that the prices are non-stationary is rejected for all time series with zero, one or two lags. One needs to include twelve lags in order for all time series to become non-stationary. However, with 110 observations the scaling factor becomes large when twelve lags are included. Cointegration analysis for flatfish and blocks is limited and is not pursued here.

Testing hypothesis D

Hypothesis D maintains that the same products, from the same species, but originating in different countries are substitutes in the same market. Consequently, this section estimates the statistical relationship between individually frozen cod fillets, by country of origin. The countries selected are Canada, Iceland, Norway and all other (includes China, Denmark, Greenland, the Faeroe Islands and other). These countries were selected based on their share of total volume imported within the product codes examined.

Results for hypothesis D

There is a price premium evident for Icelandic cod frozen fillets over the weighted average value of all other imports of frozen cod fillets by the U.S. Tests show there is one cointegrating equation, and perhaps as many as three. The hypothesis accepts at least one cointegrating equation among the four time series. A pair-wise test shows that cointegration is most likely among the Icelandic and Canadian time series. Hence, it is concluded here that these prices show a relatively strong economic relationship, as compared to results from the previous hypothesis tests.

Summary of hypothesis testing

This section started with a nested hypothesis on the segmentation of the market for seafood products. Four main hypotheses were set forth, first that all major seafood products belong to the same market. This hypothesis was rejected. The second hypothesis was that whitefish products are separate from other products, such as shrimp. This hypothesis was accepted, supporting previous research that there is one market for whitefish products. The third hypothesis stated that different product forms from different species are on the same market. This hypothesis was rejected for roundfish species, but it was not possible to perform cointegration tests for the group of flatfish species, due to the statistical properties of the time series.

The conclusion is that there is a strong long-term relationship between prices for frozen Icelandic cod fillets (Atlantic, IQF) and frozen Canadian cod fillets (Atlantic, IQF). Norway and other countries also show similar long-term relationships, though weaker. It is

therefore concluded that a reasonable model of the import demand for frozen Icelandic cod fillets only needs to include price series for Icelandic, Canadian, Norwegian, and a group of all other countries that export frozen Atlantic cod fillets to the U.S.

A word of caution is needed, however. These results are only good for the data period used, 1990 - 1999. There are also some indications that these results might not hold in the future, since aquacultured products are increasing their share in imports to the U.S. Catfish and tilapia also seem to be candidates for further competition with other whitefish species in the near future. It would be interesting to conduct this same kind of analysis in about 2-3 years, when longer data series for imported salmon fillets are available.

Cointegration Analysis of New England Exvessel Groundfish Prices

Analysis similar to that discussed above was also performed on exvessel prices of 15 groundfish species landed in four ports in New England. The fifteen species are: American plaice, cod, haddock, monkfish, ocean pout, Pollock, redfish, red hake, summer flounder, white hake, whiting, windowpane flounder, winter flounder, witch flounder, and yellowtail flounder. The four ports are Pt. Judith, RI, New Bedford MA, Gloucester MA, and Portland Maine.

We had to discontinue using data on yellowtail and widow flounder because both price series were stationary, no matter how many lags were used.

Results by Species:

With the flounder group, the prices for the various species do influence each other, but they are not perfectly integrated, indicating that the different species are imperfect substitutes. We also find that flounder prices are influenced by the price of cod, but flounder prices do not influence cod prices. Hence, the price of cod appears to be a price leader, although imperfectly because of the imperfect substitution

In fact, the price of cod has an impact on the prices of all the other groundfish, except the two species we found to be stationary, yellowtail flounder and widow flounder. There is some evidence that the prices of cod are exogenous to the formation of the prices for the other species, but only at a 10% significance level. Hence, it seems likely there is market integration consisting of all the analyzed species (with exception of the two with stationary prices). Cod is the key species in this market, and there is evidence that the cod price is often the leading price.

A difficulty working with this data is that there is a lot of 'noise' in the data, and in some cases, the data are pretty thin, particularly for those species with relatively few landings. This unfortunately results in many estimates with a relatively low degree of precision.

Results by Ports:

With imperfect substitution between most of the species analyzed, a natural question is whether this may be caused by the aggregation of prices from different ports. We therefore also investigated the relationship between the prices for different species in the four ports, and between same species across each port.

For cod, the prices in all ports influence each other, but only the markets in Gloucester and New Bedford are fully integrated, as the LOP holds only in this relationship. The price in New Bedford is exogenous in all relationships, and the price in New Bedford accordingly seems to be the leading price. With the important role of the cod price relative to the other species, the cod price in New Bedford accordingly seem to be the most important indicator in this market. However, since the substitution in many cases is only imperfect, its importance should not be overstated.

With the most price series at the harbor level the ‘noise’ in the data increase substantially giving many imprecise estimates and tests. However, in general the picture supports the conclusions above in that the prices for different species influence each other in the different harbors, and the prices in for each species in the different harbors are influenced by each other. Substitution is in general not perfect although the LOP holds in some relationships. Although the conclusion is fragile, it seems that substitution is complete mostly in relationships between prices in different harbors, but the relationships are certainly not present in enough cases to conclude that the port where the fish is landed matters.

In conclusion, even with the relatively weak results of this analysis, we can say that groundfish prices are influenced by the prices of cod. There is some cointegration among the other groundfish species, except for yellowtail and widow flounder. Therefore, estimation of the demand equations could probably proceed by using cod as the substitute species in all equations, and using the rest of the groundfish species (except yellowtail and widow flounder) as an aggregated good.

Functional Forms used in Demand Analysis

An increasing number of studies have utilized demand systems in their analysis of demand for seafood. Barten and Bettendorf (1989), Beach and Holt (2001), Burton (1992), Chiang, Lee and Brown (2001), Eales and Wessells (1999), Eales, Durham and Wessells (1997), Fousekis and Karagiannis (2001), Holt (2002), Holt and Bishop (2002), and numerous papers by Asche, are among those studies. Many of these studies focused on demand either at the retail or wholesale (import) level. A few look at demand at the exvessel level. We will examine the functional forms used, beginning with quantity or share-dependent functional forms and then briefly review the inverse demand (or price-dependent) functional form. Finally, hybrid functional forms (those that include part of one functional form and part of another) are presented. There are no conclusions to be drawn from this section other than to display the array of functional forms being used to estimate demand for seafood at various levels of the market and for various species.

Quantity or Share-Dependent Functional Forms

This section reviews the most common functional forms used in demand studies. The following discussion on the Linear Expenditure System (LES), the Translog System (TL), the Rotterdam System and the Almost Ideal Demand System (AIDS) is based on Asche and Wessells (1997), Deaton and Muellbauer (1908; 1983), Pollak and Wales (1992), Raunekar and Huang (1987), Johnson *et al.* (1984), and Klein and Rubin (1947-1948).

Traditionally the LES function has been used to estimate demand for seafood and other food products. The LES is derived from a specific utility function (Theil 1965, 1972, 1976) and has been used extensively in demand analysis over the past fifty years. The utility function has the form of:

$$(1.1.1.1) \quad U(X) = \sum_{k=1}^n a_k \log(x_k - b_k)$$

U stands for utility from a vector of n goods, called x . Lower case b stands for a minimum level, or subsistence level of consumption for any good k . Lower case a is the fixed weight of each product k in the consumers' utility function after subsistence levels have been reached. The parameter a is the weight of each individual good, and is normalized by:

$$(1.1.1.15) \quad \sum_{k=1}^n a_k = 1.$$

Given the normalization restriction, a typical demand function derived from the Klein-Rubin utility function is derived through utility maximization, subject to a budget constraint, and deriving the Marshallian demand functions:

$$(1.1.1.16) \quad x_i = h^i(P, \mu) = b_i - \frac{a_i}{p_i} \sum_{k=1}^n p_k b_k + \frac{a_i}{p_i} \mu$$

The Marshallian demand function is a function of a price vector, P (includes p_i prices), and total expenditure, μ . Equation (1.1.1.16) can also be written as a budget share equation, by multiplying the Marshallian demand functions with the price of each individual product, and dividing by total expenditure for all products.

$$(1.1.1.17) \quad w_{it} = \frac{p_{it}}{\mu} + a_i \left[1 - \frac{\sum_{k=1}^n p_k b_k}{\mu} \right]$$

The LES model was extensively used between 1950 and 1980, and well into the 1990s in food demand analysis. However, the LES model does have several constraints, and theoretical inconsistencies that make it less valuable as a measurement tool, for instance to measure the effects of changes in prices on producer and consumer welfare. In terms of own-price elasticity the AIDS model allows the change in elasticity to be either positive, or

negative, when the budget share changes. For the LES model the own-price elasticity always becomes more inelastic if the budget share for that particular good decreases (Blanciforti *et al.* 1986). The implications for this study are that since the TAC rule for the Icelandic cod stock was calculated based on estimates for own-price elasticity of the Icelandic cod trade, it becomes most important to obtain a good, theoretical, and unrestrictive estimate of the own-price elasticity for the different product groups.

In order to solve the problems of theoretical inconsistency, researchers have estimated several different functional forms. These models include the Rotterdam model (Jorgenson and Lau 1975), the Translog system (Diewert 1974), and the Almost Ideal Demand System (Deaton and Muellbauer 1980). All of these systems are flexible functional forms. The AIDS model is theoretically consistent and allows for simultaneous testing of several restrictions imposed by consumer theory. The Rotterdam model has also been shown to possess similar attributes, at least in approximation to the AIDS model (Byron 1984, Mountain 1988). What we can label as "true" flexible functional forms are functions that are a second order approximation to any utility function (Pollak and Wales 1992). The benefits of such a functional form are that the researcher does not have to know the true underlying utility or demand function in order to be able to have an unbiased estimate of a system of demand equations.

The most commonly used flexible functional form is the translog system (Blanciforti *et al.* 1986) but other flexible functional forms are the quadratic expenditure system, the S-branch form, the Laurent form, the generalized Leontief function and the AIDS model (Asche 1997, Blanciforti *et al.* 1986, Deaton and Muellbauer 1983). Here we will examine the Translog system because the AIDS model can be seen as a special case of the Translog system. This discussion follows Christensen *et al.* (1975) closely.

The "homothetic translog" functional form (HTL) is the simplest form of the entire class of translog functional forms. The indirect utility function for the HTL is:

$$(1.1.1.18) \quad \psi(P, u) = \log \mu - \sum_k \alpha_k \log p_k - \frac{1}{2} \sum_j \sum_k \beta_{kj} \log p_k \log p_j$$

Where it holds that:

$$\begin{aligned} \mathbf{b}_{ij} &= \mathbf{b}_{ji} \text{ for all } i, j, \\ \sum_k \mathbf{b}_{ki} &= 0 \text{ for all } i, \\ \sum_k \mathbf{a}_k &= 1. \end{aligned}$$

Using Roy's identity in share format, $x_i^m = -\frac{\partial \mathbf{y} / \partial p_i}{\partial \mathbf{y} / \partial \mathbf{m}}$, and if $\beta_{kj} = \beta_{jk}$, then we can write the HTL share equations as:

$$(1.1.1.19) \quad w^i(P, \mu) = \alpha_i + \sum_j \beta_{ij} \log p_j$$

where w^i is the i -th equation share in the total budget, or $\left(w^i = \frac{P_i \cdot q_i}{\sum_k (P_k \cdot q_k)} \right)$. Equation

(1.1.1.19) serves as the base equation for further review.

Pollak and Wales (1992) set forth a demand system derived from an indirect utility function of the price independent generalized logarithm (PIGLOG) form:

$$(1.1.1.20) \quad \psi(P, u) = -\sum_k a_k \log(p_k / \mu) - \frac{1}{2} \sum \sum \beta_{kj} \log(p_k / \mu) \log(p_j / \mu)$$

The share equations, again using Roy's identity, are:

$$(1.1.1.21) \quad w^i(P, u) = \frac{\alpha_i + \sum_j \beta_{ij} \log(p_j / \mu)}{1 + \sum_j \sum_k \beta_{kj} \log(p_j / \mu)}$$

Deaton and Muellbauer (1980) call this share equation the basic translog share equation. The adding up, homogeneity and symmetry conditions can all be imposed in the estimation procedure or tested as a parameter test on the estimated coefficients. However, estimating these share equations is complicated since the equation obviously is non-linear.

By imposing the restrictions that $\sum_j \sum_k \beta_{kj} = 0$, we obtain a special case of translog function called the log TL, or:

$$(1.1.1.22) \quad w^i(P, u) = \frac{\alpha_i + \sum_j \beta_{ij} \log(p_j) - \log(\mu) \sum_j \beta_{ij}}{1 + \sum_j \sum_k \beta_{kj} \log(p_j)}$$

But again, we need non-linear estimation techniques, which considerably limit the number of equations that can be used in a demand system, in practice.

The AIDS model begins with a set of preferences under the PIGLOG class, which are represented through an expenditure or cost function. The PIGLOG function is:

$$(1.1.1.2) \quad \ln c(u, p) = (1-u) \ln[a(p)] + u \ln[b(p)]$$

where $c(\cdot)$ stands for total expenditure, u determines the level of subsistence vs. bliss consumption and $a(p)$ and $b(p)$ are relative cost functions for subsistence (a) and bliss (b) consumption. P is the price vector for all goods.

What is notable with this preference ordering is that it is only based on prices and the ratio between subsistence consumption and bliss consumption (Asche 1997). This minimizes the information needed for estimation of the system. By maximizing individual utility function using a specific functional form for the PIGLOG preference function the budget share equation is derived as:

$$(1.1.1.23) \quad w_{it} = \alpha_i + \sum_{j=1}^k \gamma_{ij} \ln(p_{jt}) + \beta_i \ln\left(\frac{\mu_t}{P_t}\right)$$

where:

$$(1.1.1.24) \quad \ln P_t = \alpha_0 + \sum_i \alpha_i \ln(p_{it}) + \frac{1}{2} \sum \sum \gamma_{ij} \ln(p_{it}) \ln(p_{jt})$$

Equation (1.1.1.23) becomes the HTL share equation (see equation (1.1.1.19)) when all the \mathbf{b} 's are zero. The problem with this specification is that one needs non-linear estimation techniques, since equation (1.1.1.24) is non-linear. That problem can be avoided by using Stone's price index, as suggested by Deaton and Muelbauer (1980), Asche and Wessells (1997), and Asche (1997).

The n ($i=1, \dots, n$) equations to be estimated using a linear approximation to the AIDS model, or the LA/AIDS are:

$$(1.1.1.25) \quad w_i = \mathbf{a}_i + \sum_j \mathbf{g}_j \ln p_j + \mathbf{b}_i \ln\left(\frac{\mathbf{m}}{P^*}\right)$$

Where the α 's, β 's and γ 's are parameters to be estimated. The Stone price index is:

$$(1.1.1.26) \quad P^* = \sum_{i=1}^n w_i \ln(p_i)$$

The Stone price index has been widely used in applied research. In recent years, researchers have found that the Stone price index can cause inconsistent coefficient estimates. In order to get consistent estimates (Moschini 1995) suggested using a "corrected" Stone price index, or other indexes such as the Tornquist or the Laspeyre price index. All of these indexes use different weights, such as mean values of prices or budget shares, to correct for the measurement error which the original Stone price index imposes on the estimation of the model. The "corrected" Stone price index uses a base period (the mean could be used as the base) to weight the price series for each individual equation, or:

$$(1.1.1.27) \quad P^{CS} = \sum_{i=1}^n w_i \ln \left(\frac{p_i}{p_i^0} \right)$$

The Tornqvist index weighs both the budget share and the price series.

$$(1.1.1.28) \quad P^T = \frac{1}{2} \sum_{i=1}^n (w_i + w_i^0) \ln \left(\frac{p_i}{p_i^0} \right)$$

The Laspeyre index uses the average budget share to weigh each price series, or:

$$(1.1.1.29) \quad P^L = \sum_{i=1}^n w_i^0 \ln(p_i)$$

All of these indexes have been shown to have good empirical attributes (Moschini 1995).

This discussion concludes that the LA/AIDS model is a good approximation to the true AIDS model when using any of the modified indexes above.

In the past few years, the Rotterdam model has reappeared in the literature, with a better theoretical foundation (Barnett 1979, Byron 1984, Mountain 1988).

The Rotterdam model can be written as (Deaton and Muellbauer 1983):

$$(1.1.1.30) \quad w_i d \log q_i = b_i d \log \bar{x} + \sum_j c_{ij} d \log p_j$$

where

$$a) \quad d \log \bar{x} = d \log x - \sum_k w_k d \log p_k = \sum_k w_k d \log q_k$$

$$(1.1.1.31) \quad b) \quad b_i = w_i e_i = p_i \frac{\partial q_i}{\partial x}$$

$$c) \quad c_{ij} = w_i e_{ij}^* = \frac{p_i p_j s_{ij}}{x}$$

where d stands for first difference, w is the budget share, b is the marginal propensity to spend on the k -th good, and c is the effect of a price change on the overall budget, since s is the ij term of the Slutsky substitution matrix. This means that the terms in (1.1.1.31) measure the total effect of the price change of a good j on the share of good i in the consumer budget.

Equation (1.1.1.30) holds if the adding up of the marginal propensities to spend on each good is one and the net effect of price change is zero, or (Deaton and Muellbauer 1983 p. 69):

$$(1.1.1.32) \quad \sum_k b_k = 1; \quad \sum_k c_{kj} = 0$$

These restrictions cannot be directly tested in the estimation of the Rotterdam model. The covariance matrix becomes singular when all the budget shares add up to one. Therefore, one equation must be omitted during the estimation process, and the estimated coefficients used to calculate the coefficients.

The Rotterdam model can be tested for homogeneity and symmetry. The condition for homogeneity is that the sum of all the own cross price coefficients are zero, or (Deaton and Muellbauer 1983 p. 69):

$$(1.1.1.33) \quad \sum_k c_{jk} = 0$$

The symmetry restriction is imposed by setting all the off diagonal elements of the C matrix equal to their counterpart, or:

$$(1.1.1.34) \quad c_{ij} = c_{ji}$$

The Rotterdam model is not known to be a flexible functional form. However, Byron (1984), Mountain (1988) and Barnett (1979) have shown the Rotterdam model to perform reasonably well as an approximation to flexible functional form, given that the coefficients of the underlying model are relatively stable.

Inverse Demand Systems

The following discussion of inverse (price dependent) and hybrid functional forms is taken from Eales, Durham and Wessells (1997), and Barten and Bettendorf (1989). Barten and Bettendorf develop differential inverse demands for application to monthly demand for fish in Belgium. Specifically, they develop inverses of the Rotterdam, Central Bureau of Statistics (CBS); Keller and van Driel, Laitinen and Theil), and differential AIDS models. Just as the ordinary CBS demand model is a hybrid of the ordinary Rotterdam and AIDS models, the inverse CBS is a combination of inverse Rotterdam quantity effects with inverse AIDS scale effects. The National Bureau of Research demand model (NBR; Neves) is also a hybrid. It has an inverse analog, the inverse NBR, which combines inverse AIDS quantity effects with an inverse Rotterdam scale effect.

The differential inverse models (Rotterdam and AIDS) and inverse hybrid models (CBS and NBR) are:

$$w_i d \ln p_i = a_i d \ln Q + \sum_j a_{ij} d \ln q_j$$

(inverse Rotterdam)

$$d w_i = \beta_i d \ln Q + \sum_j \beta_{ij} d \ln q_j$$

(inverse AIDS)

$$w_i d \ln (p_i/P) = \beta_i d \ln Q + \sum_j a_{ij} d \ln q_j$$

(inverse CBS)

$$d w_i - w_i d \ln Q = a_i d \ln Q + \sum_j \beta_{ij} d \ln q_j$$

(inverse NBR)

where p_i and q_i are the price and quantity of good i , respectively, y is total expenditure and

$$d \ln Q = \sum_j w_j d \ln q_j$$

(Divisia volume index)

$$d \ln P = \sum_j w_j d \ln p_j$$

(Divisia price index)

$$w_i = p_i q_i / y$$

(budget shares)

$$p_i = p_i / y$$

(normalized prices)

$$a_i = \beta_i - w_i$$

(coefficients of scale effect)

$$a_{ij} = \beta_{ij} - w_i d_{ij} + w_i w_j$$

(Antonelli effects)

and d_{ij} is the Kronecker delta.

Generalized Demand Models

Barten (1993) shows that the Rotterdam (Barten 1964, Theil 1965), the differential AIDS, and two hybrid demand systems (CBS and NBR) can be nested within a generalized ordinary demand system. Brown, Lee and Seale develop a generalized inverse demand system. Both the generalized ordinary and the inverse demand systems can be re-parametrized to have AIDS dependent variables, which makes comparison of the models possible.

To illustrate this transformation, consider the following generalized inverse demands of Brown, Lee and Seale:

$$w_i d \ln p_i = (\gamma_i - \gamma_1 w_i) d \ln Q + \sum_j (\gamma_{ij} - \gamma_2 w_i (d_{ij} - w_j)) d \ln q_j$$

where γ_1 and γ_2 are nesting parameters that yield the four inverse demand systems discussed above for certain values, γ 's are other parameters of the generalized inverse demands, and the variables are as previously defined. If both nesting parameters are equal to one, the associated terms transform the dependent variables of the generalized model

from those of the inverse Rotterdam to those of the inverse aids MODEL. The conversion from a model expressed with Rotterdam dependent variables to one with AIDS dependent variables, in the generalized inverse model, is accomplished using

$$d \ln w_i = w_i (d \ln p_i + d \ln q_i)$$

The papers that are most relevant to welfare analysis brought about by management changes are Barten and Bettendorf (1989) and Beach and Holt (2001). Both estimate exvessel demand for fish, Barten and Battendorf in Belgium and Beach and Holt in the South Atlantic U.S. Beach and Holt specifically use a Normalized Quadratic Inverse Demand-Quadratic Scale system using monthly South Atlantic fish landings and valuation data from 1980 – 1996.

Attached to this report is Appendix B that contains copies of some of the papers on demand systems discussed in this section of the report.

Conclusions

The purpose of this analysis was to assist NMFS economists in specifying demand for groundfish, allowing them to maintain confidence in the forecasting of changes in consumer surplus as fisheries regulations change in New England groundfisheries.

This analysis was to obtain answers to several questions, including: In estimating demand, which species are close substitutes to each other? Conventional thought is that all the whitefish species compete with one another to some extent, but which are the strongest substitutes? Can a group of groundfish be treated as an aggregate commodity? How do imports of groundfish influence exvessel demand for groundfish? What functional form should be used for the demand analysis?

The project was successful in answering some of these questions, but not all of them. It is fairly clear that imports of cod from other nations has an influence on the price of cod in New England and that Iceland is a big player in that market. Exvessel price for cod is exogenous to the prices of the other species of groundfish, such that any demand equation of a groundfish species must include the price of cod as an explanatory variable. It may be that the exvessel price for cod in New Bedford drives the other cod prices, but the evidence is not strong.

We learned that some of the data at both the exvessel and import levels are not particularly conducive to time series analysis. This includes the flatfish complex for imports and yellowtail and widow flounders for the exvessel prices. We learned that there is a lot of noise in the exvessel prices that cause many of the results of the time series analysis to either not make sense or relationships are very weak if they exist at all.

Some groundfish can probably be treated as an aggregate commodity, however, given the noise in the exvessel data, we cannot make recommendations on which species should be aggregated.

Finally, choosing the right the functional form for the analysis is not that easy to determine. That really requires doing the demand analysis on the products and then doing nested testing to determine the best functional form. Some information on various functional forms was provided, however, such that the NMFS economists can consider what they might do. On the other hand, we do not necessarily suggest that the functional form of the analysis of consumer demand done by NMFS be changed. Again, we would have to actually do some testing, but given the quality of the exvessel data as discussed above, it may be the case that a simple linear single equation regression is as good as it gets.

We have only made a dent in the analysis of groundfish markets in the U.S. Economists have been able to pretty thoroughly analyze the world's salmon markets, largely because good quality data exists. The groundfish market is so complex that it can not be as easily tackled, nor do we have the highest quality data – particularly wholesale prices and quantities for our domestically produced whitefish. Hopefully this situation is improving such that we can continue to analyze and learn more about these important species in both U.S. production and consumption.

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Appendix A

HTSUSA codes for Imported Whtiefish species

This table shows the HTSUSA codes for fisheries products used in this research. First column contains a description of the individual HTSUSA product code. The second column contains the harmonized tariff schedule code for the United States and the third column contains the year that each code was/is in effect.

HTSUSA codes for Imported Whtiefish species

Description	HTSUSA	DATE
FLATFISH FLOUNDER FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2025	90-
FLATFISH FLOUNDER FILLET FROZEN	03.04.20.6058	90-
FLATFISH HALIBUT NSPF FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2027	90-
FLATFISH HALIBUT NSPF FILLET FROZEN	03.04.20.6059	90-
FLATFISH SOLE FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2023	90-
FLATFISH SOLE FILLET FROZEN	03.04.20.6057	90-
FLATFISH TURBOT GREENLAND FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2021	90-
FLATFISH TURBOT GREENLAND FILLET FROZEN	03.04.20.6055	89-
GROUNDFISH COD ATLANTIC FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2011	90-
GROUNDFISH COD ATLANTIC FILLET FROZEN	03.04.20.3030	90-
GROUNDFISH COD ATLANTIC FILLET FROZEN	03.04.20.4030	90-90
GROUNDFISH COD NSPF FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2012	90-
GROUNDFISH COD NSPF FILLET FROZEN	03.04.20.3035	90-
GROUNDFISH COD NSPF FILLET FROZEN	03.04.20.4035	90-90
GROUNDFISH HADDOCK FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2030	89-
GROUNDFISH HADDOCK FILLET FROZEN	03.04.20.4062	90-90
GROUNDFISH HADDOCK FILLET FROZEN	03.04.20.3062	90-
GROUNDFISH OCEAN PERCH ATLANTIC FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2060	89-
GROUNDFISH OCEAN PERCH ATLANTIC FILLET FROZEN	03.04.20.4020	89-90
GROUNDFISH OCEAN PERCH ATLANTIC FILLET FROZEN	03.04.20.3020	90-
GROUNDFISH OCEAN PERCH NSPF FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2061	90-
GROUNDFISH OCEAN PERCH NSPF FILLET FROZEN	03.04.20.6071	90-
GROUNDFISH POLLOCK ALASKA FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2044	90-
GROUNDFISH POLLOCK ALASKA FILLET FROZEN	03.04.20.4065	90-90
GROUNDFISH POLLOCK ALASKA FILLET FROZEN	03.04.20.3065	90-
GROUNDFISH POLLOCK NSPF FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2040	89-90
GROUNDFISH POLLOCK NSPF FILLET BLOCKS FROZEN > 4.5KG	03.04.20.2048	90-
GROUNDFISH POLLOCK NSPF FILLET FROZEN	03.04.20.4063	90-90
GROUNDFISH POLLOCK NSPF FILLET FROZEN	03.04.20.4068	90-90
GROUNDFISH POLLOCK NSPF FILLET FROZEN	03.04.20.3068	90-
PERCH NSPF FILLET FROZEN	03.04.20.6015	90-
SALMON ATLANTIC FILLET FROZEN	03.04.20.6006	95-
SALMONIDAE NSPF FILLET FROZEN	03.04.20.6007	90-94
SALMONIDAE NSPF FILLET FROZEN	03.04.20.6008	95-

Appendix B