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MASTER'S THESIS

Prospect for Norwegian Salmon in Brazil: A Market Integration Analysis

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A thesis submitted in fulfillment of the requirements for the degree of Master of Science

in Industrial Economics

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“To be human, is not a fact, but a task ”

Søren Kierkegaard

UNIVERSITY OF STAVANGER

Abstract

Faculty of Science and Technology
Department of Safety, Economics and Planning

Master of Science

Prospect for Norwegian Salmon in Brazil: A Market Integration Analysis

by Ove A. KVANDAL

Norwegian seafood production-expansion mean looking for additional markets to sell products. In this regard, Brazil has been pointed out as one potential new market for Norwegian salmon. There are two main reasons for this: Norway already have a long history of major trade with Brazil, and two, Brazil have already been importing salmon for some years from Chile. If salmon in that time have become an integrated part of the Brazilian fish market it could mean a smoother and less risky entry for Norwegian salmon exporters.

In this thesis I apply three different, but in many regards similar, statistical techniques to look for long-term bivariate relationship between the price of salmon and 9 other local groups of fish sold locally in the Brazilian fish market. The total of 10 data series, of which these prices make up, span a period of roughly 4.5 years from February 2014 to July 2018.

The results from all three tests point toward the same conclusion, that salmon is an integrated part of the Brazilian fish market. In addition, there is statistical evidence to suggest that the price of salmon could be influencing the price of local species in the long-run.

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Finally, a thank you to NSC for their willingness to share export data on seafood to Brazil with me.

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List of Abbreviations

AC	**A**uto**c**orrelation
ACF	**A**uto**c**orrelation **F**unction
ADF	**A**ugmented **D**ickey-**F**uller (test)
AIC	**A**kaike **I**nformation **C**riterion
AR	**A**uto**r**egressive (process)
AR(*p*)	**A**uto**r**egressive process of order *p*
ARDL	**A**uto**r**egressive **D**istributed **L**ag
ASC	**A**quaculture **S**tewardship **C**ouncil
BAP	**B**est **A**quaculture **P**ractice
BIC	**B**ayesian **I**nformation **C**riterion
BOVESPA	**Bo**lsa de **V**alores do **E**stado de **S**ão **Pa**ulo
CCF	**C**ross-**C**orrelation **F**unction
CEAGESP	**C**ompanhia de **E**ntrepostos e **A**rmazéns **Ge**rais de **S**ão **P**aulo
CEO	**C**ief **E**xecutive **O**ffiser
COFINS	**Co**ntribuição para o **Fin**anciamentoanciamento de Seguridade **S**ocial
CPT	**C**onsejo **P**ara la **T**ransparencia
DNB	**D**en **N**orske **B**ank
EBIT	**E**arnings **B**efore **I**nterest & **T**axes
ECM	**E**rror **C**orrection **M**odel
EMBRAPA	**Em**presa **Br**asileira de **P**esquisa & **A**gropecuària
ETSP	**E**ntreposto **T**erminal **S**ão **P**aulo
FAO	**F**ood and **A**griculture **O**rganization of the United Nations
FOB	**F**ree **o**n **B**oard
GAP	**G**ood **A**gricultural **P**ractice
GDP	**G**ross **D**omestic **P**roduct
HOG	**H**ead-**O**n-**G**utted
I(*d*)	**I**ntegrated of order *d*
iid	**i**ndependently **i**dentically **d**istributed
IPEA	**I**nstituto **B**efore **I**nterest & **T**axes
ISA	**I**nfectious de **E**conômica **A**plicada
IUCN	**I**nternational **U**nion for **C**oncervation of **N**ature
LOP	**L**aw of **O**ne **P**rice
MTB	**M**aksimalt **T**illatt **B**iomasse
NARDL	**N**on-linear **A**uto**r**egressive **D**istributed **L**ag
NCN	**N**omenclatura **C**omun do **M**ercosul
NCS	**N**orwegian **S**eafood **C**ouncil
OECD	**O**rganisation for **E**conomic **C**o-operation and **D**evelopment
PACF	**P**artial **A**uto**c**orrelation **F**unction
PIS	**P**rograma de **I**ntegração **S**ocial
PPP	**P**urchasing **P**ower **P**arity
R&D	**R**esearch and **D**evelopment
RAS	**R**ecirculating **A**quaculture **S**ystem
SSB	**S**tatistisk **S**entral**b**yrå

SSB	**S**outh **B**razilian **B**ight
VAR	**V**ector **A**uto**r**egressive (process)
VAR(*p*)	**V**ector **A**uto**r**egressive process of order p
WWF	**W**orld **W**ildlife **F**ound

Dedicated to my family

Chapter 1

Introduction

1.1 Objective

Brazil is the main trade partner for Norway in Latin America, and the relationship goes back some 180 years. Back then, klippfish was shipped from Norway to Brazil and coffee and sugar was brought back on the return. Still to this day klippfish remain as one of the main seafood imports from Norway, though today, seafood only constitute a small fraction of the total mass of goods exported from Norway (figure 1.1) to Brazil.

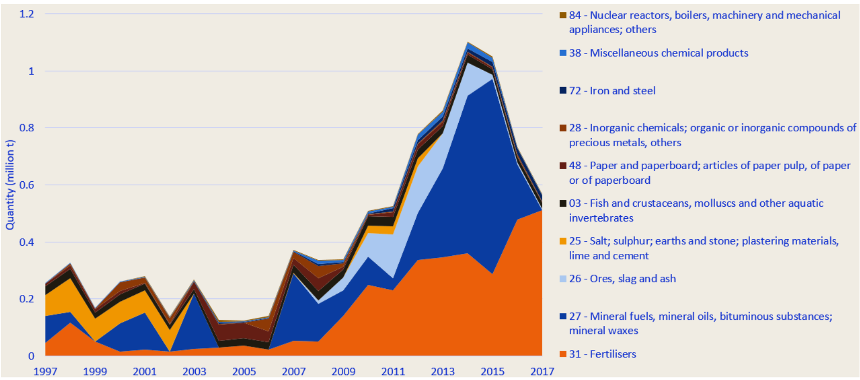


FIGURE 1.1: Brazilian imports of goods from Norway during the period 1997 - 2017. Source: (Pincinato, 2018)

The demand for seafood has been increasing in Brazil over the past years. Some of the demand has been met by increased local production, especially through aquaculture, while the remainder has been met through increased imports. Salmon was one of the main seafood imports to Brazil over the last decade, and even though Norway is the leading global producer of salmon, Chile is the main exporter of salmon to Brazil. The reason being that Norway been mainly supplying the European and the Asian market with salmon.

To understand the potential for Norwegian seafood production-expansion, in this thesis the focus will be on salmon as the product and Brazil as the market, one need to understand the potential seafood markets delimitations and interactions between farmed and wild species, imported/exported and domestic products. In general, microeconomic theory assumes that there exists a market defined over a group of commodities. The commodities compete in the same market because consumers or producers consider the goods substitutable to some extent (Asche, Gordon, and Hannesson, 2004).
As stated by (Pincinato, 2018), an integrated seafood market will provide

- an easier production expansion as one need spending less time convincing people to buy the product,
- an increase of competitiveness, and
- an increase in consumer welfare.

The objective for this thesis is to check if salmon is a unique product in the Brazilian fish market, which mean checking whether or not there exist a long-term price relationship between the price of salmon and the price of other local species in the Brazilian fish market.

1.2 Method

Three different statistical techniques have been applied to look for a long-term relationship, or cointegration, between the price of salmon and the prices of nine other species/groups of fish sold locally at the Sao Paulo wholesale market.
The objective of this thesis is not to determine an exact relationship, if any, between the prices, but rater to apply a range of techniques to see if they happen to "point" in the same direction with regard to a conclusion. Much of the reason being that only a little more than four years of data were available.

The tests were run in a bivariate configuration. This to make the results easier and more transparent to interpret, but also because there was interest in running the regressions bi-directional.
For most of the tests and the analyzing of the data series the program *R* was used. Exception being for the ARDL bounds test, where the software *Microfit* by (Pesaran and Pesaran, 2018) was used. *Microfit* compute the critical value bounds by stochastic simulations, and I used 10 000 replications.

1.3 Structure

This thesis is structured into seven main chapters. In the *second* chapter I first give an introduction on salmon farming in general, how it is to day and where it seems to be going, then focus in on salmon farming in Norway and Chile. Here I look at differences, but also similarities between the two nations, not only as salmon producers but also salmon market suppliers. The reason being that Chile, the second largest producer of salmon, is currently the main supplier of salmon to Brazil and the Americas. Norway is currently the main supplier to the European and Asian markets, and this thesis is part of the early steps of looking into the prospect of Norway becoming a supplier to the Brazilian market as well.
Then I go on to examine the Brazilian market as a whole, along with Brazil's economy. I believe it is important to have an understanding of how the Brazilian economy is, has been, and outlook as salmon sell at a quite higher price compared to many of the other local species. All this ties into the Brazilian markets susceptibility for salmon, as seen from a Norwegian perspective, along with current possibilities, and difficulties relative to Chile.

In chapter *three* I describe the fish species whose prices are being analyzed in this thesis. My focus has been to try and uncover information on the different species that can be helpful in describing their price pattern. I have to admit, in this part, being able to speak and read Portuguese I think would have definitively made researching this chapter a lot easier. The chapter is finished off with an overview of past studies on market integration that is relevant to the topic of this thesis.

Chapter *four* is about statistical theory. First a section on time series in general leading up to description on stationarity and correlation, as this is fundamental in the econometric techniques applied in this thesis.
In the second section I give a description on said econometric techniques applied in this thesis.

In chapter *five* I examine the data series. I present some descriptive statistics on the data series, and time-plot of the data series along with their ACF and PACF plots. I also tie together what I have uncovered in chapter three with what I am observing in these plots.

In chapter *six* I present the results from the tests performed along with discussion on the results. The conclusion is presented in chapter *seven*.

Chapter 2

Market Theory

2.1 Salmon Farming

Aquaculture has been the world‘s fastest growing food producing industry during recent decades (FAO, 2010). Production has increased more than 30-fold from 1970 to 2016, from 2.6 million tons to 80.0 million tons in 2016 (FAO, 2018). This is largely caused by the "blue revolution, " as producers gained control over the production processes, thereby allowing systematic innovation and R&D and as producers applied knowledge and technology from the agricultural sector to the production of seafood species (Anderson, 2002; Asche, 2008; Smith et al., 2010).

Global farmed salmon production has increased from 12,000 tons in 1980 to over 2.4 million tons in 2017 (figure 2.1) (FAO, 2018). In 1980, salmon trout was the most important species with 44.3% of the production, followed by Atlantic salmon with a 37.2% share. This largely reflects the fact that trout was domesticated before salmon. However, the industry matured, Atlantic salmon has become the dominant species with a production share of 77.9% in 2010, followed by salmon trout (*Onchorynchus mykiss* - large rainbow trout, also known as steelhead) with 15.2% and coho with 6%. This is largely due to better growth performance, and also that it is easier to have Atlantic salmon available for the market at all times of the year (Asche and Bjorndal, 2011). Chile is today the only country that produces significant quantities of all the major species, and it is the only significant producer of coho (>90% of global output).

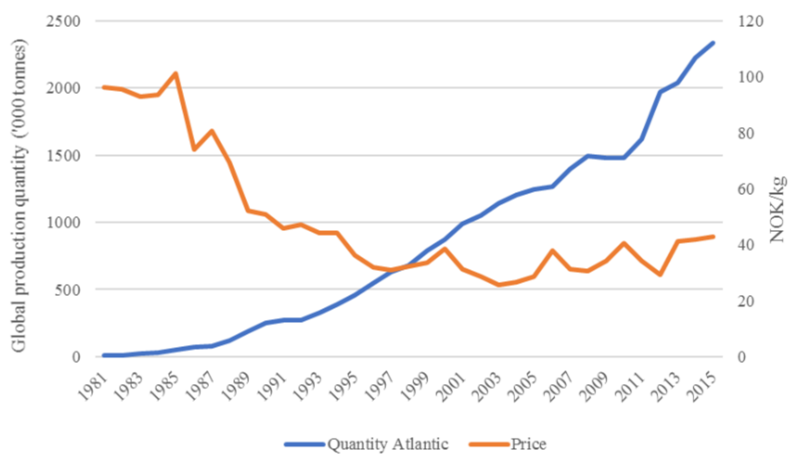


FIGURE 2.1: Global production quantity in thousand tons and real price in NOK/kg for Atlantic salmon. Source: (Bjorndal and Tusvik, 2017)

The Norwegian export price given in figure 2.1 is free on board (FOB) head on gutted (HOG). Since the high of around 100 NOK/kg in the early 80's, the price has steadily declined as production has increased, until it stabilized at about 35 NOK/kg toward the end of the 90's. In spite of salmon being a high value, relatively expensive product, demand is growing steadily, and new markets are being opened through new types of processed products (FAO, 2016).

The salmon aquaculture industry originated in Norway in the 1970s, and became commercially viable in the early 1980s. As a consequence of its successful development, it later spread to a number of countries in Europe, the Americas, Asia, and Australia, with each country or region being main suppliers to each market, as seen in figure 2.2.

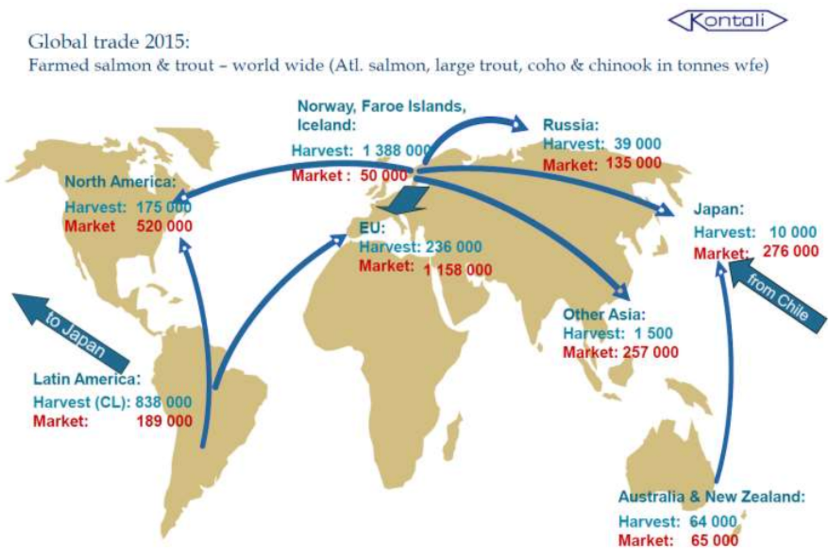
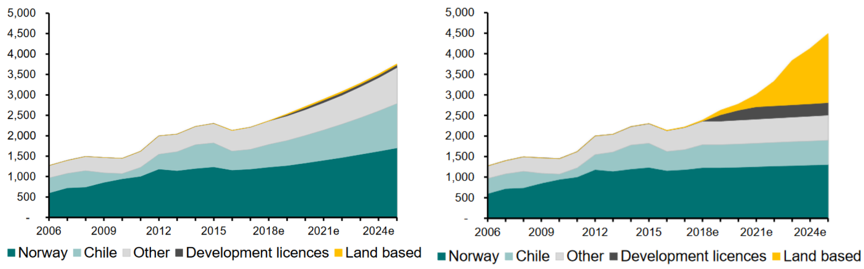


FIGURE 2.2: Main regions and trade flow. Norway supplies Europe, and Chile supplies the US. Source: Kontali.

Salmonids are usually farmed in two stages. First, the salmon are hatched from eggs and raised on land in freshwater tanks. When they are 12 to 18 months old, the smolt are transfered to floating sea cages or net pens anchored in sheltered bays or fjords along the coast. They are fed pellets feed for another 12 to 24 months until harvest (Watershed Watch Salmon Society, 2004)). At the time of harvest the salmon will have reached a weight of between 2 - 8 kg (usually $\sim$ 5.5kg). This primary method of cultivating has more or less remained the same, but the size of the pens (up to 50 m in diameter and extend 40 mm below the surface) and the number of stocked smolt (up to 200 000 individuals per cage) have been increasing (Taranger et al., 2015). A pen system will typically consist of between 6 - 14 cages.
Biological challenges, particularly sea-lice and diseases, for this traditional way of farming together with strict regulations in both Norway and Chile are limiting future supply growth. This has increased the interest for land-based farming.

A major benefit of land-based farms, compared to traditional ocean farming, is the control is gives over the entire production process due to being able to control the water quality in the tanks. This includes the problems with illness, lice and algae blooms that have been devastation to salmon-farm output at times in the past (land-based farming does not eliminate these problems, but gives the potential for lice- and disease-free production with low mortality). In a survey by DNB Markets (DNB Markets, 2017) they identified 20+ projects for full-cycle salmon production

on land, with planned capacity of ∼150 000 tons, i.e. 7% of 2016 volumes. This indicates that land-based salmon farming has come further than previously thought, and they indicate that one of the main reasons behind this sudden development is the substantial advances that has been made in recirculating aquaculture systems (RAS) over the past 5-10 years. These systems, initially developed for smolt production, has reduced the water needed by 99% compared to "flow-through" systems and the in recirculation the effectiveness has increased 3-4x since 2008. Because of this the current estimated production cost for mid-size land-based facility is at NOK37/kg (HOG), which is close to traditional sea-based farming.
This lead DNB Markets (2017) to propose two possible future scenarios for salmon farming: one where the growth from traditional farming recovers (figure 2.3 (A)), and one where land-based take off as traditional growth fails (figure 2.3 (B)).



(A) Growth from traditional farming recovers.

(B) Land-based take-off as traditional growth fails.

FIGURE 2.3: Two possible production scenarios for the future. Source: Kontali (actuals), DNB Markets (estimates).

The uncertainty in future production method stem from several challenges that still face land-based farming, but most notably: 1) higher fish density [kg/m^3] than traditional farms; 2) early maturity; 3) off-flavoring; and 4) sludge and waste removal and filtration.

2.1.1 In Norway

Norway accounted for over half of the world's salmon production in 2014 (Marine Harvest, 2016). Aquaculture in Norway dates back to 1850 when the first brown trout (*Salmo trutta*) were hatched. By around 1900 rainbow trout (Oncorhynchus mykiss) were imported from Denmark and the first attempts at pond culture were initiated. An increase in interest was shown after World War II, followed by a breakthrough in the early 1960s when for the first time rainbow trout was successfully transferred to sea water. The first successful ongrowing of Atlantic salmon (*Salmo salar*) also took place during this same period. A technological breakthrough came around 1970 when the first cage was constructed. Ongrowing in cages proved to be safer and provided much better environmental conditions than onshore tanks or the various enclosures that had been used earlier, particularly with regard to salmon farming. The long and sheltered coastline of Norway, with its thousands of islands and inlets, as well as the Gulf stream providing a reliable and stable temperature, has been proven to provide excellent opportunities for this kind of intensive fish farming (Gjedrem, 1993).

Norway is today the main producer of salmon in the world. The production in 1980 was 7,800 tons, and had increased to over 1.2 million tons in 2016 (figure 2.4)

(SSB). This has been possible as production per license has increased, although new licenses have also been awarded.

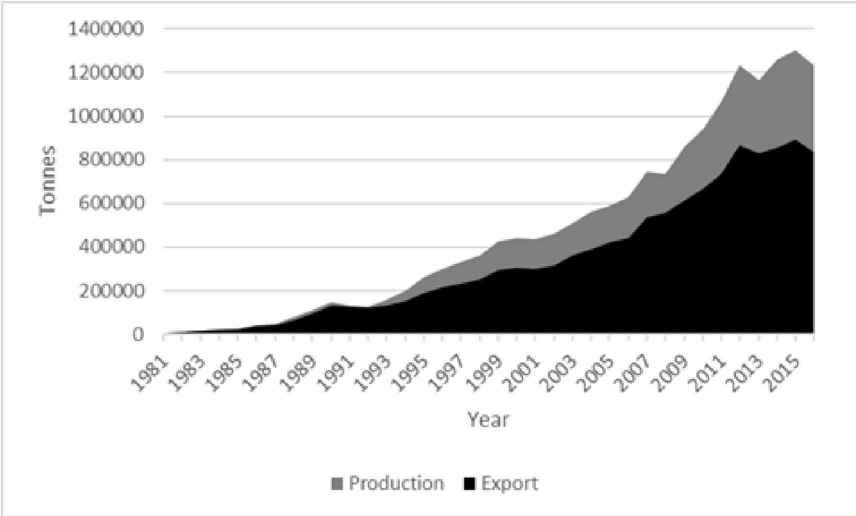
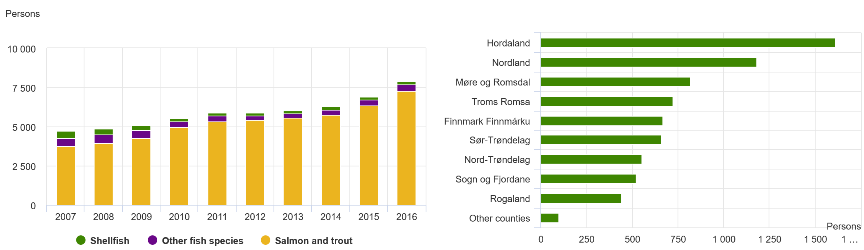


FIGURE 2.4: Historical yearly production versus export of Atlantic salmon in Norway. Source: Statistics Norway (SSB).

According to Statistics Norway, a total of 7 270 persons were engaged in salmon and trout production in Norway in 2016 (figure 2.5). This is an increase of 14% from the year before, and more than twice as much as ten years ago. Further, in terms of employment, Hordaland is the largest fish farming county in Norway. Here the increase in employment from 2015 to 2016 was 7%.



(A) Farming of fish and shellfish. Number of workers, by production.

(B) Farming of salmon and trout. Number of workers by county.

FIGURE 2.5: The figures shows that the employment number in aquaculture have been steadily increasing over the past years, and that as of 2016 it is county of Hordaland that has the highest number of people employed in aquaculture. (Source: Statistics Norway)

To operate a salmon farm at sea in Norway one needs a license, and with one license one can either produce Atlantic salmon or salmon trout. A license specifies where one can operate while also providing a measure that limits production. According to DNB Markets (DNB Markets, 2017), *SalMar* paid in 2014 NOK 66 million per license. By 2017, the market value for one license had almost doubled to NOK 120 million.
Within a region one can apply to the Directorate of Fisheries to move the license to a new location, and one can also operate several licenses together at the same site. Until 2002, the production limitations were some form of limit on pen size, while since 2004 there is a Maximum Allowable Biomass (MTB) for each license. Until 1992, the

regional policy concerns dictated that one could only have a majority share in one farm, basically creating an owner-operated industry (Asche et al., 2013).

In 2016, the Norwegian state opened for free-of-charge licenses to land-based farms. These are development permits that are granted free-of-charge for a maximum period of 15 years. If the project is carried out in line with set criteria, licenses can be converted to commercial licenses after a given period for a consideration of NOK 10 million (Norwegian Government, 2015). The main goal of the establishment of development permits was help to develop technology that can solve the environmental and area challenges facing the aquaculture industry. In 2009, the Norwegian government established a set of environmental goals for sustainability in the "Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry" (table 2.1). For every year since 2010 in response to this, the Institute or Marine Research, Norway have initiated a risk assessment of Norwegian salmon farming (Taranger et al., 2015).

TABLE 2.1: The five primary goals for the future development of the Norwegian aquaculture industry as established by the Norwegian government in 2009.

Goals	
Goal 1: Diease	Disease in fish farming will not have a regulating effect on stocks of wild fish, and as many farmed fish as possible will grow to slaughter age with minimal use of medicines.
Goal 2: Genetic interaction	Aquaculture will not contribute to pemanent changes in the genetic characteristics of wild fish populations.
Goal 3: Pollution and discharge	All fish farming locations in use will maintain an acceptable environmental state and will not have higher emissions of nutrient salts and organic materials than the reciving waters tollerate.
Goal 4: Zoning	The aquaculture industry will have a location structure and zoning which reduces impact on the environment and the risk of infection.
Goal 5: Feed and feed resources	The aquacultre industry's needs for raw materials for feed will be met without overexpoitation of wild marine resources.

As a result, Europe's largest land-based salmon farm is currently being built by *Salmon Evolution* in Fræna, Norway. The estimated cost of the plant is NOK 3 billion. and the planned output is close to 30 000 tons per year. Although this is the largest plant, it is just one of many currently being built in Norway at this time.

As Norway is currently the worlds largest salmon producer and Chile is ranked number two, much effort have put into trying to understand whether the salmon market is global or regional, i.e. does the law of one price (LOP[1]) holds for salmon. The reason this has been unclear is because the two nations have historically been

[1] The law of one price states that in the absence of trade frictions (such as transportation costs and tariffs), and under conditions of free competition and price flexibility (where no individual seller or buyers have power to manipulate prices and prices can freely adjust), identical goods sold in different locations must sell for the same price when prices are expressed in a common currency.

supplying different regional markets (figure 2.2), but production methods have also been different with regard to e.g. use of medicine. In 2016, for example, the Chilean salmon industry used 382.5 tonnes of antibiotics, which was 700 times more than the amount used in Norway (Fleitas, 2017). In figure 2.6, DNB (Slettmo, 2016) presents data that show that Norwegian and Chilean farm gate[2] prices are closely linked, thus indicate that LOP holds for the global salmon price. Norwegian prices and Chilean prices were in line until 2012. Then a ∼7 NOK/kg discount happened on Chilean products. But the movements were still in sync after this, and the gap closed after the end of the Chilean algae bloom.

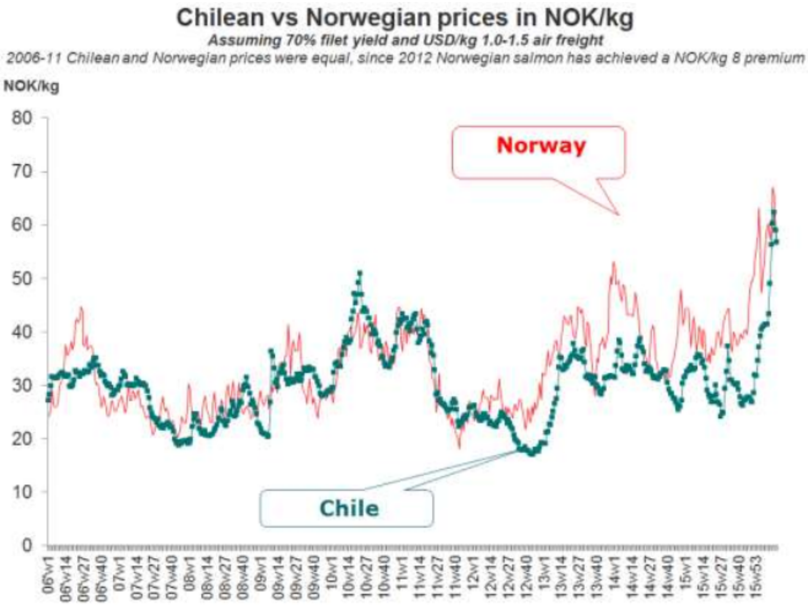


FIGURE 2.6: Chilean vs Norwegian prices in NOK/kg. Source: (Slettmo, 2016)

Further, DNB (2018) showed (figure 2.7) that historically it was Norway who set the global price for salmon and trout in the long run. It was primarily based on salmon and trout farmer's cost plus return on capital (DNB Seafood, 2018). This is in line with the findings of Asche et al. (Asche, Cojocaru, and Sikveland, 2018) in their study centered around the disease shock caused by the outbreak of ISA[3] making its first appearances in 2007. The study was based on market integration of four different product forms, and in their conclusion they write that all of these were well integrated into the global market. Moreover, they find that the Norwegian prices leads the Chilean prices, which indicating that the Chilean salmon prices are determined at the global market level.

[2]Chilean farm gate price = Norwegian farm gate price + difference in freight cost Atlantic versus Americas.

[3]Infectious salmon anemia (ISA) is a viral disease of Atlantic salmon that have previously affected fish farms in Canada, Norway, Scotland and Chile. The mortality rate for the disease can reach upward of 100%

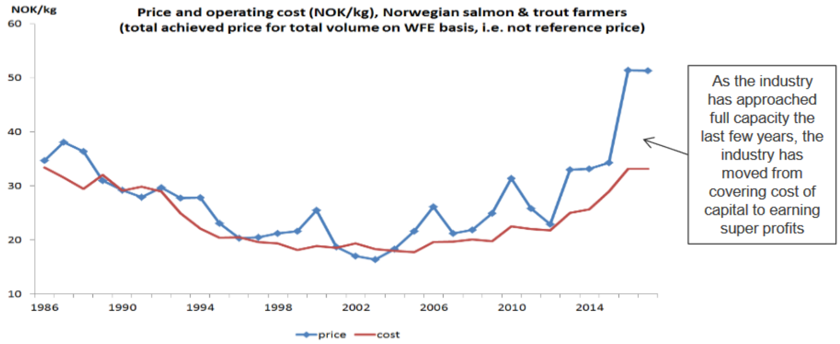


FIGURE 2.7: Price and operating cost for Norwegian salmon and trout farmers. Source: Directorate of Fisheries; (DNB Seafood, 2018)

Geir Milvik, CEO at Cermaq, point out five possible reasons for the success in Norway with regard to salmon farming (Molvik, 2016):

- Good natural conditions for salmon farming
- Good cooperation between industry and government
- High innovativeness
- Generic marketing
- Cooperation between the aquaculture and the traditional fishing industry

One of the major problems facing Norwegian salmon farming today is sea lice. The salmon mortality rose from 16% in 2015 to 19% in 2016, which equals 53 million salmons dying inside the cage, and the major contributor to this was pointed out to be sea lice (EY, 2017).

2.1.2 In Chile

Salmon are not native to Chile, but the Chilean coast provides climatic conditions very similar to their natural habitat in the northern hemisphere. The Chilean salmon industry is concentrated around Puerto Montt and Chiloè Island, about 1000 km south of Santiago (Asche and Bjorndal, 2011).
Chile is the second-largest producing country of farmed Atlantic salmon, despite of the salmon industry being relatively young in Chile, with production having commenced in the early 1980's. Chile's output reached 403,000 metric tons (mt) in 2008, before it was more than halved in 2009, and plunged to 130,000 mt in 2010. Production rebounded rapidly after 2010, reaching 460,000 mt in 2013 when Chile had largely recovered its production share and has continued to increase since as seen in figure 2.8 (Asche, Cojocaru, and Sikveland, 2018; FAO, 2018). Chile's annual salmon sales rose to USD 4.7 billion in 2017 (Central Bank of Chile, 2018), and the industry keeps 70 000 people with work, thereby ensuring that the industry is key to the country's economy. Further, the industry in Chile is composed of both local and foreign companies, the latter mainly comes from Norway, Scotland and Canada (Felzensztein, Gimmon, and Carter, 2010).

In 2007, Marine Harvest, the world's largest salmon-producing company, reported that it had discovered ISA at a farm producing Atlantic salmon in Chile. From 2008 to 2010, the production of Atlantic salmon in Chile suffered a more than 60% decrease due to the devastating viral outbreak. The production stagnated for five years, and 2011 was the first year after the crisis with production levels similar to those of 2005-2006 (Fischer, Guttormsen, and Smith, 2017). This event can clearly be seen in figure 2.8 and 2.9 below.

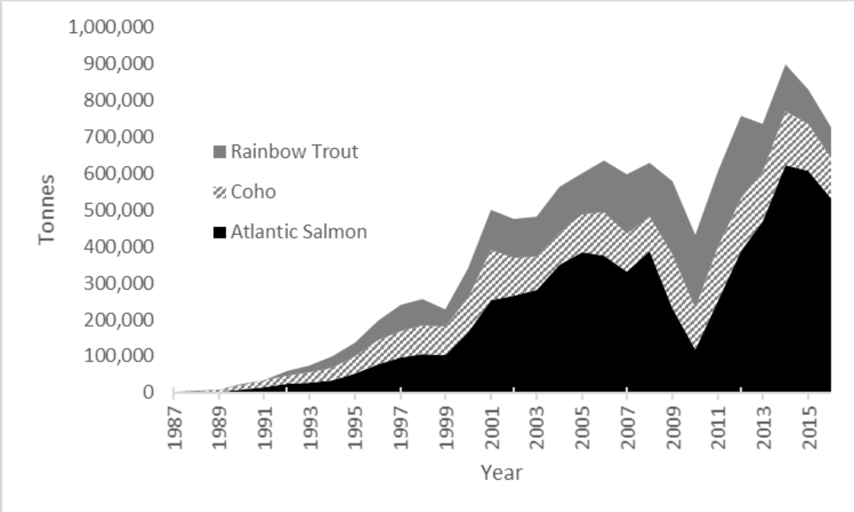


FIGURE 2.8: Chiles aquacultural production of major marine salmonids between 1987 and 2016. Source: (FAO, 2018)

Because of the disease outbreak, in Chile, fish were harvested earlier and therefore at a smaller size (Asche et al., 2009).
As different markets have varying preferences with respect to size (Asche, Bjørndal, and Young, 2001; Asche and Sebulonsen, 1998), the change in the physical size of the harvested Chilean salmon precipitated a substantial shift in the markets being served as well as in the exported product forms. Of particular interest in this case is the development of Brazil as a market for whole fresh Chilean salmon of moderate size, as exports to Brazil increased strongly during the crisis despite the reduction in total production (Asche, Cojocaru, and Sikveland, 2018).

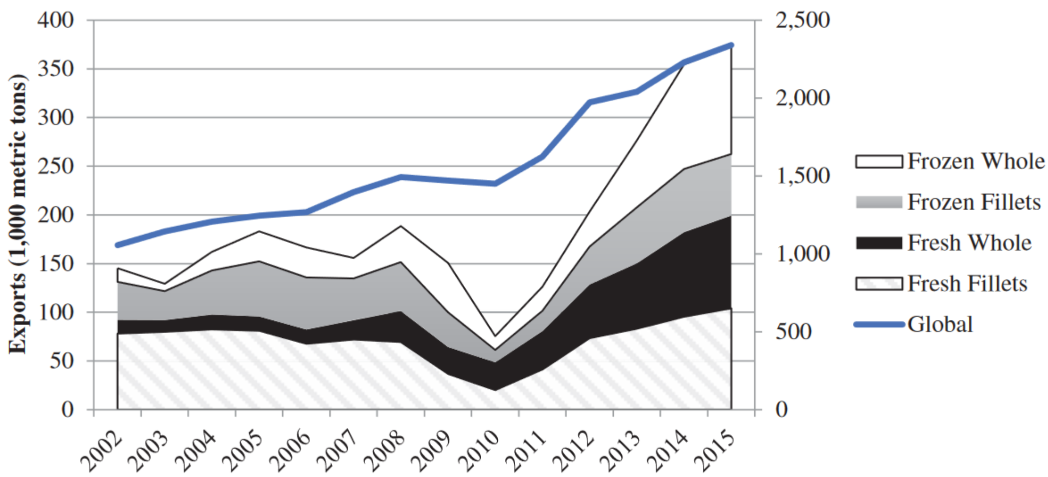


FIGURE 2.9: Annual Chilean salmon exports by product form (left axis) and global production (right axis). Source: (Asche, Cojocaru, and Sikveland, 2018)

The ISA outbreak was not the only time the Chilean salmon industry have been hit by significant, and even devastating events. A bloom of algae, most likely caused

by raising sea temperatures due to the El Nino weather phenomenon, wiped close to 20 percent of Chilean farmed salmon, some 25 million fish, in 2016. The severe drop in output from the world's second largest producer caused the salmon price to soar 44 percent by October 2016, compared the same time the year before (FAO, 2017). There have been an incident of algae blooms after this, but nowhere as severe as the one in 2016: one in November of 2017 in Magallanes that by January 2018 had killed some 110 000 fish, at market size of 6.2 kilograms.
Lastly, an event that has put the salmon industry in Chile under scrutiny, was the escape of some 650 000 fish due to a winter storm in July 2018 from a *Marine Harvest* owned farm. And it is not the first time this has happened. The problem being that salmon is a non-native species to Chile, and the long-term effect is unclear.

In response to the ISA outbreak, which not only had an environmental impact but also a social one as it caused the dismissal of thousands of workers, caused the industry to develop significant processes[4] of 1) regulation, which implied a territorial reorganization and important changes in the General Law of Fisheries and Aquaculture (Estay and Chàvez, 2015); and 2) private certification processes such as SalmonGAP[5], BAP[6], and ASC-WWF[7] (Aguayo and Parra, 2017). Further, in 2018 Chile's Council for Transparency (CPT) ordered salmon companies to provide information on the amount of antibiotics used by the company and farming center during the years 2015, 2016 and 2017. This is an attempt to reduce the amount of antibiotics being used by the industry.

A key feature of the Chilean exports is that there is one main market for fresh fillets, as the United States receives more than 90% of this product form. Similarly, there is one main market for whole fresh salmon, and that is Brazil[8]. For frozen products, where perishability is more controlled, there is no dominant market, with products going to a number of countries in Europe and Asia in substantial quantities (Asche et al., 2018).

2.2 The Brazilian Market From a Norwegian Perspective

Norway has a long history of trade with Brazil, going as far back as 1842 when the fist ship with klippfish offloaded its cargo in the port of Rio de Janeiro, before returning to Norway with sugar and coffee.
According to Innovation Norway (Innovation Norway, 2017), the import of seafood to Brazil has been growing for the last years. Suppliers are from more than 40 different countries, but despite this 90% of all the import comes from Chile, China, Norway, Argentina, Vietnam and Portugal (figure 2.10).

[4]Often described as "Salmon Farming 2.0" in Chile.

[5]An agreement with the Global GAP (Good Agricultural Practice), witch is a farm assurance program. The main objectives for SalmonGAP was to standardize and improve the production system and salmon processing industry, including the production of materials, fish health, quality and safety of food, environmental sustainability, security conditions for workers, animal welfare and biosecurity processes.

[6]Best Aquaculture Practices (BAP) certification.

[7]The Aquaculture Stewardship Council (ASC) is an independent, international non-profit organization that manages the world's leading certification and labeling program for responsible aquaculture.

[8]The Brazilian market was developed primarily for fish that had to be harvested early during the ISA outbreak, and therefore were too small to be filleted.

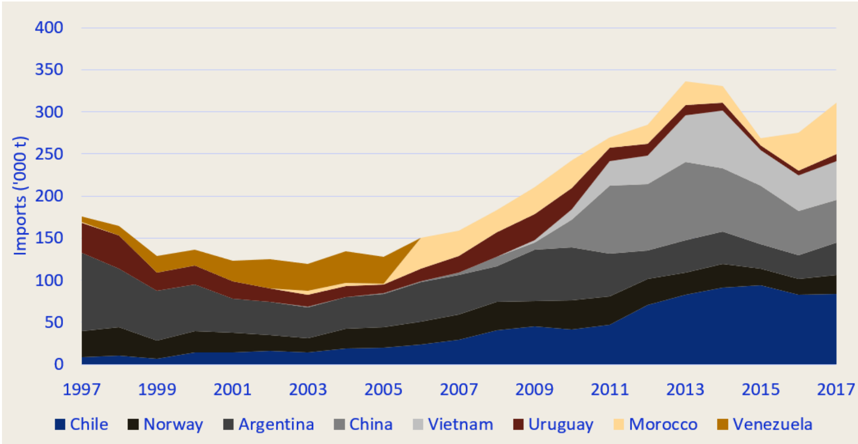
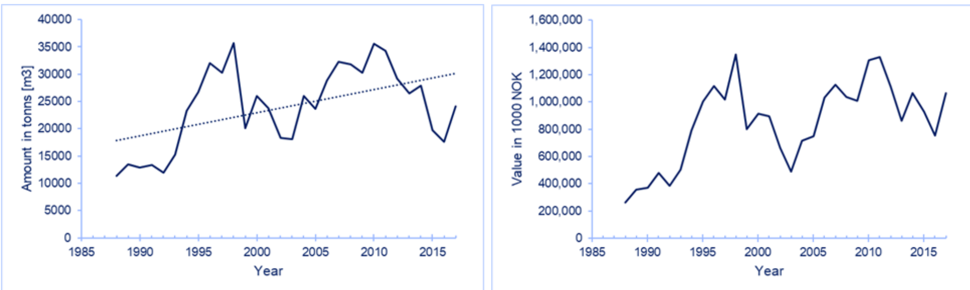


FIGURE 2.10: Brazilian seafood imports by country. Source: (Pincinato, 2018)

This fits with data from NSC, illustrated in figure 2.11, which show the total amount of seafood exported from Norway to Brazil, both in mass and value, over the last three decades. Despite some major ups and downs in the total amount, the overall trend is still positive. As table 2.2 below show, the main exported seafood commodity during this period has been klippfish. Second to this, but not shown in the table, has been whole frozen herring.
Historically, the export of salmon and salmon products from Norway to Brazil, shown in table 2.3 below, have been negligible.



(A) Total amount of seafood exported from Norway to Brazil during the period 1988 - 2017.

(B) Total value in 1000 NOK of seafood exported from Norway to Brazil during the period 1988 - 2017.

FIGURE 2.11: The figures show that export of seafood from Norway to Brazil is in an upward trend. Source: NSC

TABLE 2.2: The table show an abstract of the amount in tonnes of whole klippfish (Bacalhau), based on different species, exported from Norway to Brazil during the period 1988 to 2018. Source: NSC.

	1988	1993	1998	2003	2008	2013	2018
Pollock	2,839	3,634	12,429	11,170	19,757	12,876	5,232
Cod	1,857	4,492	14,062	4,063	6,681	9,544	3,505
Common ling	2,315	1,855	4,100	787	1,221	1,036	197
Cusk	4,073	4,818	4,393	1,611	1,792	2,209	604
Other whitefish	0	25	105	210	13	0	0

TABLE 2.3: Norwegian export of salmon to Brazil. Source: NSC.

Year	2011		2013		2015	
	Value in 1000 NOK	Amount in tonns	Value in 1000 NOK	Amount in tonns	Value in 1000 NOK	Amount in tonns
Fresh/chilled	0	0	2	0	0	0
Frozen	0	0	1,152	22	2,297	45
Smoked	106	1	0	0	5,981	48

Brazil has a total area of 8,514,876 km^2, divided into 26 states, a Federal District, and 5,561 municipalities. The states are grouped in five regions: Northern, Northeastern, Midwestern, Southeastern and Southern. Each region has its own geographical, economic and social characteristics.
The country is currently the worlds eight largest economy measured by GDP (nominal and PPP), with a current projected growth rate of -2.8%. The current population is 209.3 million (80% urban) with a projected annual growth of 2% (OECD). According to the World Bank, the country's GINI coefficient is approximately 51.3 (2015), and have been slowly declining for the past 25 years. Brazil has experienced a decade of economic and social progress from 2003-2013 in which over 26 million people were lifted out of poverty and inequality was reduced significantly. However, recently the country have been going through a challenging period in both economic and political terms (Innovation Norway, 2015).
Table 2.4 below summarizes some of these statistics.

TABLE 2.4: Statistics on Brazil from during period 1980 to 2017. Source: World Bank.

	1980	1990	2000	2010	2017
Population, total [10^6]	121.16	149.35	175.29	196.80	209.29
GDP per capita (current US$)	1,939.8	3,093.0	3,739.1	11,224.2	9,821.4
Inflation, consumer prices (annual %)	-	2,947.7	7.0	5.0	3.4
GINI index (World Bank estimate)	58.0	60.5	59.0	53.7	-
Import of goods and services (annual % growth)	0.7	10.1	10.8	33.6	5.0
Export of goods and services (annual % growth)	22.6	-4.9	12.9	11.7	5.2

Traditionally, Brazil has been one of the world's largest producers of poultry, beef and pork. But the demand for fish is growing, encouraged by the Brazilian government, but also due to the fact that the Brazilian consumers are becoming more informed and quality oriented. Compared to fish consumption worldwide (close to 18 kg/person/year), consumption by the average Brazilian is today low at only about 9 kg/person/year. The current aim of the government is for the average citizen to consume 14 kg of fish per year.
However, the national production of seafood through capture has not been able to keep up with the growing demand. Meaning that the increase in seafood supply to the Brazilian market is mainly related to increases in aquaculture activity and imports, which explains at least some of the reason behind the increase in seafood exports stated in the introduction of this section. Today, Brazil is the larges importer of fish in the Latin American region (Innovation Norway, 2015).

Brazil is a privileged country in an aquaculture sense, due to its size and richness of water resources, with a highpoint being the Amazon basin, accounting for 20 percent of all the freshwater in the world. There are also over five million hectares

of water impounded by dams constructed for hydroelectric power and drought control in the Northeaster region, and an extensive coastline that stretches for 8,000 km and is appropriate for marine aquaculture (Roubach et al., 2003). The yield from Brazilian aquaculture grew from 257,000 tons to 574,000 tons of fish, translating to a growth of 123%, during the period 2005 to 2015. Though, there was only 2% increase in production between 2014-2015 due to the national economic crisis (EMBRAPA, 2016). This is to a large part due to an increase in demand in their national market, which had an annual growth rate of over 10% during the same period.
About 75% of their total aquaculture production was in 2015 focused on two types of freshwater fish species, tilapia and tambaqui, and freshwater shrimp as shown in figure 2.12 below.

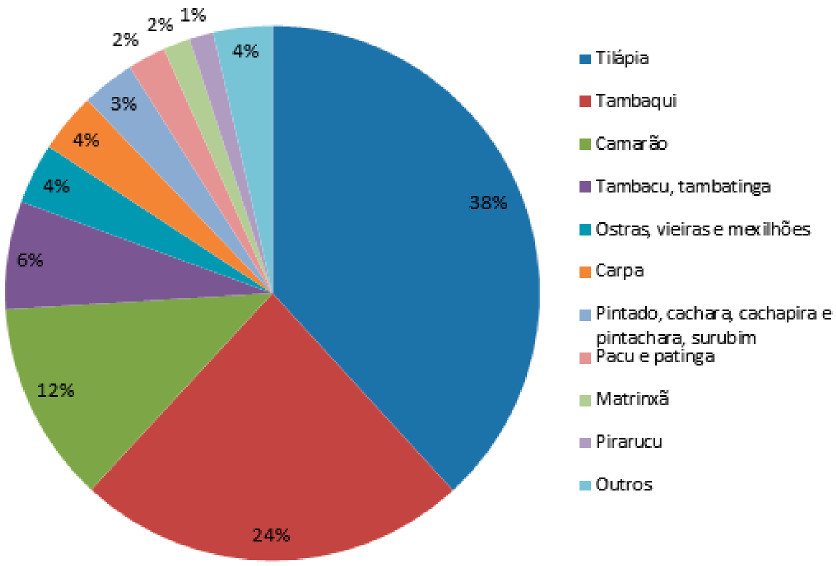


FIGURE 2.12: Brazilian aquacultural production in 2015 per species, in percentages of the total. Source: IBGE/SIDRA.

Brazil operates an international trade product coding system called the Nomenclatura Comun do Mercosul (NCM). The standard import duty on almost all live, fresh and frozen sea fish, including fillets, is 10%. Beside the import duty on the product, Brazilian importers are subjected to three other fees: two social-contribution fees (PIS[9]/COFINS[10], totaling around 9%) and the circulation fee (ICMS[11], which varies from state to state, with an average of approximately 18%). The import duty is charged on the customs value (cost, insurance and freight) of the product, the PIS/COFINS taxes are charged on the customs value *plus* the import duty, and so forth (Graham, Santos, and Correa, 2013).
There are important difference that separates Norway and Chile when it comes to exporting seafood to Brazil: currently there is a 0% import tax from Chile (Mercosur agreement). Further, exports from Chile are not subjected to customs duties or VAT at home. On the other hand, to export fish and fish products from Norway, the exporter must first of all be registered with the Norwegian Seafood Council AS

[9]The PIS (Program of Social Integration) is intended to finance the unemployment insurance system.
[10]The COFINS (Contribution for the Financing of Social Security) is intended to found social security.
[11]ICMS is a tax on sales and services and applies to the movement of goods, transportation, communication services and other general supplyiong of goods.

(NCS). The annual registration fee is NOK 15 000. Secondly, exporters are subjected to a market fee and a research fee, which are calculated as a percentage of the FOB[12] value of the exported products. The fee varies according to the type of species and product category. The current rate[13] for whole salmon is 0.6% of FOB value, and 0.3% of FOB value for processed products.

2.2.1 Brazil's Economy

From being one of the fastest growing economies between 2000 - 2012, with an annual GDP growth rate of over 5%, the country entered a recession in 2014. A country with an estimated US $21.8 trillion worth of natural resources (Capital Invest, 2018) which includes great amounts of uranium, gold, iron and timber.
The first quarter of 2017 was the first time since the start of the recession that Brazil's economy showed sign of recovery, with a 1% positive GDP growth (Xuequan, 2017).

Over a period spanning the mid 1990s to the beginning of this decade, Brazil emerged as a leader among developing nations, increasingly influential in geopolitical and economic terms. From the perspective of developing countries striving to achieve success, the point of attraction represented by Brazil's achievements during this period are multiple: the productivity of its agriculture as a global export leader; low dependence on non-renewables; a sizable and effective National Development Bank, the stability of macroeconomic policy; a high tax to GDP ratio providing resources for development; and innovative policies like the *Bolsa Famìlia*[14] (Afonso, Araújo, and Fajardo, 2016). The creation of the present currency (the Real plan) in 1994 may be considered a watershed moment. Previously Brazil's was an economy marked by hyperinflation, and which had already undergone a moratorium on foreign debt and seizure of internal savings, and which suffered from a distinct lack of fiscal discipline. Following the introduction of the Real, Brazil's economy ultimately settled into controlled inflation and rebalanced external and public accounts (Giambiagi, 2008).

In the 2000s, propelled by surging demand for key export commodities, Brazil began to generate a large trade surplus. By 2011 this had reached almost US$ 30 billion and a series of such surpluses had enabled the accumulation of significant international reserves (US$ 352 billion by 2011). The build-up of such reserves was assisted by a significant surge in the net inflow of foreign direct investment throughout the late 1990s and into the 00s.

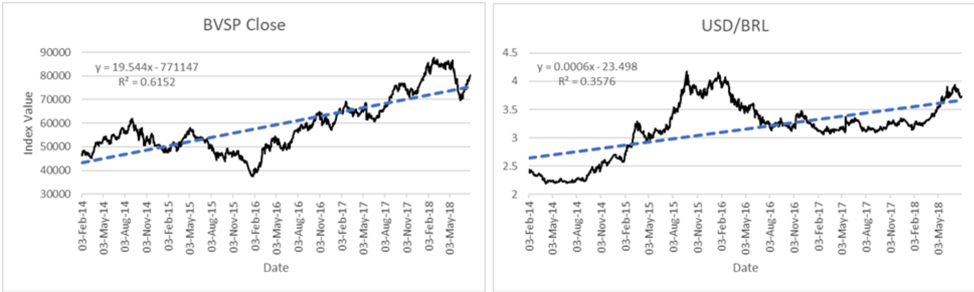
After 2011 the picture changed. Between 2011 and 2013 annual GDP growth slipped from 3.9 to 2.7%, with growth of just 0.1% being realized for 2014. For 2015 GDP contracted by 3.8%. Worryingly, the slump in growth was being accompanied by a surge in inflation: for 2015 consumer price inflation for the year reached 9.01%, well above the central target of 6.5%. Supplementing the gloomy economic picture has been a rise in political uncertainty (Afonso, Araújo, and Fajardo, 2016). As seen

[12] FOB denotes "free on boeard". FOB value is value of goods excluding carriage, insurance and freight, i.e. roughly speaking, the domestic price in the country of origin.

[13] As of 1. January 2018.

[14] Bolsa Familia is a social welfare program, part of the Fome Zero network of federal assistance programs. It provides social aid to poor Brazilian families, in part by incentivising recipient families to ensure that their children attend school. The program was formed in 2003 as a derivative of program *Bolsa Escola*, and by February 2011 26% of the Brazilian population was covered by the program.

in figure 2.13 the BOVESPA Index[15] reached a local minimum in the beginning of 2016.



(A) Closing price for the Bovespa Index, best known as IBOVESPA.

(B) Exchange rate of Brazilian Real versus US Dollar.

FIGURE 2.13: Period 03.02.14 - 30.07.18. Source: Yahoo finance and Investing.com

This was likely a result of the at that time ongoing political crisis in Brazil centered around former President Dilma Rousseff. It all started in March of 2015 with the massive corruption scandal including Petrobas state oil company. In August same year, hundreds of thousands of protesters organized marches and demanded President Rousseff's resignation, blaming her and her and the leftist Worker's Party over alleged large-scale corruption and looming secession. In December, the Congress of Brazil agrees to launch impeachment proceedings against her.
In April 2016, unemployment reached 11.2% having risen for the fourth consecutive month and having attained a level much above the record low of 4.3% achieved in December 2013. According to data provided by IPEA[16], the number of Brazilians below the extreme poverty line rose between 2012 and 2013 (from 10.08 million to 10.45 million), the first time a rise has been registered since 2003 (Amann and Barrientos, 2016).
In August of 2016 the Brazilian senate voted to remove President Dilma Rousseff from office for illegally using money from state banks to bankroll public spendings. Michel Terner was sworn in to serve the remainder of Roussoff's term, until 1 January 2019 (BBC, 2018).

Thing are currently looking up for Brazil's economy. In a report by OECD (OECD, 2018) they forecast that economic growth will gain momentum during 2019 and 2020 as private consumption, supported by improvements in the labor market (figure 2.14), will increase. But, they do point out that political uncertainty around the implantation of reforms remains significant and could derail the recovery.

[15]IBOVESPA is a benchmark index of about 60 stock that are traded on the B3. IBOVESPA is the total return index comprising the most representative companies in the market, both by market cap and traded volume. It is the benchmark index of São Paulo Stock Exchange. It is the oldest BOVESPA index, and it is being broadcast since 1968. It is composed by a theoretical portfolio that account for 80% of the volume traded in the last 12 months and that were traded at least on 80% of the trading days. The portfolio is revised quarterly in order to keep it representative of the volume traded.

[16]The Institute of Applied Economic Reasearch is a Brazilian government-led research organization dedicated to generation of macroeconomical, sectorial and thematic studies to base governmental planning and policy making.

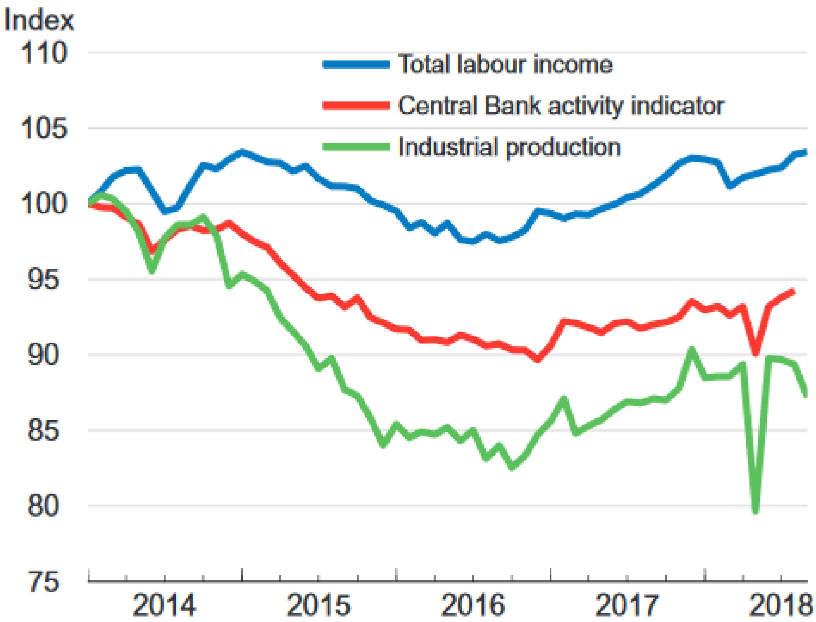


FIGURE 2.14: Activity and wages are recovering in Brazil. Source: (OECD, 2018)

Chapter 3

Background on Fish Species in the Data Series

3.1 Introduction

A total of ten different data series on ten different species or groups of fish sold at the Sao Paulo wholesale market is is analyzed in this thesis. Some are farmed and some are caught wild. This can naturally affect the prices different ways. For example will farmed fish species often be at a more stable supply to the market, but the price can be sensitive to fluctuations in cost of inputs and transport. Wild caught species on the other hand can be at a more uncertain general supply, as well as exhibit seasonal patterns in their prices.
Some of the most consumed local species of fish in Brazil are:

- **Tilapia** *(tilápia)*
- **Sardine** *(sardinha)*
- **Mullet** *(tainha)*
- **Common snook** *(robalo)*
- **Dogfish**[1] *(cação)*

The most consumed imported species in Brazil are traditionally from Norway, Chile and Argentina. However, over the part few years, fish from China and Vietnam are being sold in Brazilian supermarkets. Many question the quality of the fish from Asian countries, since some are taken from polluted rivers. Nevertheless, the low prices of such species have been attracting costumers, especially the ones with lower purchasing power (Innovation Norway, 2014).
Some of the most consumed imported species of fish in Brazil are:

- **Salmon** from Chile
- **Cod** from Norway
- **Hake** from Argentina and China
- **Panga** from Vietnam

[1]The *Squalidae*, also called dogfish sharks or spiny dogfishes, are a family of sharks in the order of *Squaliformes*.

3.1.1 Atlantic Salmon, *Salmo Salar*

Atlantic salmon occur naturally along both east and west coasts of the North Atlantic Ocean where it exists in both anadromous[2] and non-anadromous freshwater resident forms (Klemetsen et al., 2003). In the north-west Atlantic, salmon occur from approximately the Connecticut rivers in the south to Ungava Bay in the north, while in the Northeast Atlantic, salmon range from northern Portugal to rivers emptying into the Barents and White Sea areas of northern Europe (MacCrimmon and Gots, 1979) occupying a diverse array of physical and biological environments (Elliott, Lyle, and Campbell, 1997).
In 2012, Norway and Chile (31 %) made up over 80 % of the total Atlantic salmon production (figure 3.1), followed by Scotland (7.4 %), Canada (5.7 %) and the Faeroe Islands (2.7 %) (Asche et al., 2013). Summing up, this means that the top five Atlantic salmon producing countries in the world stood for 94.6 % of the total production in 2012. The total production have been steadily increasing, and between 1995 and 2014 it more than quadrupled as seen in figure 3.1 below.

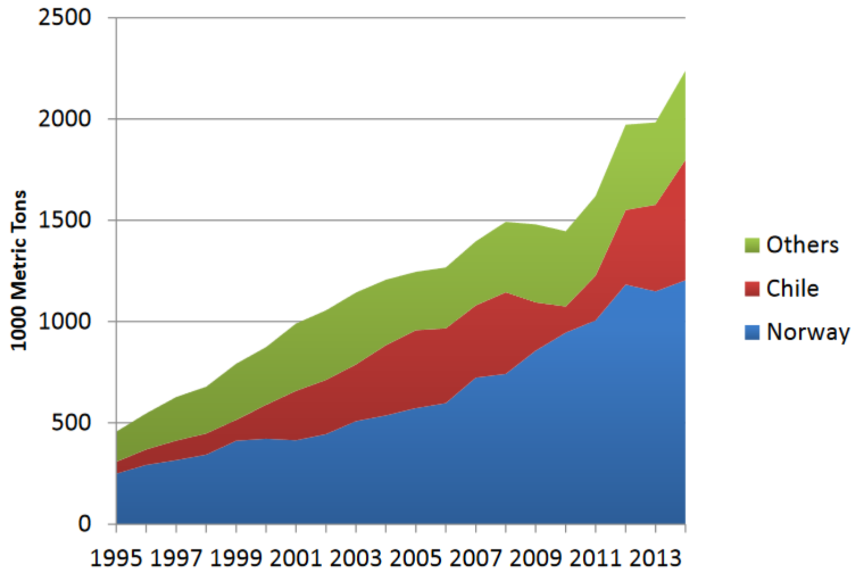


FIGURE 3.1: Atlantic salmon production by country. Source: (Fischer, Guttormsen, and Smith, 2017)

Atlantic salmon was first domesticated in the 1960s in Norway. Salmon are typically bred in fresh water (often closed systems) and, after juvenile stages, raised to market size in net pan enclosures in the natural environment (most favorably in fjords that allow water exchange with the surrounding marine ecosystem but provide protection from storms and waves) (Fischer, Guttormsen, and Smith, 2017). The Atlantic salmon is iteroparous, meaning it may spawn repeatedly, as opposed to most species of Pacific salmon (*Oncorhycus*), which are semelparous and die after only one spawning (Schaffer and Elson, 1975). In aquaculture, the salmon start life on land in an incubator tray. The roe is fertilized in freshwater and is incubated at a constant temperature for 80 days before hatching. After hatching, the fry nourish themselves on the yolk sac which they have on their stomachs. When the yolk sac has been consumed, they change to being fed. This process occurs four to six weeks after hatching. When they begin to eat feed, they are moved to larger freshwater

[2] A migratory fish that lives in the sea and breeds in fresh water.

tanks. After 10–16 months in freshwater, the salmon are ready to be put in the sea. At this stage, each fish weighs between 60 and 100 g. Before they are put into the sea, they must undergo a smoltifi cation process. This process enables the fish to live in saltwater, and then it is called a smolt. The salmon mature in pens located in the ocean and fjords. They stay in the pens for 14–22 months until they reach a favorable slaughter weight (4–6 kg). Then they are shipped in well-boats to processing facilities, where they are slaughtered and processed (Norwegian Seafood Council, 2018).

3.1.2 Tilapia, *Cichlidae*

Among cultured fish species in the world, tilapia rank third in terms of production, only after carps and salmonids. The total world aquaculture production reached almost 2.8 million tonnes in 2008, and Brazil alone produced 150 000 metric tonnes in 2015.

Tilapia are freshwater fish belonging to the family *Cichlidae*. They are native to Africa, but were introduced into many tropical, subtropical and temperate regions of the world during the second half of the 20th century (Pillay and Kutty, 2005).

In term of modern aquaculture, tilapia has been farmed for a long time. Global production was over 1500 tonnes in 1950 and passed 12 000 tonnes in 1970. In 2008, China was the largest producer (1.1 million tonnes) with about 40% of production, followed by Egypt, Indonesia, the Philippines, Thailand and Brazil (Asche and Bjorndal, 2011).

Tilapia (*Tilapia rendalli*) was first introduced to Brazil in the 1950s to control macrophytes (aquatic plants) in reservoirs. In the 1970s the first species of tilapia, Nile tilapia, specifically targeted for human consumption was introduced to reservoir of the Northeast of Brazil as a mean of sustenance for families and individuals living in the area.

The first commercial production of tilapia in Brazil started in the 1990s, and has grown somewhat exponentially since then, as shown in figure 3.2. Todays tilapia in production are mainly hybrids of multiple species, specifically bred to control for qualities like taste and color of flesh.

Tilapia is the main farmed fish species - accounting for more than 50% of total production. Though farmed all over the country, the largest Tilapia production clusters are concentrated in the west region in the State of Paranà where they are brought up in excavated pounds and in large reservoirs located in the Southeast and Northeast of Brazil (net cage) (Innovation Norway, 2015).

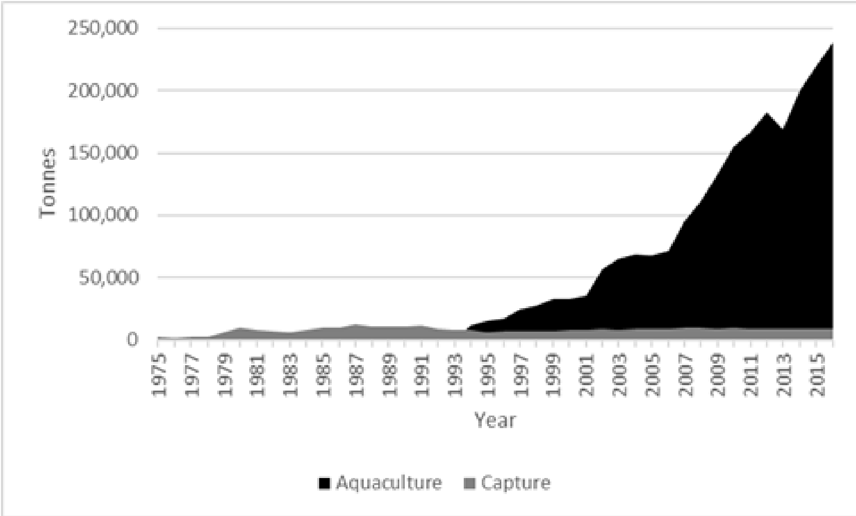


FIGURE 3.2: Historical yearly total production of tilapias from aquaculture and capture in Brazil, all species. Source: FAO(2018)/FishstatJ

As figure 3.2 shows, the majority of tilapia in Brazil comes from aquaculture. Only a tiny fraction actually comes from wild capture. Tilapia grow fast, and can reach marketable size of 500-800g in as little as 3 months. Relative to quantity produced, only a limited share is traded internationally. Although increasing, in 2008 this number was about one third of total production. One of the main reasons for this is that a majority of the tilapia production is in developing countries.

3.1.3 Spotted Sorubim, *Pseudoplatystoma Corruscans*

Sorubim are large catfish found in South America in the Amazon Basin, Sao Francisco, and Paraná river systems. They inhabit river channels, floodplains and larger rain forest streams in both running and still water. Spotted sorubim, *P. corruscans* (Spix & Agassiz, 1829), is important for Brazilian aquaculture, as fingerlings created by crossbreeding of this species with the barred sorubim, *P. reticulatum* (Eigenmann & Eigenmann, 1889), are reared in fish farms across Brazil (Naldoni et al., 2009). This hybrid fish is called "pintado" or "sorubim". It is sold in the Brazilian market, but also exported to several countries (Mar and Terra, 2018). What make the sorubim an important fish species in the Brazilian aquaculture is due to its characteristics as high growth and carcass yield (>50%), absence of intramuscular spines, high commercial value and consumers (Smerman et al., 2002; Santos and Oba, 2009). Note, figure 3.3 only show the historical capture and aquaculture production of the specie spotted sorubim as this was the only one available.

The sorubim is carnivorous and *P. corruscans* can reach a maximum documented length of approximately 160 cm and 100 kg (Froese & Pauly, 2011). *P. reticulatum* on the other hand will reach a max length of about 100 cm, with a corresponding weight of about 70 kg.

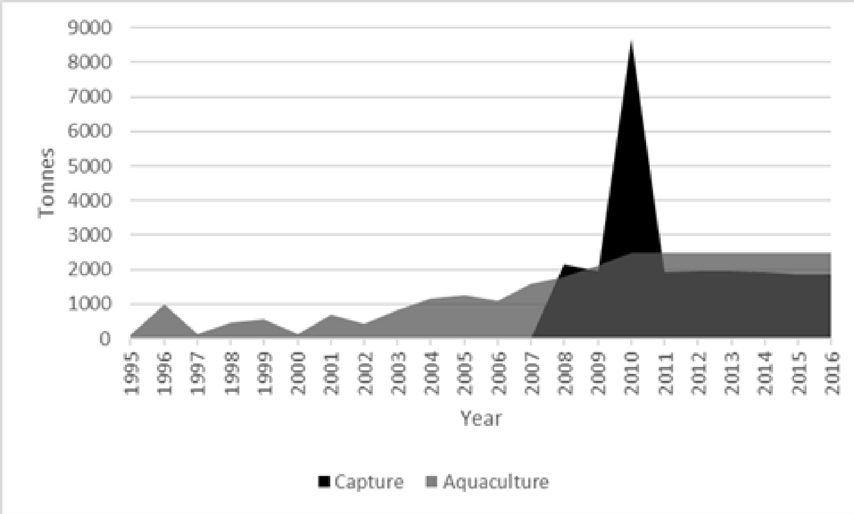


FIGURE 3.3: Historical yearly total production of Spotted sorubim from aqua culture and capture in Brazil. No updated aquaculture data exist after 2010, and the last two years values on capture are estimates. Source: FAO(2018)/FishstatJ

The aquaculture production of sorubim, along with other freshwater cultivated species like tilapia, have at times in the past been plagued by outbreaks of streptococcosis[3]. In the worst cases the losses can exceed 80% (Fukushima et al., 2017).

3.1.4 Weakfish, *Sciaenidae*

Sciaenidae, also known as croakers and drums, is a large family of percidae fishes with about 280 species in 90 genera worldwide that range in size from 10 - 200 cm total length. They are primarily tropical and warm temperate coastal marine fishes; with some confined to freshwater rivers. They are a major fishery resource in Brazil; constituting 22% of marine and 9% of freshwater fishery landings. Sciaenidae are subjected to heavy fishing pressure throughout Brazil, but habitat alteration is also an important threat to regional populations. Brazilian Sciaenids are at low to moderate risk of extinction; with the exception of the endangered Southern black drum (*Poganias cromis*) and two near threatened freshwater croakers.

Sciaenidae are popular food fishes in Brazil with moderate pricing in local markets, and exploitation is concentrated in a few high value or very abundant species (figure 3.4). The medium to large weakfishes acoupa weakfish, green weakfish (*Cynoscion acoupa, C. virescense*) and the King weakfish (*Macrodon ancylodon*) are the most targeted species in northen Brazil states (Maranhão, Pará and Amapá). Most of these catches are shipped to metropolian markets in the south (Chao et al., 2015).

[3]Streptococcosis is a general name for a variety of diseases caused by a group of bacteria called Streptococcus.

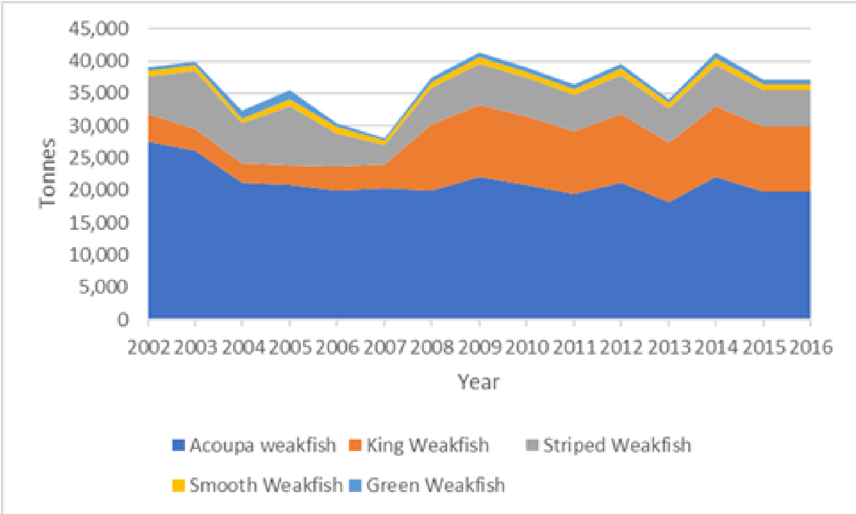


FIGURE 3.4: Historical yearly capture of the most common weakfishes in Brazil. Note that data for 2015 and 2016 are based on estimates, for all species. Source: FAO(2018)/FishStatJ

Sciaenids often are found at the interface of estuaries[4] and coastal marine areas, and/or locally migrate between flood plains and river channels. Most marine Sciaenids use estuarine environments as nursery grounds, or move along the near shore and river margins seasonally for reproduction (dry season from April to September). Sciaenids often form large aggregations during spawning migration, which make them extremely vulnerable to overfishing (Chao et al., 2015).

3.1.5 Flatfish, *Pleuronectiformes*

Flatfishes are predators, normally associated with the substratum, reflecting their benthic feeding habits and the ability to bury themselves (Gibson and Robb, 1992). They have the capacity to camouflage as a tactic to catch their pray, or to escape predation (Gibson, 2005).

The flatfishes constitute important commercial and recreational fisheries throughout the Atlantic from the deep Arctic to the southern hemisphere and around the coasts of southern Africa and south America. They are among the most productive demersal[5] fisheries from the commercial view point in the world. Although flatfishes account for a little amount of annual trawl-fish catch in comparison to other demersal Atlantic fisheries such as cod and hake, they are by far the most valuable fish per unit weight landed. They are regarded as "fine fishing" due to their value as food fish, and as a consequence, the price in the market is high (Diaz De Astarloa and Munroe, 1998; Diaz De Astarloa, 2002). Approximately 45 flatfish species belonging to six Families occur in the southwest Atlantic southward to the Amazon river. Not all of them are of commercial importance due to small size or either low abundance. Only the *pleuronectids* and *paralichthyids* are the most economically important because they are very tasty flatfishes and the fish products have a high price in the market.

The main regions of Brazilian flatfish fisheries, for the species of Patagonian flounders *P. patagonicus* (Jordan, 1889) and mud flounders *P. orbignyanus* (Valenciennes,

[4]Partially enclosed body of brackish water with one or more rivers or streams flowing into it, and with free connection to the open sea.

[5]Demersal fish live and feed near the bottom of seas and lakes (the demeral zone).

1839), occur in the southeastern and southern regions. The main fishing season for flatfish fishing is between fall and spring (Diaz De Astarloa, 2002).

3.1.6 Common Snook, *Centropomus Undecimalis*

Common snook, also known as the sergeant fish orròbalo, and Cambriaçu or Bicudo or Canjurupeba in Portuguese, are important high-level carnivorous in tropical and subtropical coastal marine waters, estuaries, and rivers. The species ranges in western Atlantic ocean and Gulf of Mexico from central Florida and southeastern Texas southward to Rio de Janeiro, Brazil, and those Caribbean and Antillean islands having permanent freshwater sources joining the sea (Rivas, 1986). Common snook are euryhaline[6] and semi-catadromous[7]. Adults are generally found in rivers and inland waters during winter (Taylor et al., 1993), but during summer they move into saline and estuarine waters to spawn. Common snook are an important food resource for Central and South American countries (figure 3.5) (Lemos, Netto, and Germano, 2006) and a valued gamefish in Florida (Marshall, 1958).

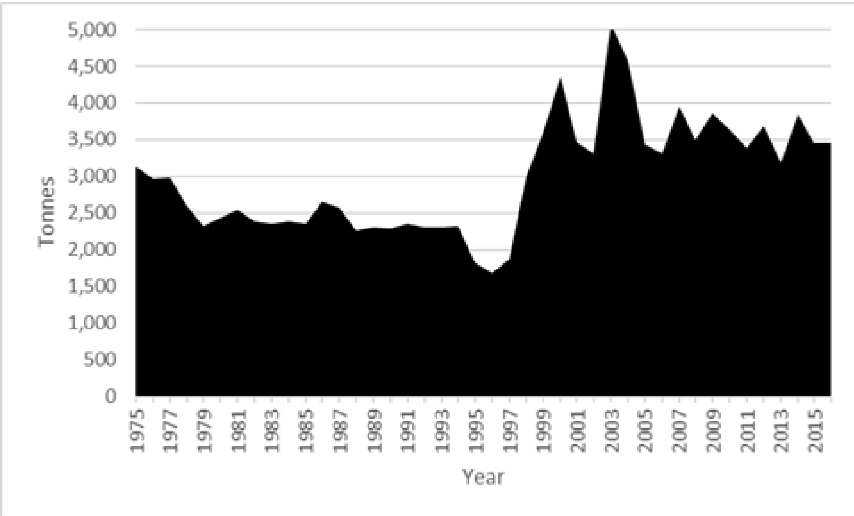


FIGURE 3.5: Historical yearly total production of snooks(robalos) *nei* from capture in Brazil. Source: FAO(2018)/FishStatJ

One of the largest snooks, *C. undecimalis* (Bloch, 1792), grows to a maximum length of 140 cm, but commonly 50 cm, and the IGFA[8] world record is 24.32 kg.
The common snook's spawning season appears to span the months of April to October, with the peak spawning occurring during July and August (Tucker and Campbell, 1988). Spawning typically occurs in near-shore waters with high salinities. Following the spawning period, the juveniles then migrate to the brackish waters of nearby estuarine environments. When these juveniles mature, they return to the higher-salinity waters of the open ocean to join the breeding population (Gracia-López, Rosas-Vázquez, and Brito-Pérez, 2006).

Although Florida have had, at times, quite extensive regulation on its common snook population, there is'nt much evidence that Brazil have done the same. For example, Andrade et al. (Andrade, Santos, and Taylor, 2013) observed in their study

[6]Euryhaline organisms are able to adapt to a wide range of salinities.
[7]Fish that migrate between sea and fresh water.
[8]The International Game Fish Association (IGFA) is the leading authority on angling pursuits and the keeper of the most current World Record fishing catches by fish categories.

from bay, Guatemala, that fishermen there wasn't size-selective with regard to their catch of common snook. Also, fishers there stated that common snook fishery had a strong seasonal component, with peak in October.

3.1.7 Mullets, *Mugilidae*

The Mugilidae, commonly known as mullets, includes 14 genera and 64 valid species (Thomson, 1997) which inhabit marine inshore, estuarine and freshwater environments in tropical, subtropical and temperate regions (Harrison and Howes, 1991). They are popularly known in Brazil as tainha, parati, curimã, caìca and pratiqueira (Menezes, 1983; Menezes and Figueiredo, 1985).
Menezes (Menezes, 1983) mentions three popular species for the Southern Brazilian waters: *Mugil curema* - also known as White mullet, *M. gaimardianus* - also known as Redeye mullet, and *M. platanus* - also known as Striped mullet. In addition there is *M. liza* - also known as the Lebranche mullet or the Liza. The number of mugilid species reported for the northern coast of South America, including the entire Brazilian coast, varies between 7 and 8 (Cervigón et al., 1993; Thomson, 1997; Menezes et al., 2003). The discrepancies are related to *Mugil hospes*, *M. cephalus*, *M. platanus* and the suppressed name of *M. gaimardianus*.

Species of Mugilidae are an important economic resource supporting several small communities in Argentina and Brazil (figure 3.6) through fishing. They utilize estuarine nursery habitats where they largely feed on plant material obtained by grubbing through bottom detritus (Cervigón et al., 1993). From April to August each year, big schools of mullets migrate northwards along the coastline of Brazil. Further, mullets have been considered to be among the most promising species for coastal aquaculture (Khemis et al., 2006).

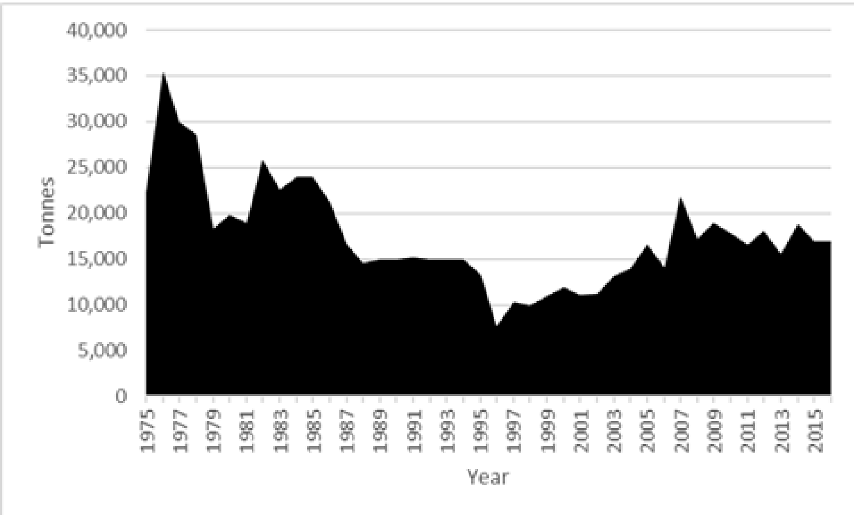


FIGURE 3.6: Historical yearly capture between 1975 and 2016 of mullets *nei.* Source: FAO(2018)/FishStatJ

Artisanal[9] mullet fishing is a very important cultural event both in southern and southeastern Brazil, not only for its economic importance, but also for the social role it plays as it requires organized practices among local community members, thus

[9]Various small-scale, low-techology, low-capital, fishing practices undertaken by individual fishing households (as opposed to commersial companies).

strengthening their sense of belonging (Diegues, 2004). In Laguna, the mullet season is also eagerly awaited because of a particular event: the cooperative fishing that involves humans and dolphins (*Tursiops truncatus*). The artisanal fishermen and the dolphins are the principal actors of this fishing practice in which both species take advantage of the same prey (Simões-Lopes, Fabián, and Menegheti, 1998; Pryor and Lindbergh, 1990). According to Simoes-Lopes (Simões-Lopes, Fabián, and Menegheti, 1998), the behavior of dolphins and fishermen in cooperative fishing are distinctly ritualized. The fishermen can differentiate the movements of dolphins, recognizing the right moment to throw their nets (Peterson, Hanazaki, and Simões-Lopes, 2008). Dolphins, in turn, drive mullet schools towards the fishermen, who act as a dynamic barrier, unraveling the schools and spreading the fish, as the fishermen cast their nets. Disoriented and isolated fishes are more easily captured by the dolphins (Simões-Lopes, Fabián, and Menegheti, 1998).

3.1.8 Sharks

Brazil currently ranks as the 11th producer and 1st importer of shark meat around the world. Large oceanic sharks, as the blue shark (*Prionace glauca*), short fin mako (*Isurus oxyrinchus*), white-tip shark (*Carcharhinus longimanus*) and others, are highly migratory species that have no direct relation to the sea-floor, spending most of their life cycle in the open ocean, being susceptible to multiple fishing fleets (Dulvy et al., 2008).

Brazil imports almost the same amount of blue sharks as its total production for the entire group of cartilaginous fishes (i.e sharks, rays, skates and chimaeras). Brazil absorbed practically all of Uruguay's blue shark production from 2002 to 2012. Other significant exporters of shark meat to Brazil according to the reviewed data are, in the following order, Spain, Taiwan Province of China and Portugal (Dent and Clarke, 2015).

Shark meat is broadly sold as "cação" in Brazil, a popular name derived from "cazón" (from the Spanish meaning dogfish) to improve consumer acceptance (Bornatowski, Braga, and Barreto, 2017). A recent study demonstrated that Brazilians do not know they are eating sharks. In a large city in southern Brazil, more than 70% of surveyed consumers were unaware that "cação" refers to sharks, and more than half of the respondents claimed to have already eaten "cação" but have never eaten sharks or rays (Bornatowski et al., 2015).

Overall, shark meat is considered low-value seafood (priced around U$2.50/kg) when compared to more common fish and is usually traded without proper labeling (Barreto et al., 2017). The total yearly capture of sharks in Brazil have been declining over the past years (figure 3.7). This is likely due to overfishing in the past (Dulvy et al., 2008) which has put a strain on the stock of many popular shark species.

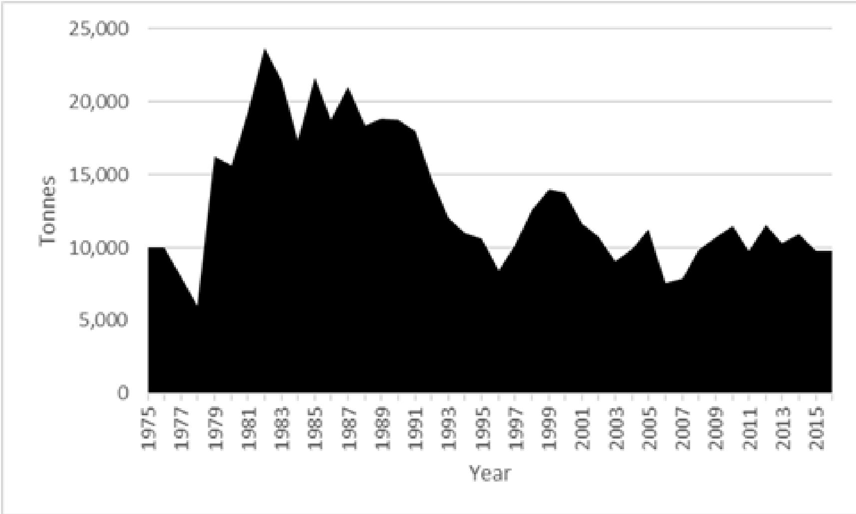


FIGURE 3.7: Historical yearly capture in Brazil between 1975 and 2016 of sharks, rays and skates grouped together. Source: FAO(2018)/FishStatJ

Between 2010 and 2012, Brazil reassessed elasmobranchs[10] following the IUCN's[11] system, resulting in 33% of species in threatened categories (VU = 19; EN = 8; CR = 28), and 36% for which the available information did not allow for any sort of categorization (i.e. Data Deficient-DD) (Rossi-Santos and Finkl, 2018).
Twenty-four percent of all known species of elasmobranchs that are not data deficient are currently threatened with extinction (Dulvy et al., 2014).

3.1.9 Sardine, *Sardinella brasiliensis*

Sardines are found in coastal waters, often forming compact schools, and commonly reach a length of 20 cm. The Brazilian sardine, *Sardinella brasiliensis* (Steindachner, 1879), together with other *Sardinella app.*, accounts for five percent of the worlds production of marine fish, but it represents a much higher proportion of the total value of the catch (FAO, 2016). The Brazilian sardine is not only ecologically important but is also one of the most commercially important fishery resource caught along the south-eastern Brazilian Bight[12] (Dallagnolo, Schwingel, and Perez, 2010). The Brazilian sardine plays an important historical role in Brazilian marine fisheries, attested by shares of up to 47% of total annual marine catches (Paiva, 1997).
Commercial catches of the Brazilian sardine began in the late 1950s and had quick growth in the 1960s (figure 3.8), reaching a peak of 228,000 tons in 1973 (Cergole and Rossi-Wongtschhowski, 2002). However, in 2011, production was only 75,223 tons (Baloi et al., 2017). It is currently captured by various fleets for use in canning industry and extensively as live bait for skipjack tuna fishery, and its availability varies seasonally due to overfishing and environmental changes (Santos and Rodrigues-Ribeiro, 2000).

[10]Sharks, skates and rays
[11]International Union for Concervation of Nature
[12]The South Brazil Bight (SBB) is a large urban, industrial and fishery area on the Brazilian coast, extending from Cabo Frio in the north to Cabo de Santa Marta in the south, and covering an area of 150 000 km2.

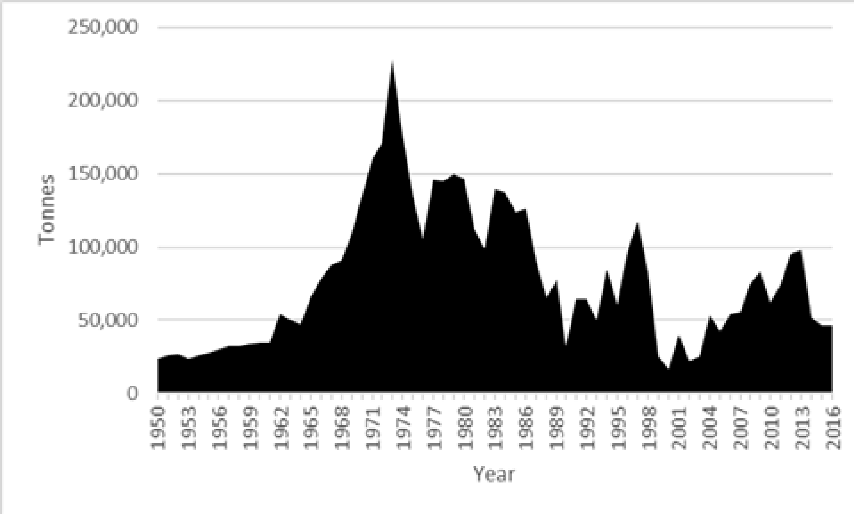


FIGURE 3.8: Historical yearly capture of *Sardinella brasiliensis* in Brazil. Note, data from 2015 and 2016 are based on estimates. Source: FAO(2018)/FishStat

A combination of overfishing and adverse environmental conditions during the reproductive season has been pointed to as the main cause of the progressive decline of *S. brasiliensis* landings since the end of the 1970s, including two successive fishery collapses in 1990 and 2000 (Cergole and Rossi-Wongtschhowski, 2002; Jablonski and Legey, 2004). In fact, most sardine populations are prone to strong inter-annual fluctuations, which are related to alternating periods of favorable and unfavorable conditions for spawning and recruitment (Klyashtorin, 2001; Takasuka, Oozeki, and Aoki, 2007). For example did Sunye and Servian (Sunye and Servain, 2002) find that the seasonal landings of the Brazilian sardine within the South Brazil Bight are influenced by the distribution of less saline waters, the coastal waters and sub-Antarctic waters. This and similar mechanisms has been supported by others, like Soares et al. (Soares et al., 2011) who showed evidence of a link between extreme events of Brazilian sardine catches and the ocean-atmosphere interaction in the southwest Atlantic.

3.1.10 Tuna

Tuna fisheries in Brazil started in 1956 in Recife City, Pernambuco State, with a fleet of a Japanese companies, targeting yellowfin and albacore in the tropical waters for export to the canning industry (Paiva, 1961; Amorim, 1976). From the end of 1970 the the tuna industry in Brazil grew rapidly (figure 3.9), and the principal specie caught have been the skipjack tuna (*Katsuwonus pelamis*) averaging roughly 20 000 metric tonnes per year.
The principal market of tunas frequently is divided into tropical tunas, such as bigeye (*Thunnus obesus*), skipjack, and yellowfin tuna (*T. albacares*), and temperate tunas such as albacore (*T. alalunga*), Atlantic bluefin tuna (*T. thynnus*), Pacific bluefin tuna (*T. orientalis*), and southern bluefin tuna (*T. maccoyii*) (Majkowski, 2007).
Further, a distinction can be made between species like the skipjack and yellowfin that are used mostly for canning, and will reach lower price than tuna used for sashimi such as bluefin and bigeye.

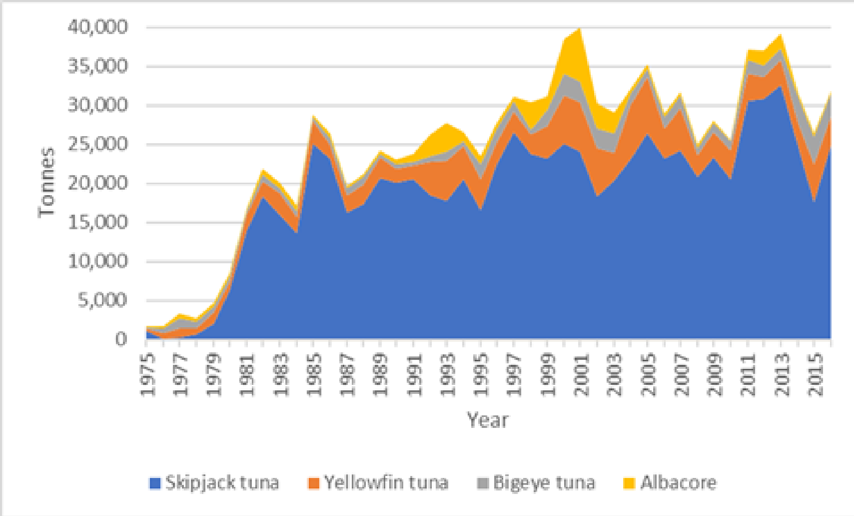


FIGURE 3.9: Historical yearly capture of the most common species of tuna in Brazil. Source: FAO(2018)/FishStat

Most tuna and tuna-like species are highly mobile and in many instances undertake extensive migrations. Skipjack tuna can be found in tropical, subtropical, and warm temperate waters. It migrates extensively between the central Pacific and the coastal waters of both the Eastern Pacific and Japan. Moreover, it can be found from Massachusetts to Brazil, including the Gulf of Mexico and the Caribbean in the Atlantic.

Southern bluefin tuna, which live only in the southern hemisphere, migrate from spawning areas around Australia to the Atlantic, Pacific, and Indian Oceans (Herpandi, Rosma, and Wan Nadiah, 2011).

The Atlantic bluefin tuna, also known as northern bluefin tuna, is a subtropical pelagic fish. It is distributed mainly in Western Atlantic areas such as Canada, the Gulf of Mexico, and the Caribbean Sea to Venezuela and Brazil. In addition, it is found around the Lofoten Islands off Norway to Canary Island, the Mediterranean, and the southern part of he Black Sea.

Albacore is a highly migratory cosmopolitan[13] fish that can be found in tropical and temperate waters of all oceans and the Mediterranean Sea. Although yellowfin and bigeye tuna undertake migrations of several thousand miles, these migrations are not as extensive as those of the other principal market species. Many of the secondary market species also appear to be less migratory than the principal market species. However, some species of billfish migrate several thousand miles (Herpandi, Rosma, and Wan Nadiah, 2011).

Blackfin tuna occur only in the western Atlantic Ocean, from Martha's Vineyard (US) to Rio de Janeiro (Brazil), including the Gulfof Mexico and the Caribbean (Collette and Nauen, 1983). Zavala-Camin and Antero da Silva (Zavala-Camin and Silva, 1991), however, recorded this species as far as 31S (southern Brazil). Off southern and northeastern Brazil, blackfin tuna are by-catch in longline fisheries targeting albacore, bigeye, yellowfin, swordfish (*Xiphias gladius*), and sharks (Freire, Lessa, and Lins-Oliveira, 2005).

[13]Meaning that it has worldwide distribution.

3.2 Relevant Past Studies on Market Integration of Salmon

Gordon, Salvanes & Atkins (Gordon, Salvanes, and Atkins, 1993) and Asche, Gordon & Hannesson (Asche, Gordon, and Hannesson, 1998) found no significant interaction between salmon and other species on the French market.

Asche and Sebulosen (Asche and Sebulonsen, 1998) looked at whether there exists different regional markets for salmon, and in particular whether the UK market is separate from the market in continental Europe. They did this by investigating the relationship between Norwegian and Scottish salmon both in France and in the UK by the method of co-integration tests (using both Engle and Granger test, and Johansen test).

Their main result was that was no indications of the UK being a separate market for salmon. Because there was no barriers to trade between France and other continental European countries, the implication is that there is one common market for salmon in EU. From that, the reason why some countries choose to supply some markets almost exclusively is simply down to transportation costs.

S. Jaffry et al. (Jaffry et al., 2000) investigated the interaction between salmon and wild caught fish species in Spain. Spain was at that point, and still is, one of the most important markets for fish within Europe and the world, and had seen a substantial increase in its demand for salmon. Through bivariate cointegration tests they found a lack of significant interaction between salmon and and other species of fish. Through a multivariate analysis they identified a sub-market potentially containing salmon, exclusion tests revealed that salmon is at most only a weak substitute for the other key species in the Spanish market, with no significant interaction being identified.

A possible explanation for this low degree of interaction may be that salmon is still regarded as being a luxury item and has high seasonality with peak consumption at Christmas and Easter seasons (BjØrndal, Salvanes, and Andreassen, 1992). Salmon is therefore not comparable to regular "table fish" species.

The results of this study indicate that there is evidence of integration between certain species within the Spanish fish market, but but no evidence to link farmed salmon with other wild caught species. This may be good news for both commercial fishers, who may not face decreasing prices as supply of farmed salmon increases, and salmon producers, who also may not face competition with other species if landings increase.

Asche and Sikveland (Asche and Sikveland, 2015) observed that prices and profits for Norwegian producers increased in response to the reduction in supply that resulted from the Chilean disease challenge, hence suggesting that the supply effect was dominant (Asche, Cojocaru, and Sikveland, 2018).

The link between the American salmon market and the rest of the world is weaker than the European and the Asian markets (Asche, Bjørndal, and Young, 2001), and Landazuri-Tveteras et al. (Landazuri-Tveteras et al., 2017) indicate that substitution is weaker between different product forms. This is important because Chile is typically the main supplier to the American market (with Canada as the second-largest supplier), whereas the other main producers, Norway and Scotland, primarily supply Europe and Asia. Moreover, fillets are the most important product form from Chile, whereas most other exporters have whole salmon as the clearly most important product form (Asche, Cojocaru, and Sikveland, 2018).

Asche et al. (Asche, Cojocaru, and Sikveland, 2018) used the market shock generated by the Chilean salmon crisis of 2008 to 2010 to investigate the market integration of the salmon market. Their results indicated that the Chilean salmon products are well integrated into the global market. Moreover, they found that the Norwegian prices leads the Chilean prices, indicating that Chilean salmon prices are determined at the global market level.The lack of impact of the Chilean disease shock on priced determination for salmon provides strong evidence of a highly integrated salmon market, where trade patterns shift to maintain a stable relative price.

Chapter 4

Statistical Theory

4.1 Time Series

The background on this first section for the most part come from the two books (H. Shumway and Stoffer, 2011) and (Lütkepohl and Krätzig, 2004).
A time series is a series of data points indexed in time order, whereas cross-sectional data is collected by observing multiple subjects at a fixed point in time. The main difference between the two then being that although both methods relate to the study of set populations, when time becomes a factor, the parameters mean and variance (heteroskedasticity) may vary in that population.

In order to provide a statistical setting for describing the character of data that seemingly fluctuate in a random fashion over time, we assume a time series can be defined as a collection of random variables indexed according to the order they are obtained in time (H. Shumway and Stoffer, 2011).

4.1.1 Introduction

Some important questions to first consider when first looking at a time series are (PennState, 2018):

- Is there a **trend**, meaning that, on average, the measurements tend to increase (or decrease) over time?
- Is there **seasonality**, meaning that there is a regularly repeating pattern og highs and lows related to calendar time such as seasons, quarters, days of the week, and so on?
- Are there **outliers**? In regression, outliers are far away from your line. With time series data, outliers are far away from your other data.
- Is there a **long-run cycle** or period unrelated to seasonality factors?
- Is there **constant variance** over time, or is the variance non-constant?
- Are there any **abrupt changes** to either the level of the series or the variance?

When this preliminary visual examination of the data is done, we can turn to our basic technical tool for analyzing the data.

The **mean function** of a time series is defined as

$$\mu_{xt} = \mathbb{E}(x_t) = \int_{-\infty}^{\infty} x f_t dx \tag{4.1}$$

The **autocovariance function** measures the linear dependence between two points on the same series observed at different times and is defined as the second moment product

$$\gamma(s,t) = cov(x_s, x_t) = \mathbb{E}[(x_s - \mu_s)(x_t - \mu_t)] \; \forall s,t. \tag{4.2}$$

$\gamma(s,t) = 0$ implies that x_t and x_s are not linearly related.
We can also imagine scenarios where we have multiple time series. In the case that we have two time series, say x_s and y_t, and both have finite variance, the **cross-covariance function** is given by

$$\gamma_{xy}(s,t) = cov(x_s, y_t) = \mathbb{E}[(x_s - \mu_{xs})(y_t - \mu_{yt})] \tag{4.3}$$

Cross-covariance measures the similarity between x_t and shifted (lagged) copies of y_t as a function of the lag. In other words, we can measure the predictability of another series y_t from the series x_s.
Autocorrelation, also known as **serial correlation**, is the correlation of a signal with a delayed copy of itself as a function of delay. Informally, it is the similarity between observations as a function of time lags between them.
The **autocorrelation function (ACF)** is given by

$$\rho(s,t) = \frac{\gamma(s,t)}{\sqrt{\gamma(s,s)\gamma(t,t)}}, \tag{4.4}$$

where $-1 \leq \rho(s,t) \leq 1$ (can be proven using the Cauchy-Schwarz inequality [reference]). If we can predict x_t perfectly from x_s through a linear relationship, $x_t = \beta_0 + \beta_1 x_s$, then the correlation will be +1 if $\beta_1 > 0$ and -1 if $\beta_1 < 0$.
The autocorrelation function can be used for the following two purposes:

1. To detect non-randomness in data.
2. To identify an appropriate time series model if the data are not random.

As with the autocovariance function, the autocorrelation function can be extended to multiple time series. This gives us the **cross-correlation function (CCF)**. For two time series, x_t and y_t, the CCF is defined as

$$\rho_{xy}(s,t) = \frac{\gamma_{xy}(s,t)}{\sqrt{\gamma_x(s,s)\gamma_y(t,t)}} \tag{4.5}$$

In the relationship between two time series, x_t and y_t, the series y_t may be related to past lags of the x-series. The CCF is helpful for identifying lags of the x-variable that might be useful predictor of y_t. The *sample* CCF is defined as the set of sample correlation between x_{t+s} and y_t for $s \in \mathbb{N}$.
A negative value for s is a correlation between the x-variable at a time before t and the y-variable at time t (PennState, 2018).

- When one or more x_{t+s}, with s *negative*, are predictors of y_t, it is sometimes said that **x leads y**.
- When one or more x_{t+s}, with s *positive*, are predictors of y_t, it is sometimes said that **x lags y**.

4.1.2 Stationarity

Stationarity is an important concept in time series because it provides a framework in which averaging makes sense. Unless properties like the mean and covariance are either fixed or "evolve" in a known manner, we cannot average the observed data.

A **strictly stationary** time series is one for which the probabilistic behavior of every collection of values from a multivariate time series

$$\{x_{t1}, x_{t2}, ..., x_{tk}\}$$

is identical to that of the time shifted set

$$\{x_{t1+h}, x_{t2+h}, ..., x_{tk+h}\}$$

That is,

$$Pr\{x_{t1} \leq c_1, ..., x_{tk} \leq c_k\} = Pr\{x_{t1+h} \leq c_1, ..., x_{tk+h} \leq c_k\} \tag{4.6}$$

for all $k = 1, 2, ...$, all time pionts $t_1, t_2, ..., t_k$, all numbers $c_1, c_2, ..., c_k$, and all time shifts $h = 0, \pm 1, \pm 2, ...$

This implies, for example, that the probability the value of a time series sampled hourly is negative at 1AM is the same as at 10AM.

In addition, if the mean function, μ_t, of the series exists, 4.6 implies that $\mu_s = \mu_t \forall s, t$, and hence μ_t must be constant.

This further implies that, if the variance function of the process exists, that the autocovariance function of the series x_t satisfies

$$\gamma(s, t) = \gamma(s + h, t + h)$$

for all s and t and h. We may interpret this result by saying the autocovariance function of the process depends only on the time difference between s and t, and not on the actual times.

The concept of strict stationarity is too strong for most applications. This leads us to the concept of **weakly stationary** (or **second-order**) time series. A weakly stationary time series, x_t, is a finite variance process such that

1. the mean value function, μ_t, is constant and does not depend on time t, and

2. the autocovariance function, $\gamma(s, t)$, depends on s and t only through their difference |s-t|.

From now on when I refer to the term **stationary**, I mean weakly stationary. Stationarity requires regularity in the mean and autocorrelation function so that these quantities (at least) may be estimated by averaging.

The concept of stationarity allows us to simplify our equations to some degree. First, we have that the mean function, $\mathbb{E}(x_t) = \mu_t$, is independent of the time t, we will write

$$\mu_t = \mu \tag{4.7}$$

Secondly, because the autocovariance function, $\gamma(s, t)$, of a stationary series, x_t, depends on s and t only through their difference |s-t|, the **autocovariance function of a stationary time series** can now be written as

$$\gamma(h) = cov(x_{t+h}, x_t) = \mathbb{E}[(x_{t+h} - \mu)(x_t - \mu)] \tag{4.8}$$

where $s = t + h$, and h represents the time shit or lag.

The **autocorrelation function (ACF) of a stationary time series** is written as

$$\rho(h) = \frac{\gamma(t + h, t)}{\sqrt{\gamma(t + h, t + h)\gamma(t, t)}} = \frac{\gamma(h)}{\gamma(0)}. \tag{4.9}$$

Again, $-1 \leq \rho(h) \leq 1 \; \forall h$.
Two time series, say x_t and y_t, are said to be **jointly stationary** if they are each stationary, and the cross-covariance function

$$\gamma_{xy}(h) = cov(x_{t+h}, y_t) = \mathbb{E}[(x_{t+h} - \mu_x)(y_t - \mu_y)] \tag{4.10}$$

is a function only of lag h.
The **cross-correlation function (CCF)** of a jointly stationary time series x_t and y_t is defined as

$$\rho_{xy}(h) = \frac{\gamma_{xy}(h)}{\sqrt{\gamma_x(0)\gamma_y(0)}}. \tag{4.11}$$

4.1.3 Estimation of Correlation

Because analysis is being performed on sampled data and not theoretical models, we must in most cases use estimation to describe the properties the statistical models. Because we typically will not have *iid* copies of time series, say x_t, the assumption of stationarity becomes critical. (må skrives litt om) If a time series is stationary, the mean function 4.7, is constant so that we can estimate it by the **sample mean**

$$\bar{x} = \frac{1}{n}\sum_{t=1}^{n} x_t \; . \tag{4.12}$$

Variance and standard error can be estimated using

$$var(\bar{x}) = var(\frac{1}{n}\sum_{t=1}^{n} x_t) = \frac{1}{n^2}cov(\sum_{t=1}^{n} x_t, \sum_{s=1}^{n} x_s) = \frac{1}{n}\sum_{h=-n}^{n}(1 - \frac{|h|}{n})\gamma_x(h) \; . \tag{4.13}$$

The **sample autocovariance function** is defined as

$$\hat{\gamma}(h) = \frac{1}{n}\sum_{t=1}^{n-h}(x_{t+h} - \bar{x})(x_t - \bar{x}) \; , \tag{4.14}$$

with $\hat{\gamma}(-h) = \hat{\gamma}(h) for h = 0, 1, ..., n-1$.
The **sample autocorrelation function** is defined as

$$\hat{\rho}(h) = \frac{\hat{\gamma}(h)}{\hat{\gamma}(0)} \; . \tag{4.15}$$

The sample autocorrelation function has a sample distribution that allows us to assess whether data comes from a completely random or white series or whether correlation are statistically significant at some lags.

The estimator for **sample cross-covariance function** is given by

$$\hat{\gamma}_{xy}(h) = \frac{1}{n}\sum_{t=1}^{n-h}(x_{t+h} - \bar{x})(y_t - \bar{y}) \; , \tag{4.16}$$

with $\hat{\gamma}_{xy}(-h) = \hat{\gamma}_{xy}(h)$.
Finally, the estimator for the **sample cross-correlation function** is given by

$$\hat{\rho}_{xy}(h) = \frac{\hat{\gamma}_{xy}(h)}{\sqrt{\hat{\gamma}_x(0)\hat{\gamma}_y(0)}} \; . \tag{4.17}$$

Note.

- Under general conditions, if x_t is white noise, then for n large, the sample ACF, $\hat{\rho}_x(h)$, is approximately normally distributed with zero mean and and a standard deviation given by

$$\sigma_{\hat{\rho}_x(h)} = \frac{1}{\sqrt{n}} .$$

- The large sample distribution of $\hat{\rho}_{xy}(h)$ is normal with mean zero and

$$\sigma_{\hat{\rho}_{xy}(h)} = \frac{1}{\sqrt{n}} ,$$

  if at least one of the processes is independent white noise.

4.2 Econometric Specification

Analysis of relationships between prices is a common tool in market integration analysis. This is based on market definitions as old as modern economics (Marshall, 1890; Cournot, 1971).
Over the last two decades, market integration studies have become a common tool when investigating relationships between prices. Most studies are based on the market definition of Stingler (p.85) (Stigler, 1969) who defines a market as, "the area within which the price of a good tends to uniformity, allowance being made for transportation costs," or similar definitions by, for instance, Cournot (1971) and Marshall (1980). Thus, information on the relationship between goods can be gathered from price movements over time (Asche, Gordon, and Hannesson, 2004).
In order to examine whether salmon and other common local species compete in the same market in Brazil, some of the currently most common econometric techniques to test for market integration are applied.

Cointegration between data series imply that there is a linear long-run relationship between them. A linear combination of two or more first-order non-stationary series that yields a stationary series is said to be cointegrating.
For example, for two time series, say x_t and y_t, we say that they are cointegrated if

$$y_t - \gamma x_t = \alpha + \epsilon_t \sim I(0) , \tag{4.18}$$

where α is a constant, γ is a scaling factor, and ϵ_t is i.i.d. $\sim N(0, \sigma^2)$. The determining test in this case would be to test whether $\gamma \neq 0$, i.e. reject $H_0 : \beta = 0$. This would imply constant relative prices, and thus, we could conclude that the prices are cointegrated and belonging to the same market.

4.2.1 Augmented Dickey-Fuller Unit Root Test (Dickey and Fuller, 1979; 1981)

Starting with a simple $AR(1)$ model:

$$y_t = \rho y_{t-1} + \epsilon_t. \tag{4.19}$$

where ρ is a constant and $\epsilon_t \sim N(0, \sigma^2)$. A unit-root is present if $\rho = 1$, and the model would be non-stationary in this case. Subtracting y_{t-1} from both sides of equation

4.19 the model can be rewritten as

$$\Delta y_t = (\rho - 1)y_{t-1} + \epsilon_t = \delta y_{t-1} + \epsilon_t \tag{4.20}$$

where δ is the first-difference operator. In this model (4.20) we test for a unit root by testing if $\delta = 0$ (where $\delta \equiv \rho - 1$). There are three main versions of the test:

1. Test for a unit-root:
   $\Delta y_t = \delta y_{t-1} + \epsilon_t$

2. Test for unit-root with drift:
   $\Delta y_t = \mu_0 + \delta y_{t-1} + \epsilon_t$

3. Test for unit-root with drift and deterministic time trend:
   $\Delta y_t = \mu_0 + \mu_1 t + \delta y_{t-1} + \epsilon_t$

Common for all tests is that the null hypothesis is that there exist a unit-root, $\delta = 0$. The tests have low statistical power in that they often cannot distinguish between true unit-root processes and near unit-root processes where δ is close to zero. This is known as the "near observation equivalence" problem.

The standard Dickey-Fuller (DF) test described above can be extended to autoregressive processes of orders greater than 1. Consider for example a simple $AR(2)$ process:

$$y_t = \mu + \rho_1 y_{t-1} + \rho_2 y_{t-2} + \epsilon_t. \tag{4.21}$$

Through some simple manipulation this equation can be rewritten as

$$y_t = \mu + (\rho_1 + \rho_2)y_{t-1} - \rho_2(y_{t-1} - y_{t-2}) + \epsilon_t \tag{4.22}$$

and subtracting y_{t-1} from both sides gives:

$$\Delta y_t = \mu + \beta y_{t-1} - \alpha_1 \Delta y_{t-1} + \epsilon_t \tag{4.23}$$

where $\beta = \rho_1 + \rho_2 - 1$ and $\alpha_1 = -\rho_2$. The standard Dickey-Fuller model described in equation 4.20 have now been "augmented" by Δy_{t-j}. Generalized for an $AR(p)$ process, the Augmented Dickey-Fuller (ADF) regression model for unit-root testing is given by

$$\Delta y_t = \mu + \beta y_{t-1} - \sum_{j=1}^{p} \alpha_j \Delta y_{t-j} + \epsilon_t \tag{4.24}$$

The null hypothesis for this model is there exist a unit root, $\beta = 0$.

4.2.2 Johansen‘s test (Johansen, 1988; 1991)

The Johansen test can be seen as multivariate generalization of ADF test for unit-root, and is a procedure for testing cointegration of several, say k, $I(1)$ time series. Compared to the also often used Engle-Granger test, which is also based on (augmented) Dickey-Fuller test for unit-root, the Johansen test permits more than one cointegration relationships.

Although Gonzalo (Gonzalo, 1994) presents Monte Carlo evidence that the full information maximum likelihood procedure of Johansen test performs better than others and the test is appropriate when the identification of exogenous variable is not possible at prior, but the Johansen test result is very sensitive in the case of small sample and the use of different lag length (Odhiambo, 2009a).

Let X_t denote an $nx1$ vector, where the maintained hypothesis is that X_t follows an unrestricted vector auto regression (VAR) in the level of the variables

$$X_t = \mu + \sum_{i=1}^{k-1} A_i x_{t-i} + A_k X_{t-k} + \epsilon_t \tag{4.25}$$

where each of the A_i is an $n \times n$ matrix of parameters, μ is a constant term and ϵ_t are i.i.d. residuals with zero mean and contemporaneous covariance matrix Ω (Asche et al., 2009).
The VAR system in equation 4.25 written in error correction form (ECM) is

$$\Delta X_t = \mu + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + A X_{t-k} + \epsilon_t \tag{4.26}$$

with $\Gamma_i = -I + A_1 + ... + A_i,\ i = 1, ..., k-1$ and $A = -I + A_1 + ... + A_k$. Hence, A is the long-run "level solution" to equation 4.25. If X_t is a vector of *I(1)* variables, the left-hand side of (k - 1) elements of equation 6.2 are *I(0)*, and Kth element of 6.2 is a linear combination of *I(1)* variables. Given the assumptions of the error term, the kth element must also be *I(0)*: $AX_{t-k} \sim I(0)$.
Hence, either X_t contains a number of cointegrated vectors, or A must be a matrix of zeros. The rank of A, r, determines how many linear combinations of X_t are stationary. If $r = n$, the variables in levels are stationary; if $r = 0$, none of the linear combinations of X_t are stationary. When $0 < r < n$, there exists r cointegrated vectors - or r stationary linear combinations of X_t. In this case one can factor $\Pi; \Pi == \alpha\beta'$, where both α and β are $n \times r$ matrices, and β contains the cointegration vectors (the error-correcting mechanism in the system, or put differently, what corresponds to γ in equation 4.18), and α the adjustment parameters (Asche et al., 2009).

$$H_0 : r = 0 \tag{4.27}$$

$$H_1 : r > 0 \tag{4.28}$$

Time series are cointegrated only if there exists a statistical significant relationship between them. The Johansen method is to estimate the Γ_k matrix from an unrestricted VAR and to test whether we can reject the restriction implemented by the reduced rank Γ_k. There are two asymptotically equivalent tests for cointegration in the Johansen framework, a likelihood ratio (maximum eigenvalue) test and a trace test:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} ln(1 - \hat{\lambda}_i) \tag{4.29}$$

$$\lambda_{max}(r, r+1) = -Tln(1 - \hat{\lambda}_{r+1}). \tag{4.30}$$

Where λ_i is the estimated ordered eigenvalue obtained from the estimated matrix and T is the number of usable observations after lag adjustment. The trace statistics tests the null hypothesis that the number of distinct cointegration vectors, r, is less than or equal to r against a general alternative. The maximum eigenvalue tests the null that the number of cointegrating vectors is r against the alternative of $r + 1$ cointegrating vectors (Alam and Huylenbroeck, 2011). According to Yin-Wong & Lai (Cheung and Lai, 1993) the trace test is considered more robust against skewness and excess kurtosis.

4.2.3 Market Integration (Based on Ravallion, 1986)

A market is considered completely integrated when the relative price is constant or "the price of a commodity tends to uniformity, allowance being made for transportation costs" (Stingler, 1969, p. 85). If there is no market integration, prices do not correlate, while if the products are imperfect substitutes and there is some market integration the prices move in the same direction but with varying magnitudes so the relative price is not constant (Pincinato and Asche, 2016).

The following model is useful when one is able to assume stationary data series. A major difference between this model and the other described in this section, is the fact that this one does not take into account first-differences. Rather, this is a simple log-log regression on the available data series where the optimal lag-length is decided by a suitable IC criterion. To test for market integration, the following dynamic equation is specified (Ravallion, 1986);

$$lnp_t^1 = \alpha + \sum_{i=1}^{m} \gamma_i lnp_{t-i}^1 + \sum_{j=0}^{n} \beta_j lnp_{t-j}^2 + \epsilon_t \tag{4.31}$$

where p^1 is the price of product 1 and p^2 is the price of product 2; α, β, γ, are coefficients to be estimated and ϵ_t is the error term. Lags of both prices are included to account for dynamic adjustment and to ensure that ϵ_t is white noise. The constant term α captures transportation cost and quality differences, and the long-run relationship between the prices is given as $\frac{\sum \beta_j}{1-\sum \gamma_i}$.

As the prices may be considered stationary, conventional hypothesis testing can be applied to test three hypotheses of interest concerning market integration:

1. If $\beta_j = 0, j = 0, ..., n$, there is no market integration;
2. If $\beta_j \neq 0, j = 0, ..., n$, there is imperfect market integration;
3. If $\sum \gamma_i + \sum \beta_j = 1, i = 1, ..., m$ and $j = 0, ..., n$, there is complete market integration.

Because economic theory does not give any guidance with respect to what price should be on the left-hand side, the regression is usually run in both directions (Goodwin, Grennes, and Wohlgenant, 1990). In some cases, one will find evidence of market integration in only one direction. This implies that one variable Granger causes the other, and this variable will be the leading price (Asche, Gordon, and Hannesson, 2004).

4.2.4 Autoregressive distributed lag (ARDL) bound test for cointegration (Pesaran and Shin, 1998; Pesaran et al., 2001)

When one cointegrating vector exists, Johansen's (Johansen, 1991) cointegration procedure cannot be applied. Hence, it become imperative to explore Pesaran and Shin (Pesaran and Shin, 1995) and Pesaran et al. (Pesaran, Shin, and Smith, 1996) proposed Autoregressive Distributed Lag (ARDL) approach to cointegration or bound procedure for a long-run relationship, irrespective of whether the underlying variables are I(0), I(1) or a combination of both. In such situation, the application of ARDL approach to cointegration will give realistic and efficient estimates (Nkoro and Uko, 2016).

Pesaran and Shin showed in their paper (Pesaran and Shin, 1998) strong evidence that the use of autoregressive distributed lag (ARDL) models for analyzing

long-run relations had the additional advantage of yielding consistent estimates of the long-run coefficients that are asymptotically normal irrespective of whether the underlying regressors are I(1) or I(0).
Later, in the paper by Pesaran et al. (Pesaran, Shin, and Smith, 2001), they proposed a new approach to test for the existence of a long-run relationship which is applicable irrespective of whether the underlying regressors are $I(0)$, $I(1)$ or mutually cointegrated. This is in contrast to the two other main approaches used to test for the existence of long-run relations using cointegration techniques: the two-step residual-based procedure for testing the null of no-cointegration (Engle and Granger (Engle and Granger, 1987), Phillips and Ouliaris (Phillips and Ouliaris, 1990), and the system-based reduced rank regression approach due to Johansen (Johansen, 1991; Johansen, 1995) (Pesaran, Shin, and Smith, 2001).

ARDL bound test has some advantages over other cointegration tests. The ARDL does not impose any restriction that all the variables used under study must be integrated of the same order; therefore the test can be applied whether the selected variables are integrated of order zero or order one. The test is also not sensitive to the size of the sample. Moreover, the ARDL test generally provides unbiased estimates of the long run model and provides valid t-statistics even when some of the regressors are endogenous (Narayan and Smyth, 2005). Pesaran and Shin (1998) show that it is possible to test the long run relationship between the dependent and the set of regressors when it is not known a prior whether the variables are stationary or non-stationary.

A general $ARDL$ model can be formulated as:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=1}^{n} \sum_{i=0}^{q} \beta_{jp} x_{j(t-i)} + \epsilon_t, \tag{4.32}$$

where ϵ_t is a $i.i.d.$ random "disturbance" term.

Narayan & Smyth (Narayan and Smyth, 2005) present the (Pesaran et al., 2001) model as following:
To implement the bounds test, consider a vector of two variables z_t where $z_t = (y_t, x_t^{'})^{'}$, y_t is the dependent variable and x_t is a vector of regressors. The data generating process of z_t is a p-ordered vector autoregression. For cointegration, Δy_t is modeled as a conditional Error-Correction Model (ECM):

$$\Delta y_t = \beta_0 + \beta_1 t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i \Delta y_{t-i} + \sum_{j=0}^{q-1} \phi_j^{'} \Delta x_{t-j} + \theta w_t + \mu_t. \tag{4.33}$$

Here, π_{yy} and π_{yx} are long-run multipliers. β_0 is the drift and t is the time trend. w_t is a vector of exogenous components. Lagged values of Δy_t and current and lagged values of Δx_t are used to model the short-run dynamic structure. The bounds testing procedure for the absence of any level relationship between y_t and x_t is through exclusion of the lagged variables y_{t-1} and x_{t-1} in equation 4.33.

It follows, then, that our test for the absence of a conditional level relationship between y_t and x_t entails the following null and alternative hypotheses:

$$H_0 : \pi_{yy} = 0,\ \pi_{yx.x} = 0^{'} \tag{4.34}$$

$$H_1 : \pi_{yy} \neq 0,\ \pi_{yx.x} \neq 0^{'}\ or\ \pi_{yy} \neq 0,\ \pi_{yx.x} = 0^{'}\ or\ \pi_{yy} = 0,\ \pi_{yx.x} \neq 0^{'} \tag{4.35}$$

These hypotheses can be examined using either F-statistic or t-statistics. Critical value bounds exist for all classifications of the regressors into purely $I(0)$, purely $I(1)$ or mutually cointegrated. If the computed F - statistic falls outside the critical bounds, a conclusive decision can be made regarding cointegration without knowing the order of integration of the regressors. If the estimated F - statistic is higher than the upper bound of the critical values, then the null hypothesis of no cointegration is rejected. If the estimated F - statistic is less than the lower bound of the critical values, then the null hypothesis of no cointegration cannot be rejected. This is illustrated in figure 4.1. As discussed in Philips (Philips, 2016), the upper and lower bounds of the cointegration test are nonstandard, and depend on the number of observations, the number of regressors appearing in levels, and the restrictions (if any) placed on the intercept and trend. There are two groups of critical values: the ones based on Pesaran et al. (2001), and the ones based on Narayan (2005) that are more suitable for smaller sample sizes (≤ 80).

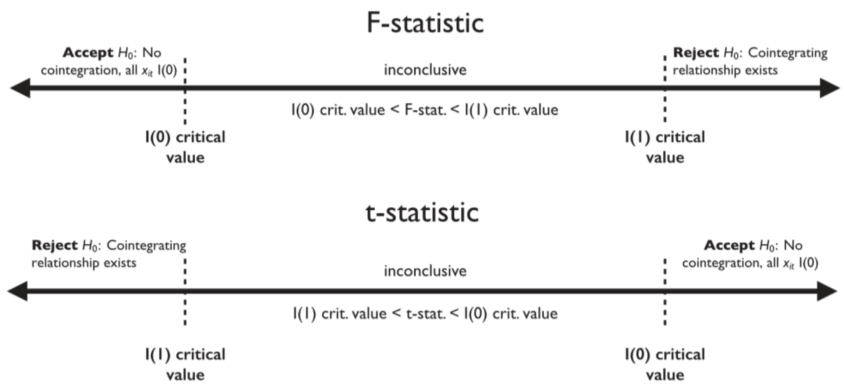


FIGURE 4.1: Bound Test Statistics. Source: (Philips, 2017)

In addition to the F-test, a one-sided t-test may be used to test the null hypothesis that the coefficient on the lagged dependent variable is equal to zero (equation 4.34). The alternative hypothesis is the same as shown in equation 4.35, which suggests cointegration. This is known as the bounds t-test.
No small-sample critical values are currently available for the t-test, so in small samples it should only be used for confirmatory purposes (Philips, 2017).

Finally, Pesaran et al. (2001) described five different scenarios, or cases, for which the bounds test can be performed. For most testing scenarios, either case 1, 3 or 5 will be relevant.

- Case 1: (No intercept, no trends) $\beta_0 = \beta_1 = 0$.
- Case 2: (Restricted intercept, no trends) $\beta_0 = -(\pi_{yy}, \pi_{yx.x})\mu$ and $\beta_1 = 0$.
- Case 3: (Unrestricted intercepts, no trends) $\beta_0 \neq 0$ and $\beta_1 = 0$.
- Case 4: (Unrestricted intercepts, restricted trends) $\beta_0 \neq 0$ and $\beta_1 = -(\pi_{yy}, \pi_{yx.x})\mu$.
- Case 5: (Unrestricted intercepts, unrestricted trends) $\beta_0 \neq 0$ and $\beta_1 \neq 0$.

Chapter 5

Data

5.1 Introduction

The data series, or prices, analyzed in this thesis is taken from the Sao Paulo wholesale market and span the period 02.03.14 to 07.31.18. Each data series represent either one specie or genus/family.
Wholesale markets were implemented in Brazil during the 70's to attend the expansion of urban centers, and as part of the Brazilian Strategic Development Plan (Sette and Alberto, 2017). Wholesale markets provide the infrastructure for food distribution within the food supply chain as illustrated in figure 5.1 below.

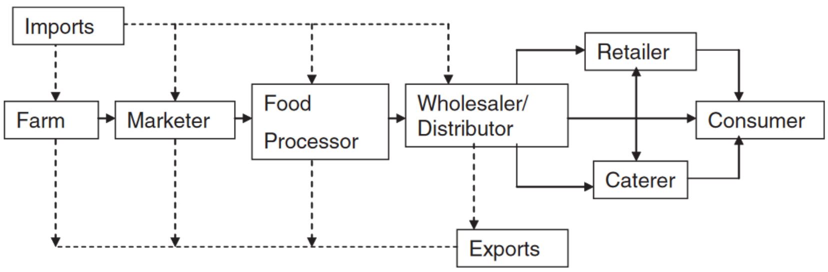


FIGURE 5.1: A typical food supply chain. Source: (Dani and Deep, 2010).

The likes of the Sao Paulo wholesale markets are for the most part referred to as CEASA (Centrais de Abastecimento - State Supply Center) in most parts of Brazil. The wholesale market in Sao Paulo, called Entreposto Terminal de Sao Paulo (ETSP) - Terminal Warehouse of Sao Paulo, is together with 12 other markets within Sao Paulo State part of CEAGESP (Companhia de Entrepostos e Armazèns Gerais de Sao Paulo - Sao Paulo General Warehouse and Centers Company).
CEAGESP is under the Ministry of Agriculture, Livestock, and Food Supply. ETSP is one of the largest wholesale markets in the world, commercializing 280,000 tons of fruit, vegetables, legumes, seafood and flowers monthly (Sette and Alberto, 2017).

5.2 Visual Inspection of the Data Series

As a first step, all the individual data series have been plotted and is shown in figure 5.3 below. The data series have also been fitted with linear regression lines. The equation for each individual regression line is reported along with R^2.
First thing to notice is that with the exception of salmon, sardine, and arguably tilapia, the remaining data series looks to be quite stationary. Secondly, the data series for common snook, mullet, sardine, and tuna (the last two years for tuna)

show seasonal pattern in their prices. This fit with what was uncovered about these species in chapter 3, that they are either migratory or easier to catch during spawning season.
For the remaining non-farmed species; weakfish, flatfish and shark, the price pattern with a lack of clear[1] seasonal pattern indicate a relatively stable supply throughout the year.

The price of tilapia has a weak upward upward trend, and quite a bit of price volatility. Similar volatility can be seen for the spotted sorubim as well. Thus, it is reasonable to assume that this volatility is related to production problems, like parasites and bacterial infections in fish (Pádua and Cruz, 2014), commonly seen in fresh water aquaculture in Brazil. These types of production problems can also give rise to seasonal price patter since the risk of bacterial infection increases with temperature, thus, the probability for loss of stock is higher in the warmer summer months.

The price of salmon follows the linear trend quite nicely except for two period: one spike and one dip. The spike in price is most certainly the result of an algae bloom in Chile at that time. The total production of salmon in Chile saw a reduction of 15% in 2016, compared to 2015, caused by two unpredicted algae blooms that year.
The dip, starting toward the end of 2017, was the first time the average price of Atlantic salmon dropped since 2012. This was due to the a increase in global supply, seen in figure 5.2, that was larger than the long-term demand growth.

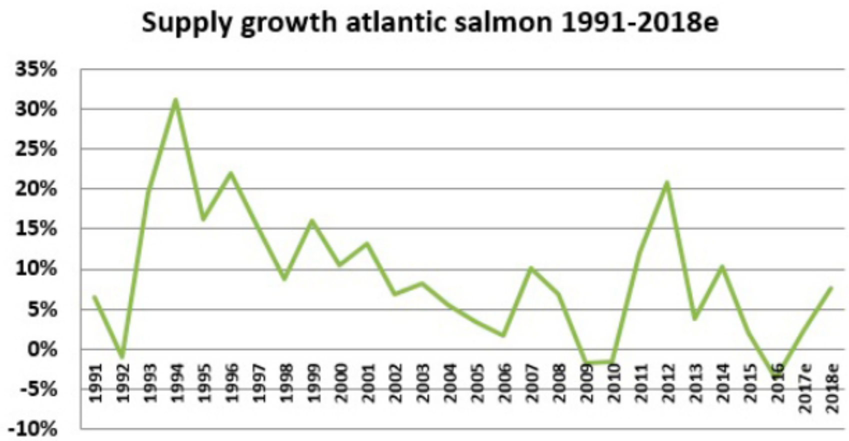


FIGURE 5.2: Supply growth for Atlantic salmon. Source: Nordea Markets.

Table 5.1 give an overview of the stochastic properties of the data series. Here "JB" is an abbreviation of Jarque-Bera (Jarque and Bera, 1980) which is a goodness-of-fit test of whether the sample data have the skewness and kurtosis matching a normal distribution. The null hypothesis is a joint hypothesis of the skewness being zero and the excess kurtosis being zero.

[1]Flatfish show a weak seasonal pattern that repeats roughly every six months.

TABLE 5.1: Stochastic Properties of the Data Series.

	Salmon	Tilapia	Spotted Sorubim	Weakfish	Flatfish	Common Snook	Mullet	Shark	Sardine	Tuna
Mean	27.02	5.63	11.26	9.13	11.52	32.35	6.52	8.05	3.98	14.76
Maximum	43.33	8.00	15.00	27.00	24.00	43.00	15.50	11.00	8.00	32.67
Minimum	12.00	4.25	8.00	2.38	6.50	19.00	2.77	3.84	0.85	6.50
Std. Dev.	6.10	0.77	1.06	2.29	2.02	4.49	1.92	0.96	1.74	3.76
Skewness	0.186	0.266	0.081	1.004	2.030	-0.122	0.972	-0.488	0.255	0.930
Kurtosis	-0.940	-0.147	-0.026	9.020	8.101	-0.244	1.396	1.175	-0.949	1.324
JB Test	42.42***	12.05***	1.23	3484.60***	3382.47***	4.94*	238.53***	97.94***	48.08***	217.18***

*,**, and *** indicates statistical significance at the 10%, 5%, and 1% levels, respectively.

The result of the Jarque-Bera test is that for all data series, except spotted sorubim and common snook, are we able to reject the joint null of normality. The rejection of this null can be an early indicator of non-stationarity as, for example, if the data series were trending we would expect there to be excess skewness.

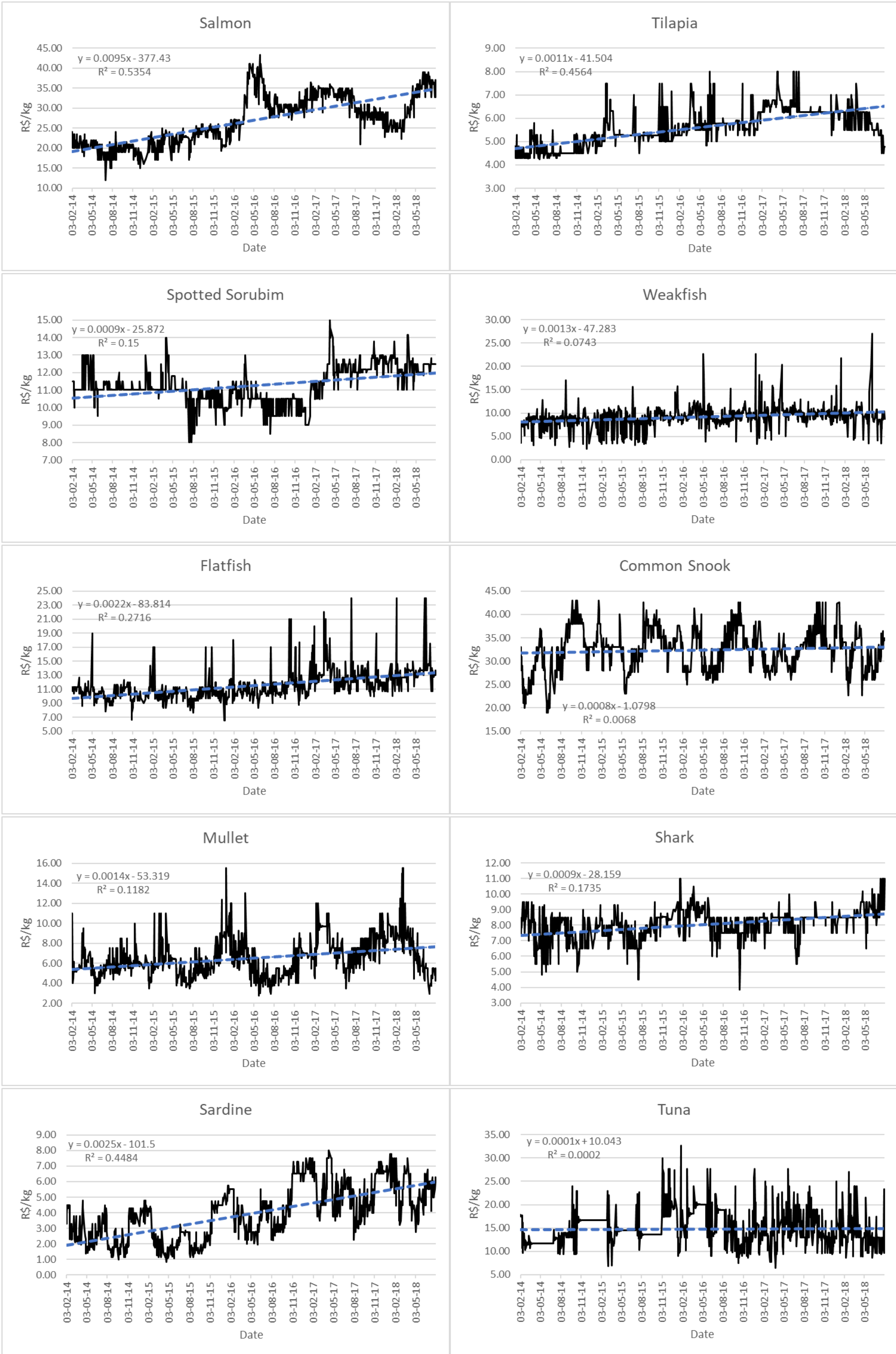


FIGURE 5.3: Plot of the data series. A linear regression line is fitted on each data series and the equation of the line is given along with R^2 for each case.

5.2.1 Correlograms

The ACF flots in figure 5.5 shows clear sine functions in the prices of common snook, mullet and tuna. This correlates with the observations done of the price plots in figure 5.3. Further, all the ACF plots of the data series reveal that we are dealing with $AR(p)$-processes. This is also supported by the sharp cut-off seen in the PACF plots in figure 5.6.

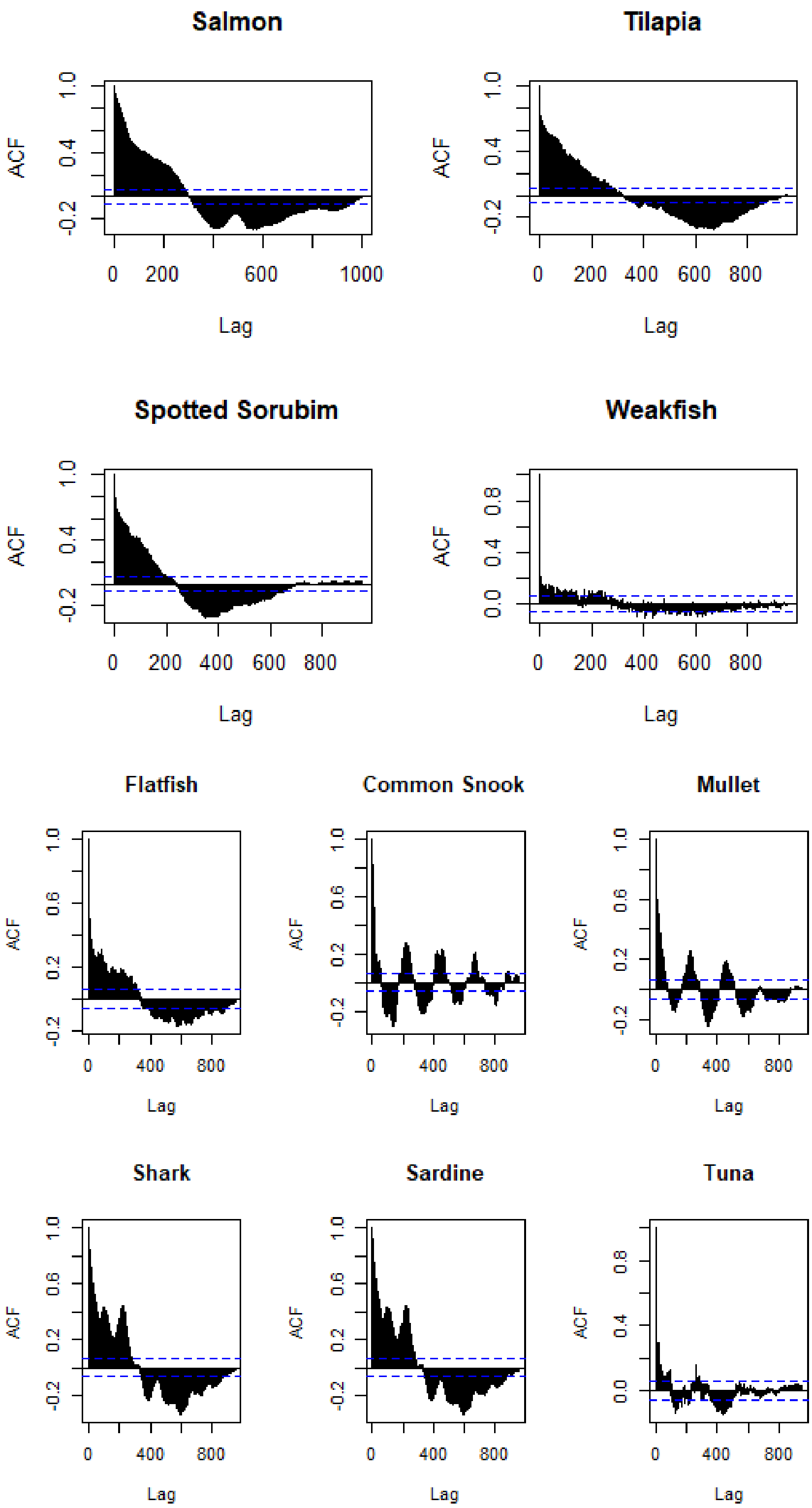


FIGURE 5.5: Autocorrelation plots for all the time series. Lag is in trading days during the period 02.03.14 - 07.31.18.

The partial autocorrelation plots, shown in figure 5.6, is the correlation of the time series with a lag of itself, with the linear dependence of all the lags between them removed.

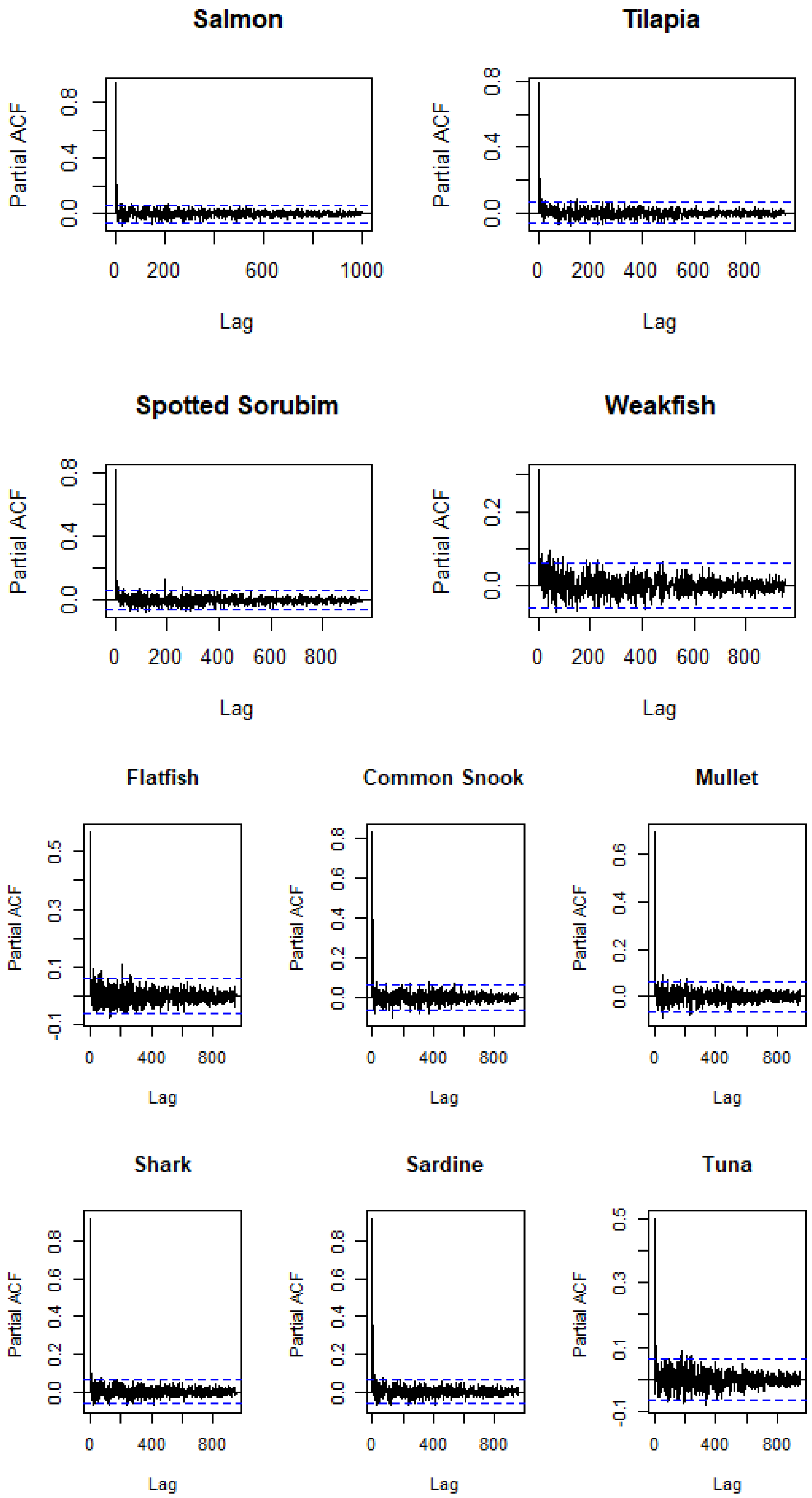


FIGURE 5.6: Partial autocorrelation plots for all the time series. Lag is in trading days during the period 02.03.14 - 07.31.18.

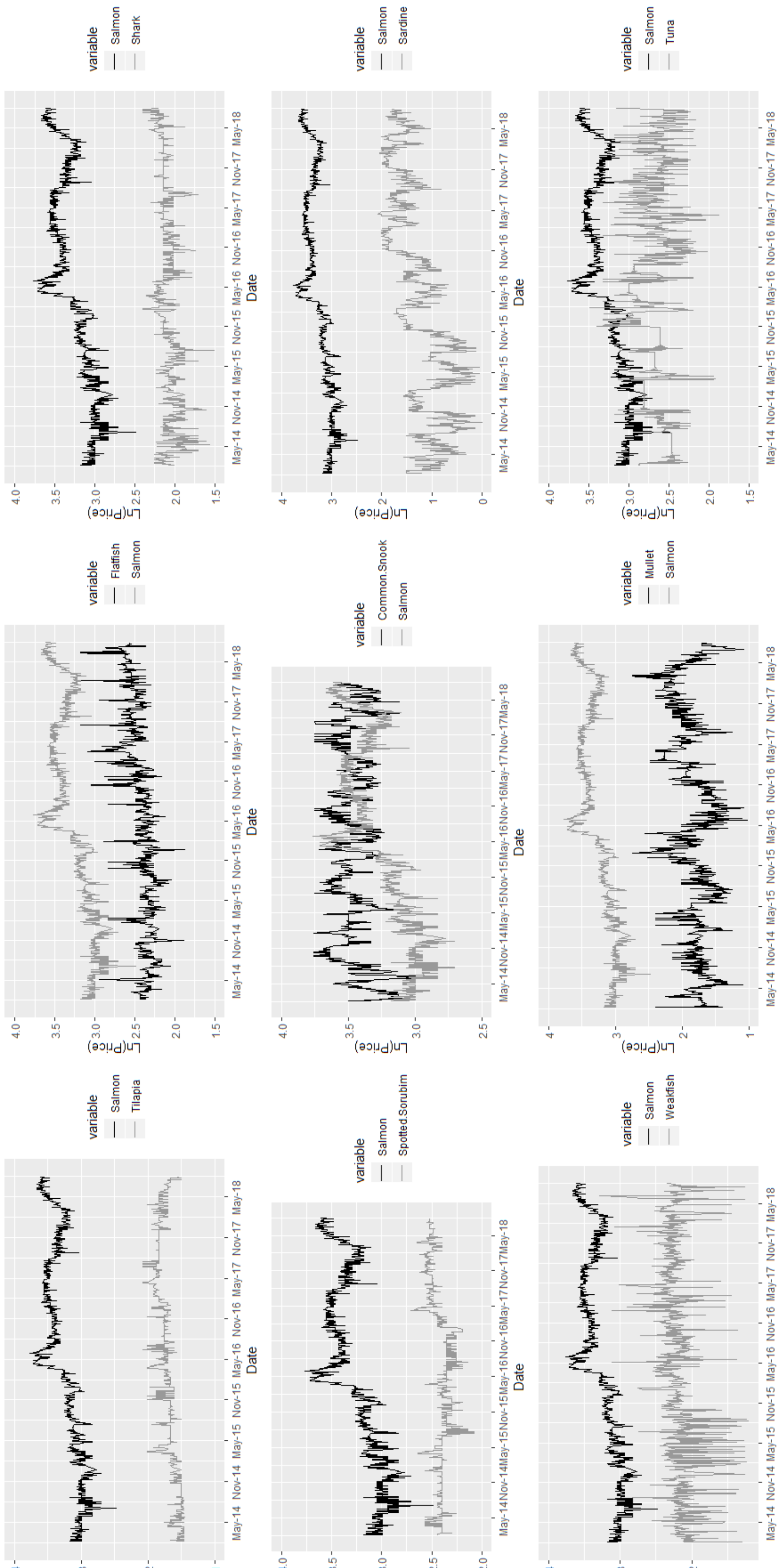


FIGURE 5.4: Bivariate plots of price of salmon versus price of the other species. Note, the prices are in log.

Chapter 6

Results and Discussion

6.1 Unit-Root Test

Before conducting the formal tests for market integration, the time series properties of the data series are investigated. This is done by applying the ADF unit-root test to the data series. The unit-root test was run with all three possible specifications; no constant, with constant, and with trend and constant. The case of "No Constant" does not really make much sense to include since none of the data series are varying around zero as seen in figure 5.4. It was included in the table never the less since it was an option (and possibly of curiosity reason), but no regard will be put toward it. The results of the unit-root test (table 6.1) are the same for all data series; for both relevant specifications, *Trend* and *Constant*, we can reject the null hypothesis at a 5% significance level, i.e. there is significant evidence that the data series are stationary. Further, table 6.1 show that for all prices at first-difference, we can strongly reject the null hypothesis of non-stationary. Figure 6.1 give a visual confirmation that taking the first-difference was successful in de-trending the data series. This is an important result, not just with regard to the performed Johansen's test, but also as a first step in avoiding spurious regression when looking at, among other, correlation and in forecasting. Hence, we can conclude that all data series, independent of specification of the ADF model, are integrated of order one, $I(1)$ (i.e., stationary at first difference), or less.

TABLE 6.1: Augmented Dickey-Fuller (ADF) Unit Root Test Performed on the Data Series.

	Trend		**Constant**		**No Constant**	
	Levels	First Difference	Levels	First Difference	Levels	First Difference
Ln(Salmon)	-5.00***(1)	-38.58***(1)	-3.14**(1)	-38.60***(1)	0.14(1)	-38.62***(1)
Ln(Tilapia)	-8.58***(1)	-32.82***(1)	-6.02***(1)	-32.83***(1)	-0.77(1)	-32.85***(1)
Ln(Spotted Sorubim)	-6.75***(1)	-35.58***(1)	-6.10***(1)	-35.59***(1)	-0.11(1)	-35.61***(1)
Ln(Weakfish)	-16.94***(1)	-35.88***(1)	-15.73***(1)	-35.90***(1)	-1.37(1)	-35.92***(1)
Ln(Flatfish)	-13.16***(1)	-36.30***(1)	-9.89***(1)	-36.32***(1)	-0.51(1)	-36.34***(1)
Ln(Common Snook)	-6.18***(1)	-32.08***(1)	-6.18***(1)	-32.10***(1)	0.01(1)	-32.12***(1)
Ln(Mullet)	-7.80***(1)	-35.81***(1)	-7.29***(1)	-35.83***(1)	-1.02(1)	-35.84***(1)
Ln(Shark)	-11.18***(1)	-36.00***(1)	-9.62***(1)	-36.01***(1)	-0.48(1)	-36.03***(1)
Ln(Sardine)	-6.78***(1)	-30.49***(1)	-4.41***(1)	-30.50***(1)	-1.56(1)	-30.51***(1)
Ln(Tuna)	-10.87***(1)	-34.82***(1)	-10.88***(1)	-34.84***(1)	-0.73(1)	-34.85***(1)

*, **, and *** indicates statistical significance at the 10, 5, and 1% levels, respectively. Optimal number of lags, shown in parentheses, is selected based on the Akaike Information Criterion (AIC). Critical value at the 5% level is -1.95 without constant and trend, -2.86 with a constant, and -3.42 with a constant and trend.

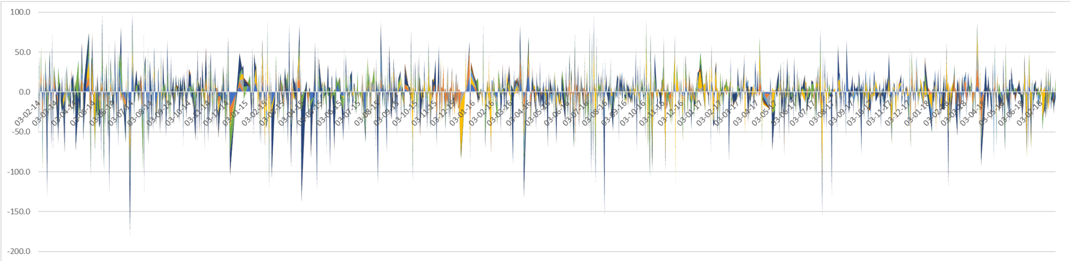


FIGURE 6.1: Plot of the first-difference (FD) in percentage of all data series.

The results in table 6.1 are not very surprising. The observations in the data series of the prices only span a period of 4.5 years. This does not allow prices of certain fish species, mainly those caught and traded locally in Brazil - i.e., prices not influenced by international trade, to evolve. Also, some of the data series show significant seasonal pattern and this could more easily affect the results in such a short time frame. On the other hand, during this period the Brazilian economy, along whit the Brazilian Real, has seen some volatility. To a large degree related to the political uncertainty in the country. Assuming LOP holds for species that are exported to an international market, they should show more movement and volatility relative to the value of the Brazilian Real. This also goes for farmed species, even if the final product is not exported internationally, but the inputs in the farming process is imported from an international market. Thus, this could potentially make it easier to reveal which species does not belong to the same market as salmon.

6.2 Johansen's Test

The results of the trace and eigenvalue tests for testing the null hypothesis of no cointegration (rank = 0) are presented in column 2 and 3 of table 6.2, while column 4 and 5 contains the results for testing the null hypothesis that there is less than or one cointegrated vector (rank ≤ 1). In all the bivariate specifications of the test except for the two cases involving the two farmed species *tilapia* and *spotted sorubim*, the null hypothesis of no cointegration vector, rank = 0, is rejected at minimum a 10% level and allows rejection of the hypothesis of zero cointegration vectors. With regard to this, the statistical result is a bit stronger for the maximum eigenvalue test compared to the trace test, where the null of $rank = 0$ only could be rejected at a 10% level for two of the specifications. Further, the null hypothesis of less than or equal to one cointegration vector, rank ≤ 1, cannot be rejected in either case, even at a 10% level. Conclusion then being that r is at most of order one.

TABLE 6.2: Bivariate Johansen's test for cointegration between salmon and the other data series.

	Rank = 0		Rank ≤ 1	
Data series	Max[a]	Trace[b]	Max	Trace
Ln(Salmon)/Ln(Tilapia) (10)	12.94	16.19	3.24	3.24
Ln(Salmon)/Ln(Spotted Sorubim) (5)	12.89	16.27	3.39	3.39
Ln(Salmon)/Ln(Weakfish) (8)	92.63***	95.15***	2.51	2.51
Ln(Salmon)/Ln(Flatfish) (5)	41.35***	44.63***	3.28	3.28
Ln(Salmon)/Ln(Common Snook) (5)	21.57***	25.05***	3.48	3.48
Ln(Salmon)/Ln(Mullet) (7)	16.39**	19.83*	3.44	3.44
Ln(Salmon)/Ln(Shark) (8)	28.91***	31.13***	2.22	2.22
Ln(Salmon)/Ln(Sardine) (5)	16.57**	19.17*	2.59	2.59
Ln(Salmon)/Ln(Tuna) (12)	27.09***	29.96***	2.87	2.87

*,**, and *** indicates statistical significance at the 10, 5, and 1% levels, respectively. Optimal number of lags, shown in parentheses, is selected based on the Akaike Information Criterion (AIC). The null hypothesis is that the number of cointegrated vectors are equal to zero or one. [a] Maximum eigenvalue test. [b] Trace test.

The indication from the Johansen test is, therefore, that salmon for the most part does not belong to a separate market in Brazil, but rather that the prices of the involved fish species in the test follow each other. Exception, off course, being for salmon against tilapia and spotted sorubim. The validity of these results are questionable at best since the unit-root test indicated that all the data series are stationary. Thus, one of the key criteria for the Johansen's test is not valid as the test is based on a premise of all the involved data series be $I(1)$. The reason for performing this test then, and keeping the result, is that in addition to this test, two other tests are also performed. When comparing the result from all the tests for cointegration and long-term relationship, we are interested in if they all "point" in the same direction with regard to a conclusion.

6.3 Market Integration Test

As the unit-root test, table 6.1, indicate that the data series can be treated as stationary, it is therefore appropriate to run a bivariate regression on the data with the model given in equation 4.31, based on (Ravallion, 1986), to look for long-run relationship between prices. The lags in the model are determined using AIC, such that ϵ_t is white noise. The regressions are run bi-directional.

TABLE 6.3: Market integration hypothesis testing, assuming prices are stationary. The reported results are the Wald χ^2 statistics. * and ** indicates statistical significance at the 10% and 5% levels, respectively.

	Dependent Variable	Independent Variable	$H_0 : \beta_j = 0, \forall j$	$H_0 : \sum \gamma_i + \sum \beta_j = 1$
(1)	Salmon	Tilapia	15.50**	4.53**
(2)	Tilapia	Salmon	14.53**	9.20**
(3)	Salmon	Spotted Sorubim	8.52	0.21
(4)	Spotted Sorubim	Salmon	0.44	10.28**
(5)	Salmon	Weakfish	30.76**	4697.1**
(6)	Weakfish	Salmon	43.77**	147.36**
(7)	Salmon	Flatfish	3.17*	0.10

Table 6.3 continued from previous page

(8)	Flatfish	Salmon	17.14**	25.89**
(9)	Salmon	Common Snook	5.01**	1.43
(10)	Common Snook	Salmon	4.06	21.45**
(11)	Salmon	Mullet	26.28**	0.03
(12)	Mullet	Salmon	49.70**	8.91**
(13)	Salmon	Shark	50.81**	3.26*
(14)	Shark	Salmon	23.74**	18.00**
(15)	Salmon	Sardine	25.65**	3.15*
(16)	Sardine	Salmon	36.55**	0.17
(17)	Salmon	Tuna	8.67**	0.11
(18)	Tuna	Salmon	6.87**	25.90***

The null hypothesis of no market integration, column 4 in table 6.3, is rejected for all equations at the 5% level, except for the cases involving Spotted sorubim, (3) and (4), flatfish (7) and common snook (10). Further, in two of the cases, (7) vs. (8) and case (9) vs.(10), the results suggest that the price relationship is directional, although there will be made no assumptions with regard price leadership or causality at this point, and thus, this will just remain an observation. In Ravallions paper (Ravallion, 1986) he describes the model used here as a model to test for interaction between central and local markets. To be specific, if the central market is assumed to be the dependent variable and likewise a local market is given by the independent variable, if the null in column 4 can't be rejected there is market segmentation, i.e., central market prices does not influence prices in the local market. These results provide evidence to suggest that salmon and local species for the most part does not belong to different markets.

The null hypothesis of complete market integration, or long-run market integration, column 5 in table 6.3 suggest that there are a number of cases where this exists, i.e. where we fail to reject the null. For the most part, this is when salmon is the dependent variable.

Building on these results I will be applying the more powerful ARDL-bounds test, which estimates on a first-difference form, next.

6.4 ARDL Bounds Test

As a final step an ARDL-bounds test (Pesaran, Shin, and Smith, 2001) was also performed. One of the strengths of this test is that it absolves the user of having to distinguish between stationary and first-order nonstationary regressors. It does, however, require the dependent variable to be non-stationary in order for the model to behave better. Again, this is not the case as seen in table 6.1.

The model specification was based on BIC, and the maximum lag length was adjusted such that there was evidence suggesting no residual serial correlation[1] nor heteroskedasticity at a significant level. The procedure for the test as proposed by (Philips, 2017) is summarized in figure 6.2 below, and the results are shown in table 6.4 and table A.1.

[1]Based on Breusch-Godfrey test (LM) for serial correlation.

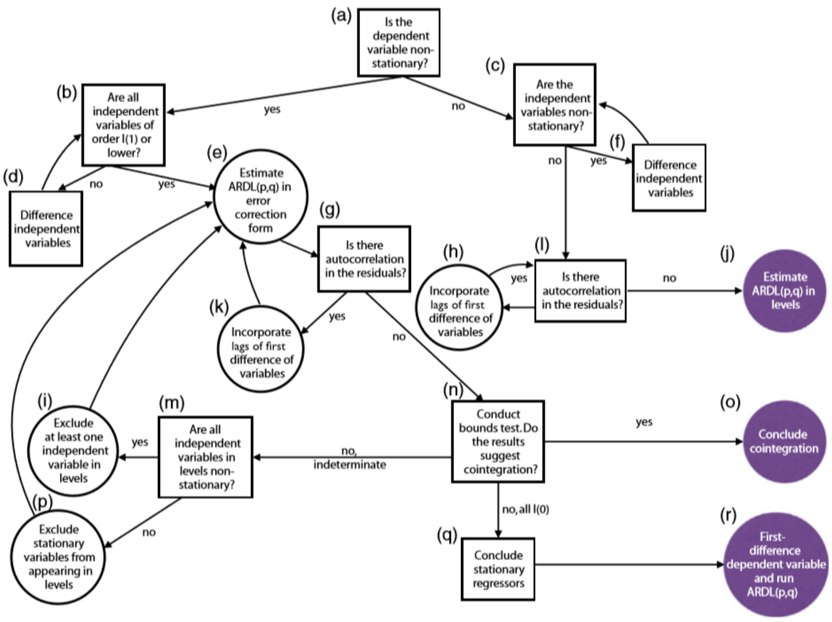


FIGURE 6.2: The ADRL-bounds procedure's comprehensive approach to time-series analysis. Source: (Philips, 2017).

TABLE 6.4: ARDL bivariate cointegration test results.

	Modeling			Diagnostic		
	ARDL(p,q)	F-stat	ECM(-1) Coeff.(Prob.)	R^2	$\bar{R}^2$	DW-Stat.
Ln(Salmon) ∼ Ln(Tilapia)	(5,0)	3.48	-0.047(0.00)	0.458	0.455	2.00
Ln(Tilapia) ∼ Ln(Salmon)	(5,0)	9.61**	-0.134(0.00)	0.343	0.338	2.01
Ln(Salmon) ∼ Ln(Spotted Sorubim)	(5,0)	1.51	-0.016(0.09)	0.449	0.446	2.01
Ln(Spotted Sorubim) ∼ Ln(Salmon)	(5,0)	6.23**	-0.064(0.00)	0.325	0.321	2.00
Ln(Salmon) ∼ Ln(Weakfish)	(5,0)	2.72	-0.011(0.28)	0.451	0.448	2.00
Ln(Weakfish) ∼ Ln(Salmon)	(2,1)	147.04**	-0.691(0.00)	0.436	0.434	2.03
Ln(Salmon) ∼ Ln(Flatfish)	(5,0)	2.32	-0.025(0.02)	0.451	0.448	2.01
Ln(Flatfish) ∼ Ln(Salmon)	(5,0)	19.05**	-0.215(0.00)	0.338	0.334	2.00
Ln(Salmon) ∼ Ln(Common Snook)	(5,0)	2.24	-0.015(0.12)	0.451	0.448	2.01
Ln(Common Snook) ∼ Ln(Salmon)	(3,0)	15.73**	-0.095(0.00)	0.232	0.229	2.01
Ln(Salmon) ∼ Ln(Mullet)	(5,1)	3.33	-0.017(0.08)	0.464	0.460	2.02
Ln(Mullet) ∼ Ln(Salmon)	(5,1)	7.99**	-0.084(0.00)	0.388	0.383	2.01
Ln(Salmon) ∼ Ln(Shark)	(5,0)	1.57	-0.035(0.00)	0.462	0.459	2.00
Ln(Shark) ∼ Ln(Salmon)	(10,2)	10.97**	-0.167(0.00)	0.368	0.360	2.00
Ln(Salmon) ∼ Ln(Sardine)	(5,1)	2.40	-0.024(0.03)	0.466	0.460	2.00
Ln(Sardine) ∼ Ln(Salmon)	(5,1)	6.58*	-0.052(0.00)	0.212	0.206	2.00
Ln(Salmon) ∼ Ln(Tuna)	(5,0)	1.49	-0.017(0.07)	0.452	0.449	2.01
Ln(Tuna) ∼ Ln(Salmon)	(5,0)	23.27**	-0.229(0.00)	0.346	0.342	1.99

* and ** indicates statistical significance (cointegration) at the 10% and 5% levels, respectively.
LR ECM show the statistical significance of the long-run relationship:
$ECM = C + Y + \beta X$, and Y is the dependent variable.
DW is the Durbin-Watson test statistics for autocorrelation in the residuals of the regressions. Test statistics close to 2 indicates no evidence of autocorrelation.

When causality is assumed to run from salmon price to the other fish prices, the F-statistics suggest there is no long-run relationship. However, when causality is assumed to run in the opposite direction, there is evidence of a stable and significant long-run relationship.

If a long-run relationship exist then the coefficient ECM(-1) gives the rate of adjustment back to the long-run equilibrium in the case of a short term shock. In other words, if there is a cointegration between the variables, equation 6.1 presents the long-run model and equation 6.2 shows the short-run dynamics:

$$Y_t = \alpha + \sum_{i=1}^{m} \phi_i Y_{t-i} + \sum_{j=0}^{n} \beta_j X_{t-j} + \mu_t \tag{6.1}$$

$$\Delta Y_t = \alpha + \sum_{i=1}^{k} \phi_i \Delta Y_{t-i} + \sum_{j=0}^{l} \beta_j \Delta X_{t-j} + \psi ECM_{t-1} + \xi_t \tag{6.2}$$

where ψ is the coefficient of the error correction model. As mentioned, it shows how quickly variables converge to equilibrium and it should have a statistically significant coefficient with a negative sign.
The estimated long-run coefficients are given in table A.1.

6.4.1 Granger Causality Test

ARDL cointegration method tests whether the existence or absence of long-run relationship between the fish prices. It does not indicate the direction of causality (Ozturk and Acaravci, 2010).
Therefore, the Granger causality test have been applied. According to Granger's definition of causality, a time series X_t, causes another time series, Y_t, if Y_t can be predicted better (in a mean-squared-error sense) using past values of X_t than by not doing so. That is, if past values of X_t significantly contribute to forecasting Y_t, then X_t is said to Granger cause Y_t. Causality from Y to X can also be defined in the same way. That is, if past values of Y_t significantly contribute to forecasting future values of X_t, then Y_t is said to Granger cause X_t (Odhiambo, 2009b).
Based on the estimated results given by equation 6.1, Granger causality found through the following models

$$\Delta Salmon_t = \alpha_1 + \sum_{i=1}^{p1} \phi_{1i} \Delta Salmon_{t-i} + \sum_{j=0}^{q1} \beta_{1j} \Delta Other_{t-j} + \psi_1 ECM_{t-1} + \xi_{1t} \tag{6.3}$$

$$\Delta Other_t = \alpha_2 + \sum_{i=0}^{p2} \phi_{2i} \Delta Salmon_{t-i} + \sum_{j=1}^{q2} \beta_{2j} \Delta Other_{t-j} + \psi_2 ECM_{t-1} + \xi_{2t} \tag{6.4}$$

Granger causality can be examined three ways (Lee and Chang, 2008):

1. Short-run or weak Granger causalities are detected by testing $H_0 : \beta_{1j} = 0$ and $H_0 : \phi_{2i} = 0$ for all i and j in equations 6.3 and 6.4, respectively.

2. Another possible source of causality is the ECM's. The coefficients of the ECM's represent how fast deviations from the long-run equilibrium are eliminated following changes in each variable. Thus, long-run causalities are examined by testing $H_0 : \psi_1 = 0$ and $H_0 : \psi_2 = 0$ for equations 6.3 and 6.4.

3. Strong Granger causality are detected by testing $H_0 : \beta_{1j} = \psi_{1t} = 0$ and $H_0 : \phi_{2i} = \psi_{2t} = 0$ for all i and j in equations 6.3 and 6.4, respectively.

The results from the Granger causality test is given in table 6.5. The test is not conclusive for all bivariate relationships, but the results do suggests that for some cases the price of salmon have an influence on the price of local species in the long-run. These are the cases involving: spotted sorubim, common snook, weakfish, flatfish and mullet. The direction of causality is as expected since there is evidence, (Asche, Cojocaru, and Sikveland, 2018), that the price of Chilean salmon products are set at the global market.
For the short-run and for strong causality the results are inconclusive.

TABLE 6.5: The reported results for the Granger causality test. The reported results are the Wald χ^2 statistics, and P-values are given in the parenthesis.

	Short-run Causality	Long-Run Causality	Strong Causality
ΔSalmon ∼ ΔTilapia	15.50** (0.00)	14.53** (0.00)	18.30** (0.00)
ΔTilapia ∼ ΔSalmon	14.62** (0.00)	28.08** (0.00)	28.82** (0.00)
ΔSalmon ∼ ΔSpotted Sorubim	0.20 (0.65)	2.88* (0.09)	2.96 (0.23)
ΔSpotted Sorubim ∼ ΔSalmon	0.44 (0.51)	12.64** (0.00)	12.72** (0.00)
ΔSalmon ∼ ΔWeakfish	3.20* (0.07)	1.18 (0.28)	5.97* (0.05)
ΔWeakfish ∼ ΔSalmon	7.75** (0.01)	294.08** (0.00)	314.42**(0.00)
ΔSalmon ∼ ΔFlatfish	3.02* (0.08)	5.22** (0.02)	5.79* (0.06)
ΔFlatfish ∼ ΔSalmon	17.14** (0.00)	43.87** (0.00)	44.26** (0.00)
ΔSalmon ∼ ΔCommon Snook	3.79* (0.05)	2.46 (0.12)	6.56** (0.04)
ΔCommon Snook ∼ ΔSalmon	0.17 (0.68)	30.23** (0.00)	30.34** (0.00)
ΔSalmon ∼ ΔMullet	26.20** (0.00)	3.09* (0.08)	29.06** (0.00)
ΔMullet ∼ ΔSalmon	24.75** (0.00)	15.77** (0.00)	39.71** (0.00)
ΔSalmon ∼ ΔShark	23.06** (0.00)	25.89** (0.00)	11.52** (0.00)
ΔShark ∼ ΔSalmon	20.38** (0.00)	21.95** (0.00)	39.06** (0.00)
ΔSalmon ∼ ΔSardine	25.58** (0.00)	4.70** (0.03)	28.06** (0.00)
ΔSardine ∼ ΔSalmon	35.93** (0.00)	13.14** (0.00)	44.55** (0.00)
ΔSalmon ∼ ΔTuna	4.73** (0.03)	3.27* (0.07)	7.50** (0.02)
ΔTuna ∼ ΔSalmon	1.45 (0.23)	47.75** (0.00)	47.99** (0.00)

* and ** indicates statistical significance at the 10% and 5% levels, respectively.
Δ is the first-difference operator.

Chapter 7

Conclusions

7.1 Conclusions

Three different statistical methods have been applied to examining whether salmon is an integrated part of the Brazilian fish market. The results from all three test are pointing toward the same conclusion, that there is significant statistical evidence for salmon being integrated, or at least have a long-term relationship with local species in the Brazilian fish market. Further, the Granger causality test performed based on the ARDL-bounds test suggest that in the long-run the price of salmon could be an influencer on the prices of local fish species. The results of the causality test are inconclusive with regard to the short-run.
The validity of these results, at least regarding the Johansen's test and the ARDL bounds test, may be put to question as in the initial ADF-test I was able to reject the null of non-stationarity at a significant level for all data series. On the other hand, as the test results from all three individual test suggest the same conclusion, including the Ravallion test for market integration which is not dependent on non-stationarity in the data series, combined they give credibility to the final conclusion of salmon being integrated into the Brazilian fish market.

Similar studied previously performed have not found the same result. For example did (Gordon, Salvanes, and Atkins, 1993) and (Asche, Gordon, and Hannesson, 1998) not find a significant interaction between salmon and other species in the French market. Similarly, (Jaffry et al., 2000) who investigated the interaction between salmon and wild caught species in the Spanish fish market, found that salmon at best was a weak substitute for other key species in the Spanish fish market, and no significant interaction being identified.
A possible explanation for this by (BjØrndal, Salvanes, and Andreassen, 1992) was that salmon could be regarded a luxury item, and therefore not comparable to other "table fish" species.

Two important factors separated the Brazilian market from the European. First, (Asche, Bjørndal, and Young, 2001) found that the link between the American salmon market and the rest of the world is weaker than the the European and the Asian market. Chile is typically the main supplier of salmon to the American market, whereas other main producers, Norway and Scotland, primarily supply Europe and Asia.
Secondly, the Brazilian salmon market was developed during the ISA outbreak in Chile at the end of the 2000's, and is today the main market for whole, moderate size salmon at $\sim$ 1.5 kg, compared to regular slaughter salmon at 5.5 - 6.5 kg whose products are found in the European and Asian markets. Because of this it is possible that salmon in Brazil is regarded as less of a "luxury" item, and therefore is more comparable to other local species.

7.2 Future Work

This thesis is just one part of a grater task which is to examine the potential for Norwegian seafood production expansion, and to this salmon is just one element. How much salmon production will increase in the future seems to depend on how successful the implementation of land-based salmon farms will be. The reason being that both Norway and Chile have had challenges in the past, and some still persist to this day, regarding salmon production. For Chile a major challenge today is the risk of new algae blooms, and for Norway it is sea-lice. Over the past years Chile have actively been taking steps to mitigate factors that can cause episodes of mass-loss of salmon as seen in the past, e.g. the ISA outbreak and multiple incidents of algae blooms[1]. Likewise, in Norway there is advanced technology[2] being developed to combat sea-lice. All these steps will likely translate into a more predictable future production and supply, but not necessarily a major increase in output.

There is still much more work to be done related to the topic of this thesis, and based on my findings, here are a few issues I think will be important to investigate:

- Salmon has to be transported from Norway to Brazil in a way that is economically viable.
- There are import and export taxes that separate Chilean and Norwegian exporters that may negatively affect the bottom line for Norwegian exporters.
- The future of the Brazilian economy is still very uncertain, even though things are currently looking up. Salmon in Brazil is priced higher than a number of the other popular local species, and the future success of salmon in the Brazilian market hinges on a sufficient number of people actually being able to afford, or choosing to buy this product.

[1]There is being speculations in whether there is a connection between the increasing number of fish farms and the occurrence of algae blooms.

[2]Example being the Stingray laser.

Appendix A

Tables

TABLE A.1: Estimated long-run coefficients using the bivariate ARDL approach.

Dependent Variable	Regressor	Coifficient	Standard Error	T-Ratio (Prob.)
Ln(Salmon)	Ln(Tilapia)	1.710	0.374	4.58 (0.00)
	Constant	0.356	0.642	0.55 (0.58)
Ln(Tilapia)	Ln(Salmon)	0.382	0.071	5.37 (0.00)
	Constant	0.474	0.233	2.03 (0.04)
Ln(Salmon)	Ln(Spotted Sorubim)	0.623	1.397	0.446 (0.66)
	Constant	1.850	3.370	0.549 (0.58)
Ln(Spotted Sorubim)	Ln(Salmon)	0.071	0.106	0.67 (0.50)
	Constant	2.191	0.347	6.32 (0.00)
Ln(Salmon)	Ln(Weakfish)	-1.336	1.609	-0.83 (0.41)
	Constant	6.312	3.617	1.75 (0.08)
Ln(Weakfish)	Ln(Salmon)	0.345	0.053	6.56 (0.00)
	Constant	1.050	0.173	6.08 (0.00)
Ln(Salmon)	Ln(Flatfish)	1.063	0.568	1.87 (0.06)
	Constant	0.743	1.376	0.54 (0.59)
Ln(Flatfish)	Ln(Salmon)	0.356	0.072	4.92 (0.00)
	Constant	1.265	0.238	5.33 (0.00)
Ln(Salmon)	Ln(Common Snook)	2.00	1.672	1.19 (0.23)
	Constant	-3.570	5.759	-0.62 (0.54)
Ln(Common Snook)	Ln(Salmon)	-0.043	0.104	-0.41 (0.68)
	Constant	3.618	0.341	10.61 (0.00)
Ln(Salmon)	Ln(Mullet)	0.968	0.711	1.36 (0.17)
	Constant	1.576	1.278	1.232 (0.22)
Ln(Mullet)	Ln(Salmon)	-0.018	0.279	-0.07 (0.95)
	Constant	1.893	0.915	2.07 (0.04)
Ln(Salmon)	Ln(Shark)	2.509	0.723	3.47 (0.00)
	Constant	-1.898	1.494	-1.27 (0.20)
Ln(Shark)	Ln(Salmon)	0.224	0.077	2.91 (0.00)
	Constant	1.343	0.253	5.31 (0.00)
Ln(Salmon)	Ln(Sardine)	0.306	0.183	1.67 (0.10)
	Constant	2.938	0.246	11.95 (0.00)
Ln(Sardine)	Ln(Salmon)	1.202	0.482	2.49 (0.01)
	Constant	-2.640	1.582	-1.67 (0.10)
Ln(Salmon)	Ln(Tuna)	1.100	0.761	1.44 (0.15)
	Constant	0.435	1.996	0.22 (0.83)
Ln(Tuna)	Ln(Salmon)	0.142	0.118	1.21 (0.23)
	Constant	2.200	0.387	5.69 (0.00)

[]

TABLE A.2: Seafood exported from Norway to Brazil during the period 1988 through August 2018. Source: NSC

		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
		Amount in tonn																														
Klippfisk whole	Pollock	2,839	2,162	2,135	2,770	2,817	3,634	7,621	9,149	10,014	9,478	12,429	7,723	11,926	12,158	10,491	11,170	16,782	14,847	17,091	18,593	19,757	16,730	18,309	18,465	14,700	12,876	11,716	8,647	7,976	11,824	5,232
	Cod	1,857	2,636	2,617	3,669	2,713	4,492	6,771	10,550	14,191	14,029	14,062	6,373	5,702	5,157	4,288	4,063	5,818	5,714	7,490	7,833	6,681	6,916	9,775	9,561	9,099	9,544	12,047	7,930	6,226	8,520	3,505
	Common ling	2,315	3,922	3,256	2,551	1,577	1,855	3,069	2,821	2,874	2,350	4,100	2,337	3,099	1,755	1,087	787	1,431	1,091	1,454	1,560	1,221	2,012	2,431	1,877	1,617	1,036	1,675	1,247	1,295	983	197
	Cusk	4,073	4,621	4,788	3,937	4,040	4,818	4,901	3,891	4,179	3,377	4,393	3,379	4,535	4,112	1,989	1,611	1,435	1,564	1,316	1,840	1,792	2,410	3,027	2,654	2,624	2,209	2,080	1,578	1,697	1,987	604
	other whitefish			13	38		25	251	169	207	265	105	29	93	15	33	210	107	11	133	308	13	25	2	28	18				141	75	
Frozen filet	Pollock											16	4	13						12												
	Cod		20					15	47	91	97	54		2																		
	Herring												10								26											25
	Salmon									1			2	5	5												22		35			
	Mackerel												15																			
Frozen whole	otherfish								3	8											8		47	26	20							
	Haddock																				1		1							2		15
	Cod							1	3	31	62	17	24	5	13			241		6	24	44	32	39	38	10						10
	Pollock							4			6									8	10		1		1						460	331
	Herring							12	25	231	290	98	75	267	367	101	124	65	320	891	1,581	2,047	1,706	1,372	988	629	631	350	186	207	182	93
	Salmon				1				5	43	15	6							19										9			
	Capelin														9					3	1	30	102		51		26					
	Mackerel							24	29										25	15	1			126	25	78						
Salted filet, conventional	other whitefish													25				1	1	209	138			14	25							
	Cusk							10				16									26		12	23	155							
	Common ling																					20		111	78							
	Cod						20	33	7	40	10	21	13				10	17	33		219	137	81	95	188							
Saltet whole, conventional	Cusk											27			13				3	6												
	Common ling	25			4													8														
	Pollock	125						13					25		38			25		13												
	Cod							22		10	19	23		13	38	13	8			20	44		91					25				
Stockfish filet	other whitefish									13	25			8	7	1						25	8									
	Common ling																															
Stockfish whole	other whitefish	45	48	18		20	30					115	50	23	24	115																
	Cusk	25														22											2					
	Pollock	6	2	6	15	5							13	100		136				64						150						
	Cod			3	5			8					25										26									
Smoked whole and filet	other fish							2	6	1	1		9				13															
	Salmon		1		2	3	6	16	12	20	23	29	11	14	6	6	2	0	1	1					1				48			
	Herring		13	10	10	13	6	8	6	11	5	40	14	2	5	6	6	1		2	9	2		2	1	4				2		
Saltet whole	other fish																						3									
	Herring				2	1	8	14	2	5	15	6	1	2	8	6	16	1			25											

TABLE A.3: BDS Test for Nonlinearity.

		ϵ			
		0.5	1.0	1.5	2.0
Salmon	m = 2	364.9 (0)	220.4 (0)	110.4 (0)	76.5 (0)
	m = 3	646.8 (0)	291.8 (0)	126.7 (0)	83.3 (0)
	m = 4	1229.7 (0)	390.5 (0)	142.3 (0)	86.0 (0)
	m = 5	2469.3 (0)	539.3 (0)	161.7 (0)	88.4 (0)
	m = 6	5451.7 (0)	775.3 (0)	187.7 (0)	91.5 (0)
Tilapia	m = 2	172.5 (0)	79.1 (0)	56.2 (0)	50.3 (0)
	m = 3	306.1 (0)	99.2 (0)	63.5 (0)	53.5 (0)
	m = 4	569.5 (0)	123.1 (0)	68.7 (0)	53.5 (0)
	m = 5	1150.3 (0)	155.9 (0)	74.7 (0)	53.3 (0)
	m = 6	2567.3 (0)	205.5 (0)	83.2 (0)	54.0 (0)
Spotted Sorubim	m = 2	83.1 (0)	72.6 (0)	55.4 (0)	48.8 (0)
	m = 3	123.7 (0)	90.7 (0)	62.0 (0)	52.5 (0)
	m = 4	187.7 (0)	111.6 (0)	66.9 (0)	53.6 (0)
	m = 5	300.7 (0)	140.0 (0)	72.2 (0)	54.1 (0)
	m = 6	510.6 (0)	180.0 (0)	78.8 (0)	54.9 (0)
Weakfish	m = 2	10.1 (0)	5.6 (0)	4.8 (0)	5.3 (0)
	m = 3	13.3 (0)	8.1 (0)	6.6 (0)	6.8 (0)
	m = 4	14.7 (0)	9.1 (0)	7.3 (0)	7.3 (0)
	m = 5	15.4 (0)	9.3 (0)	7.3 (0)	7.4 (0)
	m = 6	17.8 (0)	10.3 (0)	7.7 (0)	7.7 (0)
Flatfish	m = 2	49.8 (0)	35.6 (0)	24.4 (0)	15.8 (0)
	m = 3	64.6 (0)	40.3 (0)	25.8 (0)	16.1 (0)
	m = 4	83.3 (0)	44.1 (0)	25.9 (0)	15.6 (0)
	m = 5	109.7 (0)	48.8 (0)	26.3 (0)	15.4 (0)
	m = 6	152.6 (0)	55.3 (0)	27.0 (0)	15.5 (0)
Common Snook	m = 2	93.4 (0)	67.1 (0)	53.3 (0)	49.5 (0)
	m = 3	136.7 (0)	83.0 (0)	58.9 (0)	52.4 (0)
	m = 4	205.6 (0)	102.6 (0)	63.3 (0)	53.2 (0)
	m = 5	330.4 (0)	129.1 (0)	68.1 (0)	53.9 (0)
	m = 6	589.2 (0)	168.5 (0)	74.3 (0)	55.3 (0)
Mullet	m = 2	55.7 (0)	45.5 (0)	39.4 (0)	33.6 (0)
	m = 3	80.0 (0)	55.2 (0)	44.5 (0)	36.9 (0)
	m = 4	120.9 (0)	65.3 (0)	47.7 (0)	37.6 (0)
	m = 5	190.6 (0)	78.6 (0)	50.8 (0)	37.8 (0)
	m = 6	326.2 (0)	96.6 (0)	54.9 (0)	38.3 (0)
Shark	m = 2	38.2 (0)	30.2 (0)	26.6 (0)	20.6 (0)
	m = 3	66.6 (0)	40.5 (0)	31.8 (0)	24.3 (0)
	m = 4	120.6 (0)	51.2 (0)	35.1 (0)	26.2 (0)
	m = 5	239.7 (0)	64.9 (0)	38.3 (0)	27.3 (0)
	m = 6	514.7 (0)	84.8 (0)	42.0 (0)	28.3 (0)
Sardine	m = 2	336.8 (0)	140.3 (0)	97.5 (0)	77.7 (0)
	m = 3	571.0 (0)	178.8 (0)	108.6 (0)	80.0 (0)

Table A.3 continued from previous page

	m = 4	1043.6 (0)	230.0 (0)	119.5 (0)	80.4 (0)
	m = 5	2098.2 (0)	306.5 (0)	133.6 (0)	81.6 (0)
	m = 6	4563.1 (0)	424.7 (0)	152.8 (0)	83.8 (0)
Tuna	m = 2	46.0 (0)	34.7 (0)	25.3 (0)	16.0 (0)
	m = 3	70.6 (0)	41.5 (0)	28.6 (0)	18.2 (0)
	m = 4	110.8 (0)	48.0 (0)	30.1 (0)	18.5 (0)
	m = 5	191.2 (0)	56.1 (0)	31.6 (0)	18.4 (0)
	m = 6	374.3 (0)	68.3 (0)	33.8 (0)	18.8 (0)

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