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Impacts of the Russo-Ukrainian War on the Norwegian Farmed Salmon Price

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Abstract

The Norwegian farmed salmon industry holds a prominent position in the global market, making it vulnerable to various external factors that can significantly affect its pricing and profitability. This study focuses on investigating the potential effects the Russo-Ukrainian war, which escalated on February 24, 2022, had on the Norwegian farmed salmon price. Through a comprehensive analysis of data spanning over a specific period, including factors such as standing biomass, feed consumption, wheat price, exchange rate, sea temperature, meat price index and other relevant variables, this research aims to investigate the connection between the war and the Norwegian farmed salmon price.

Using an Autoregressive Distributed Lag (ARDL) model with a dummy variable, this research explores the variables and their relationship to the Norwegian farmed salmon price, represented by the Fish Pool Index, and allows for a comprehensive understanding of the dynamics between the various factors and their influence on the salmon price. The analysis reveals that the salmon price experienced a significant price shock when the war escalated. While the explanatory variables account for this shock, no unexplained impact directly attributed by the war are identified. The results reveal a correlation between the wheat price, a key ingredient in fish feed, suggesting an indirect impact of the war on the salmon price.

This study provides valuable insights into the complex relationship between the Russo-Ukrainian war and the Norwegian farmed salmon price. By shedding light on the interplay of various factors influencing the price, this study aims to provide valuable insights for industry stakeholders, policymakers, and researchers. With the Norwegian salmon industry demonstrating resilience and continued growth, investigating the link between the war and salmon prices contribute to arrange for informed decisions to mitigate risks, support the industry's growth, and ensure a reliable food supply in the face of geopolitical disruptions.

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List of Acronyms

Acronym	Full meaning
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag Model
FDI	Foreign Direct Investment
FPI	Fish Pool Index
MAB	Maximum Allowable Biomass
MPI	Meat Price Index
NFD	Norwegian Ministry of Trade, Industry and Fisheries
SSB	Statistics Norway

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1. Introduction

Salmon farming stands as one of Norway´s most significant industries, providing valuable employment, settlement and development opportunities and contributing significantly to the country´s economy (Norsk Industri, 2017). In 2022, Norway´s seafood industry had its most successful year yet, with a total export of 2.9 million tons of seafood valued at 151,4 billion NOK (Norwegian Seafood Council, 2023). As the leading nation in the world of production and exports of Atlantic salmon (NFD, 2021), Norway makes a vital contributor to the global market. However, the industry's success and position in the global market make it vulnerable to external factors that can impact its pricing and profitability. The global nature of the industry leads us to believe that it would be influenced by geopolitical disruptions such as the war. Recent data shows that the Norwegian farmed salmon price experienced a notable disruption in 2022 (see Appendix I), with higher price fluctuations this year compared to the past 10 years. This finding is of particular interest as it suggests the presence of factors influencing the price, which has not been observed in previous years. Consequently, this indicates the importance of exploring the potential impacts of the Russo-Ukrainian war, which escalated on February 24, 2022. In this paper we seek to study the potential impacts of the Russo-Ukrainian war on the price of Norwegian farmed salmon, shedding light on the relationship between geopolitical disruptions and the salmon industry.

1.1 Motivation

The Norwegian farmed salmon price is characterized by high volatility, which cause uncertainty and additional costs throughout the industry's value chain (Oglend, 2013). The price of farmed salmon is influenced by a variety of volatile factors, including unpredictable and seasonal elements such as disease outbreaks, feed consumption. standing biomass and changing sea water temperatures. Understanding the influence of these price dynamics in the salmon industry is essential for market participants to make informed decisions and mitigate risks. The Russo-Ukrainian war has already made a significant global impact on a worldwide scale, with ongoing geopolitical disruptions affecting trade and economic activity (Mbah & Wasum, 2022). Despite the consistent growth of the Norwegian salmon industry in recent years, the ongoing war poses potential challenges for the industry and all stakeholders involved.

Using the ARDL (Autoregressive Distributed Lag) model allows us to examine how the war may have influenced the price of Norwegian farmed salmon, while also considering the potential lagged effects and interactions with other relevant variables. This approach provides a robust framework to evaluate the potential impacts of the war and gain a comprehensive understanding of its relationship with the price dynamics in the Norwegian salmon farming industry. Comprehending the effects of the war on the salmon price could contribute to safeguarding the sustainability of the Norwegian salmon industry and allow for informed decision-making and proactive measures, benefiting both the industry and consumers. The research could also enable stakeholders to better understand the factors that influence market dynamics in order to adjust their business strategies accordingly.

In conclusion, the salmon market is an interesting area of studying, as it is influenced by a wide range of factors and has significant economic and social consequences for many countries around the world. Research on the impact of the Russo-Ukrainian war on the farmed salmon price in Norway can provide valuable insights into the price dynamics and inform policy and business decisions in the future. The notable shock in the salmon price during 2022 compared to earlier years underscores the importance of investigating the potential underlying drivers behind it.

1.2 Problem Description

Given the aforementioned discussion and the potential advantages of investigating the relationship between the Russo-Ukrainian war and the salmon price, we have formulated the following problem description:

> "How has the Russo-Ukrainian war impacted the Norwegian farmed salmon price?"

Thus, the objective of this paper seeks to formulate and understand how the Russo-Ukrainian war has affected the Norwegian farmed salmon price, and we do this by implementing the Autoregressive Distributed Lag model.

1.3 Thesis Structure

This paper consists of six chapters. Following this introduction, Chapter 2 provides an overview of the key concepts and information that serve as the foundation for the study. Chapter 3 presents details on the data processing employed in the study, and explains how the data were gathered, organized, and prepared for analysis. Chapter 3 also explains the approach and techniques used in the study to investigate our problem description, with an explanation on the Autoregressive Distributed Lag model, dummy variables, and the AIC specifically. Chapter 4 presents the findings of the study, describing the data collected, the statistical analysis performed, and the results of the analysis. Chapter 5 discuss the findings of the study in the context of the problem description and relates the findings to the existing literature. This chapter also provides insights into the limitations of the study and suggestions for future research on the topic. Chapter 6 offers a summary of the key findings of the study and the conclusions drawn.

2. Background

The aim of this chapter is to give an overview of the relevant background and literature related to the impacts of the Russo-Ukraine war on the Norwegian farmed salmon price. The chapter contextualize the problem description and provides a review of the available literature on the topic, identifying key theories, findings, and gaps in the current research. Finally, the chapter outlines the specific dataset used in our empirical study.

2.1 The Norwegian Salmon Industry

Atlantic salmon, the main species produced in Norway, benefits from the country's stable and cold temperatures along with its long coastline, which provides the ideal natural conditions for salmon farming (Norwegian Seafood Council, 2021). This thriving industry has become Norway´s most significant export industry after oil and gas within just fifty years since the 1960s, symbolizing one of the greatest success stories in modern Norway (Hersoug, 2021). The industry contributes significantly to the Norwegian economy, with an estimated export value of NOK 151,4 billion in 2022 (Norwegian Seafood Council, 2023). In 2020, the

Norwegian fish farming industry produced approximately 1.5 million tons of farmed fish on an annual basis (NFD, 2021). This demonstrates the significant capacity of Norwegian fish farms to meet both domestic and international demand for farmed fish. A few large Norwegian companies, including Mowi, Cermaq, Lerøy Seafood, and SalMar, dominate the industry. According to "Salmon World 2022", a report published by Kontali (2022), eight of the worlds' 15 biggest salmon farm companies in 2021 was Norwegian, with Mowi as the largest farm company in the world.

2.1.1 A Global Industry

The success and expansion have enabled the Norwegian salmon farming industry to become a major player in the global market, accounting for more than half of the total farmed salmon production in the world (Norsk Industri, 2017). According to an international survey held by the Norwegian Seafood Council (2021), salmon has become the most preferred fish option globally, with 44% of the respondents preferring the origin of their salmon to be Norwegian. With a significant contribution to employment and international trade, Norwegian salmon farming has become a response to the challenge of meeting the growing demand for healthy food. Due to an increasing global population, the demand for animal-based food is set to increase by 70% by 2050 (Global Salmon Initiative, 2023). Meeting the rising demand can be challenging, but fish, including farmed salmon, can offer a solution. According to the report *Fish to 2030* by the World Bank (2013), nearly two thirds of global food fish supply will be farm-raised by 2030. Consequently, aquaculture plays a vital role in global food production, with Norway emerging as a key player in the industry.

Since 2010, there has been a significant increase in air freighted seafood exports from Norway (Steinset, 2020). While majorities of the air freighted exports are to Asia, significant quantities are also sent to the United States and the Middle East. Recent periods have shown a considerable increase in exports to China and South Korea (Steinset, 2020). The reliance on international trade entails any factors affecting global supply and demand, such as trade restrictions or geopolitical conflicts, could lead to price fluctuations that affect the Norwegian salmon farming industry.

2.1.2 Navigating Challenges

The Norwegian salmon industry is also facing challenges despite current global circumstances, some bigger than others. The total fish mortality rate in the industry remained unacceptably high in 2021 according to the fish health report 2021 (Sommerset et al., 2021). The report indicates that well over 50 million fish die during the sea phase, a percentage that has not changed significantly over past five years. A few of the major issues include sea lice, escapes, diseases, access to enough space and sufficient feed resources (Lekve, 2012). Despite these challenges, the Norwegian salmon industry has, driven by the increasing demand from markets worldwide, continued to grow.

2.2 Behaviour of Salmon Price and Export

The behavior of salmon price is complex and influenced by several factors. By examining how salmon prices have behaved historically, we might gain insights into how the industry would respond to future challenges and external disruptions such as the Russo-Ukranian war.

2.2.1 Salmon Price Volatility

Oglend (2013) revealed that the volatility of salmon prices has been on the rise since the early 2000s. The volatility could be explained by different potential factors contributing to tighter supply/demand conditions and lower short-run supply elasticity. Examples of such factors include an overall strong price for relevant commodities globally, increasing production costs and an overall increasing demand for salmon. According to Oglend (2013) some analysis indicates that the trend in farmed salmon price volatility is primarily explained by the common trend observed in prices of other foods relevant to salmon, such as meats, cereals, oils, and fishmeal in recent year. This indicates that a current environment of robust demand for fish and elevated input costs results in increased price fluctuations. If the trend in food prices relevant to salmon can explain a significant portion of the trend in salmon price volatility, it highlights the importance of analyzing the interdependence of the global food market and its potential impacts.

2.2.2 Fish Feed

According to a report by Nofima (Aas et al., 2022), 92% of all ingredients used in fish feed 2020 was imported, with 212 689 tons of plant ingredients imported from Russia. Wheat is one of the most commonly used ingredients in salmon feed (Aas et al., 2022) which indicates that fluctuations in the prices of wheat may affect the farmed salmon market's stability. When feed prices increase, the opportunity cost of harvesting also increases since fish must be kept in pens longer, resulting in additional costs for feeding the fish without much net growth benefits (Oglend, 2013). Farmers may choose to harvest their fish earlier than usual due to higher feed prices and strong demand, which can lead to less supply smoothing and reduced short-run elasticity of supply. As a result, the volatility of prices is likely to increase.

2.2.3 Historical Effects from Geopolitical Disruptions

While there is limited research specifically examining the impact of the Russo-Ukrainian war on the Norwegian salmon price, previous studies have shown that geopolitical disruptions can have significant effects on salmon exports. For example, Russia was one of the largest importers of Norwegian salmon until 2013. In 2014, the imposition of sanctions by the European Union and Norway on Russia following the annexation of Crimea made Russia close its borders to Norwegian salmon and rainbow trout (Steinset, 2020). This in turn led to increased competition in other markets and downward pressure on prices. Belarus increased its import after 2013 and resold to Russia, but since 2020 the Russians have also put a stop to the import of Norwegian salmon from Belarus (Steinset, 2020). The Norwegian seafood industry got affected by spillover effects from this geopolitical conflict between Russia and the West, but the industry handled it in a way that proved the industry is robust and well-organized (Bjørkmann, 2016)

The export of Norwegian salmon to China has increased significantly in recent years, following a period of boycott due to diplomatic tensions (Steinset, 2020). Norway signed a salmon agreement with China in late 2017, and since 2018, this market has reopened. Additionally, the impact of the COVID-19 pandemic on international seafood trade has become a popular topic in the literature, with numerous studies exploring its effects on various aspects of the industry, both positive and negative. According to an article by Yang et al. (2022), the COVID-19 pandemic had some impacts on salmon prices. At the beginning of the pandemic, the closure of restaurants and food service industries resulted in a decrease in demand for salmon and other seafood products, which led to a brief decline in prices. However, as consumers shifted towards purchasing more seafood from grocery stores, prices quickly rebounded and eventually increased due to a combination of factors such as supply chain disruptions, changes in consumer preferences, and the overall economic uncertainty caused by the pandemic (Yang et al., 2022).

2.3 The Russo-Ukrainian War

The Russo-Ukrainian war escalated February 26 2022, and has caused notable economic and financial shocks, affecting trade and economic activity with soaring prices on agricultural products, energy, and raw materials (OECD, 2022). With the global economy still handling the aftermath of the COVID-19 pandemic, the attack by Russia on Ukraine compounded the challenges with increased commodity prices and disruptions to supply chains. According to the World Bank report "The Impact of the War in Ukraine on Global Trade and Investments" (Ruta, 2022), the economic shock waves were transmitted through five channels: commodity markets, logistics networks, supply chains, foreign direct investment (FDI), and sectors such as tourism. The war directly impacted firms operating in Russia and Ukraine, as well as those dependent on suppliers from these markets. However, the shock caused by the war extends beyond these two countries, as it contributed to an overall increase in geopolitical risks globally (Ruta, 2022). Europe is the most affected region with regard to trade links and reliance on Russian energy and food supplies (Mbah & Wasum, 2022). Overall, the significant impact of the war on the world economy resulted in increased prices and weakened confidence in the financial market, supported by stringent global sanctions imposed on Russia (Liadze et al., 2022).

2.3.1 Commodity Prices

Compared to other geopolitical disruptions, the Russo-Ukraine war had a more substantial impact on the volatility risk of commodity markets (Fang & Shao, 2022). This intensifies the commodity price volatility, which is detrimental to global economic growth. The volatility for some commodities, like wheat, reached record highs in February and March 2022 (World Bank, 2022). The report "Commodity Markets Outlook" by the World Bank (2022) claims that there are two main channels through which the war impacted commodity markets: the physical effects of blockades and destruction of productive capacity, and the consequences on trade and production due to the imposition of sanctions. The war significantly disrupted the transport of commodities due to Black Sea ports no longer being operational, damage on infrastructure, safety concerns and increased costs of shipping. Further, sanctions imposed on Russia and disruptions on agricultural production also slowed down the trade (World Bank, 2022). In the report for October, as concerns about a global recession intensified and global growth started to slow down, most commodity prices had declined from their post-pandemic demand surge and the war in Ukraine (World Bank, October 2022). The global growth saw a sharp slowdown, and the commodity prices were impacted by concerns about an impending global recession.

2.3.2. Wheat Price

According to OECD (2022), Russia and Ukraine combined account for around 30% of global exports of wheat, 20% for corn, mineral fertilizers, and natural gas, and 11% for oil. As already discussed, the Russo-Ukrainian war created a major shock to commodity markets, with prices rising sharply for all energy commodities and some food commodities, including wheat (World Bank, 2022). According to *Commodity Markets Outlook April 2022* (World Bank, 2022), wheat prices saw a very steep increase in the beginning of 2022, with an almost 30 percent higher price in March 2022 compared to December 2021. The report claims that Ukraine was expected to export 20 million tons of wheat during the season, which corresponds to about 10 percent of global wheat exports, but disruptions to the exports from Ukraine affected several importing countries. Overall, the war caused major supply disruptions and led to historically higher prices for a number of commodities, including wheat. Given this information in addition to the importance of wheat in fish feed, the wheat price will be given further consideration and analyzed in more detail throughout this study.

2.4 Dataset Variables

To construct a machine learning model that can predict and comprehend the factors influencing the dependent variable, explanatory variables or lagged dependent variables are required (Hyndman & Athanasopoulos, 2018). Our dataset includes some factors that are not affected by geopolitical disruptions, and some factors that in light of the earlier discussions are affected by the war such as the wheat price, MPI and exchange rates. The variables we have chosen to include in our research are based on what previous papers on salmon price forecasting have utilized, and chapter 3.1 provides a more detailed explanation on the data preprocessing. However, we will now briefly explain the specific variables related to the salmon industry that are relevant for our study.

Standing Biomass

A prerequisite for gaining a license to farm fish is that a permit is granted (County Governor of Nordland, 2023). Every individual permit is limited by a maximum allowable biomass (MAB) for each farming site. The regulation is used to ensure that farming becomes profitable and competitive, within the framework of sustainable development and optimal use of the coastline (Fiskeridirektoratet, 2023). The standing biomass of salmon is defined as the volume of live fish present in the fish farm at any given time, measured in metric tons (BarentsWatch, 2012). As well as being a regulation, MAB is used as a tool by the fisheries to control and monitor production, as monitoring and knowing the number of fish in the net cages at any given time is crucial for efficient operation and productivity. The feeding and growth potential of the fish can be optimized with better control so that the production time and possible feed waste are minimized (Høy et al., 2013).

Smolt Release

The definition of smolt is a juvenile salmon (Biørnstad, 2015). Before the smolt can be released, it must go through many changes. The salmon first sees a roe, hatching and infantile stage in freshwater environments. These three stages usually take around 800 days, about two years, in total. After these three stages, the smolt is ready to be released into net cages and further transform into harvestable fish (4-6kg). This process takes up to two years (Erko Seafood, 2023). Smolt release is a good indicator for future harvest and supply two years after its release. Significant changes to the smolt release will have impacts on the future supply, thus negatively impacting the price.

Feed Consumption

The feed consumption is measured as the weight of feed consumed by the salmon in a period. In our case, it is the weight of feed consumed by the fish each month (Directorate of Fisheries, 2023). The variable is an indicator for future short-term supply, as more feed consumed means an increasing rate of growing biomass, lowering the production time of harvestable salmon as well as the price. Salmon consuming less feed could indicate slower growing salmon, therefore delaying the supply of harvestable fish and rising prices.

Harvest Volume

Harvest volume is the total weight of all harvested salmon in a period. The data utilized in our analysis is also measured on a monthly basis (Directorate of Fisheries, 2023). Harvest volume is important in determining short term supply of salmon. As harvesting is one of the last steps in the farming process, the number of harvestable salmon highly depends on other variables such as smolt release, sea temperature, feed consumption, sea lice and fish loss. If these variables provide good conditions for the salmon to grow, there will be higher harvest volumes. There will also be seasonal differences. This will occur with variables such as sea temperature, which is highly influential on the salmon's growth and changes are outside human control.

Sea Temperature

Sea temperature affects the health, growth, and survival of the fish. Salmon are cold-blooded animals, which means that their bodies can`t regulate temperatures internally and their temperature is determined by the environment (Kinhai, 2017). The optimal temperature range for Atlantic salmon growth and survival is between 8°C and 14°C (Gjerdrum, 2020). A temperature within the optimal temperature range should correspond to higher supply and lower price. If the sea temperature gets too warm the salmon get stressed, eat less, and grow slower (Gjerdrum, 2020). As temperature rises, the scope for activity and growth as well as the optimal temperature for growth also increase, reaching a point of maximum efficiency (Jonsson & Jonsson, 2009). Beyond this point, the oxygen content of the water becomes a limiting factor. As a result, both too high and too low sea temperatures lead to a longer production cycle and lower expected harvest volumes.

Sea Lice

Sea lice is the most common parasite found on salmon (Lusedata, 2023). Due to the lice's potential for contagion and the number of available hosts, as well as the potentially severe impact on both wild and farmed fish, salmon lice is one of the most serious problems in fish farming in Norway today (Sommerset et al., 2021). Large amounts of sea lice can cause the salmon to die and makes the fish more susceptible to other infections

(Havforskningsinstituttet, 2018). Therefore, sea lice can impact pricing as it might cause a decrease in expected harvest volume, In 2018, sea lice cost the Norwegian salmon industry more than NOK 5.2 billion, and these are only the direct costs for keeping the level of lice under control (Berglihn, 2019). In addition, there are significant indirect costs on top of this. A high number of sea lice can also threaten populations of wild salmon fish, and it is causing the Norwegian salmon industry additional costs as concerns over environmental factors increase the consumer demand for sustainably farmed salmon. As a result, we could expect a high amount of sea lice to result in a smaller healthy biomass, higher numbers of fish loss, which leads to lower future supply, consequently resulting in higher prices.

Meat Price Index

The MPI is computed from average export unit values/market prices of bovine, pig meat, poultry meat and ovine meat, weighted by world average export trade shares (Trading Economics, 2023). It shows price trends of alternate substitute protein sources for salmon. A lowered MPI will result in consumers being more likely to substitute seafood, having an immediate impact on the prices. If the MPI increases, consumers are more likely to resort to seafood alternatives instead of bovine, pig, poultry, and ovine meats. This raises the demand and price for salmon. If the MPI decreases, consumers may be less incentivized to choose seafood options, in which the supply decreases along with the price.

Wheat Price

As already discussed, the wheat price has been on the rise due to the Russo-Ukraine war. We have chosen to include the wheat price as one of our variables due to its significance in the Russian/Ukrainian exports and potential impact on the cost of salmon production. Changes in wheat price can affect the salmon farmers' profitability through fish feed and may have implications on the overall supply of salmon in the market, making it an important variable to consider in our analysis.

Exchange Rates

Currency exchange rates can affect the price of Norwegian farmed salmon in foreign markets. The instability in the global financial markets caused by the war has resulted in significant fluctuations in exchange rates, which have affected the industry's profitability. According to numbers from SSB most salmon is being traded with the EU (Steinset, 2020), which means the price received for exports is typically in Euros. As a result, fluctuations in the EUR/NOK exchange rate can have a significant impact on Norwegian salmon producers' profitability. For example, a weakening of the Euro relative to the Norwegian Krone can lead to lower revenue for Norwegian exporters, and vice versa. If the NOK currency strengthens, it will cause a significant drop in the salmon price, measured in NOK. Therefore, tracking the movements of the EUR/NOK exchange rate can provide valuable insights into the performance of the Norwegian salmon industry.

Fish Loss

Fish mortality and losses in the production phases play a significant role in the economics of the fish farming industry and how efficient the resource management is (Mikkelsen, 2023). Reported losses in production occur either in the net cages or at the slaughterhouse. Some fish die in the cages, some escape and some may be lost due to other reasons. These losses are categorized as "dead fish", "escaped fish" or "other waste". Losses occurring in the slaughterhouse are due to scrapped fish. According to numbers collected from the Directorate of Fisheries lost fish between 2017 and 2022 were at its lowest in 2020 at 14,6% of all production, and at its highest in 2017 at 15% (2023). Death is the most common reason for fish loss, while escaped fish is the least common. (Lekve, 2012). Fish loss has an inverse relationship with the FPI. A higher fish loss count means there will be a lower supply of salmon in the future. Depending on what stage of production the loss occurs, it can impact both short term- and long-term supply, consequently impacting the price.

3. Data and Methodology

In order to understand the impacts of the war on the salmon price, we need to identify the key factors that contribute to price changes and examine their relationships. While our main focus is not on forecasting salmon prices, we aim to develop a model that incorporates the salmon price along with other relevant variables. By utilizing a statistical model such as the ARDL model to analyze the data, we aim to assess and quantify the specific impact of the war on the salmon price while accounting for other influential factors. This model provides valuable insights into the dynamics of the salmon market and the factors driving its pricing fluctuations. In the next chapter, we present an empirical description of this study, including details on the data processing techniques employed, as well as an outline of the approach and methods used, with a primary focus on the ARDL model.

3.1 Data Preprocessing

While our main focus is not on forecasting salmon prices, it is still essential to establish a model that incorporates the salmon price and other relevant variables. By utilizing a machine learning approach, we can identify the key explanatory variables or lagged dependent variables that influence the salmon price. This enables us to determine if there are any abnormal price fluctuations that cannot be accounted for by the variables already included in the model and to detect any significant deviations from the expected patterns.

3.1.1 Variable selection

In our study, the salmon spot price, represented by the FPI, is the dependent variable, and the predictors are selected based on the approaches used in prior research on forecasting salmon prices (Lien, 2018), (Tharmarajah & Gjesdal, 2020). To keep our research consistent with these papers, we also chose our forecasting model based on the choice of model used in these previous papers. Both Lien (2018) and Tharmarajah & Gjesdal (2020) utilized the variables described in chapter 2.4. The only additional variable in our study is the wheat price, which we have chosen to include based on the aforementioned relevance to the war as well as for the fish farming industry and fish feed.

3.1.2 Data Collection

The data utilized in this paper is collected from publicly available sources and comprises one response variable with 10 features spanning from October 2017 to December 2022, with a monthly time resolution. This results in a total of 63 observations for each variable. An overview of the sources used for collection of the data is provided in Appendix II. The data is collected from various sources in different formats, requiring several preprocessing steps to ensure its suitability for the ARDL method. For instance, some variables had a higher frequency of observations, with data collected at daily or hourly intervals. For time series with daily or weekly observations, we have chosen the first observation of the month with the aim to reduce noise and seasonality.

A large portion of our data is collected from the Norwegian Directorate of Fisheries (2023) website. The data reported by the Directorate dates back no further than October 2017, so this became a natural starting point for all data gathering as it was the only source limiting us. While other studies have analyzed data going back over 10 years prior to our study period, we did not deem it necessary to do the same as our research model does not require forecasting capabilities, but rather the ability to identify significant differences over a shorter timeframe.

3.1.3 Descriptive Statistics

As discussed in chapter 2.4, lagged dependent variables are required in order to construct a machine learning model that can predict and comprehend the factors influencing a dependent variable (Hyndman & Athanasopoulos, 2018). To utilize the ARDL model effectively, it is essential that all explanatory variables have, at most, an integrated order, to ensure the accuracy and reliability of the ARDL model. Lags are a central part of defining the time series relationship to the data, and by including different lags for each variable, we aim to capture the time-dependent relationships and assess their influence on the salmon price dynamics. Table 3-1 presents an overview of the variables included in our study along with their respective number of lags. The selection of lags for all variables except wheat is based on previous research on forecasting salmon price using the ARDL model (Lien, 2018) and (Tharmarajah & Gjesdal, 2020), as mentioned in chapter 3.1.1.

In terms of supply, the Fish Pool Index represents the monthly average price of salmon in NOK/kg on a global scale. The FPI is lagged by one month. Standing Biomass, measured in tons, captures the total weight of salmon in Norwegian farms, based on an average generational makeup of salmon. As it is regularly monitored throughout the salmon's production cycle, the standing biomass is set to eight months lag. Smolt Release denotes the number of smolt released in thousands over a period of 24 months. Smolt release is lagged at 24 months because this is the time it takes smolt to become harvestable fish.

Table 3-1: Variables Description and Specifications

Variable	Number of Lags	Measurement Unit	Resolution
Supply			
Fish Pool Index	1 Month	NOK/kg	Global
Standing Biomass	8 Months	Tonnes	Norway
Smolt Release	24 Months	Individuals	Norway
Feed consumption	3 Months	Tonnes	Norway
Harvest volume	1 Month	Individuals	Norway
Sea Temperature	3 Months	Celsius Degrees	Norway
Sea lice	8 Months	Individuals	Norway
Fish loss	1 Month	Individuals	Norway
Demand			
Meat price index	1 Month	USD/tonnes	Global
Wheat price	5 Months	USD/Bushel	Global
*Other**			
NOK/EUR Exchange rate	12 Months	NOK/EUR	Norway/Europe

*Factors that affects both supply and demand

Feed consumption indicates the total amount of feed consumed in tons in Norway, and shows an increasing trend in feed consumption, which indicates fish growth, where larger salmon's consumption peaks right before they are harvestable. It is therefore set to a 3-month lag. Harvest Volume represents the number of harvested salmon in thousands in Norway, lagged at 1 month. Sea Temperature is the monthly average sea temperature in Celsius degrees, specific to Norway. Data on sea temperature utilized in our research is collected from Lusedata (Ocean Data Collector, 2023) and shows weekly sea temperature measured in different parts of Norway. We have collected and calculated the average total temperatures for each month. As fluctuations in sea temperature can cause fluctuations in the expected harvest volumes regardless of generations (Tharmarajah & Gjesdal, 2020), we expect variation in sea temperature to affect the FPI with three months lag. Sea lice is measured in individuals and represents the average number of lice per fish, including adult female lice, moving lice, and sessile lice. If an outbreak occurs, it is expected to affect the long-term supply for 12 months (Tharmarajah & Gjesdal, 2020). If the fish is harvested early to avoid an outbreak, it is expected to have a three-month impact on the short-term supply. The eight-month lag is therefore based on an average of these expectations. Our data on sea lice is also collected from Lusedata. Fish loss indicates the number of fish lost in thousands in Norway. Fish loss is set to a one-month lag because we expect it to have an immediate impact on the available supply. On the demand side, the MPI reflects the monthly average price of meat in USD/tons on a global scale, set to a one-month lag. The calculation includes two poultry, three bovine, three pig, and one ovine meat products, with 27 quotations in total used in the calculation (Trading Economics, 2023). The Wheat Price is expected to have an immediate impact on the FPI due to expectations of future production costs, but we have also added room for the feed production costs at peak-biomass. It is therefore lagged at 5 months. The NOK/EUR Exchange Rate has a long-term impact on production due to purchasing of production goods to be used in the future. Therefore, it is reasonable to expect a lag of 12 months.

3.1.4 Approach and techniques

After processing the data, we perform exploratory data analysis to identify any patterns or trends, with the aim to gain a deeper understanding of the relationships between the variables and to identify any potential issues or challenges with our dataset. Then we utilize the ARDL model to estimate the coefficients of the independent variables and to analyze the significance and direction of their effects on the dependent variable. Finally, we add a dummy variable. The dummy variable will allow us to define a time period we wish to look at, so we can analyze whether or not there have been any unexplained abnormal fluctuations in the FPI.

3.2 The ARDL Model

The Autoregressive Distributed Lag (ARDL) model is an econometric approach for analyzing the relationship between two or more exogenous time series variables. The ARDL framework enables consistently estimation of both the short-run and long-run relationships among variables (Bentzen & Engsted, 2001). It is also flexible to test for the presence of cointegration. ARDL models are commonly used in econometrics to estimate the short- and long-run effects of policy interventions, changes in market conditions, or other shocks on economic variables (Shrestha & Bhatta, 2018). They are also widely used in forecasting and prediction, as well as in testing hypotheses about the relationships between variables.

The basic ARDL model involves regressing a dependent variable as a function of current and past values of an explanatory variable x. By including these lagged values of the independent variable, the model can also capture the potential effects of the independent variable on the dependent variable (Yobero, 2017).

The model is specified as follows:

$$y_t=\delta+\varphi_1 y_{t-1}+\ldots+\varphi_p y_{t-p}+\theta_0 x_t+\theta_1 x_{t-1}+\ldots+\theta_q x_{t-q}+u_t \tag{3.1}$$

where y(t) is the dependent variable, δ represents the intercept term or the constant coefficient. It is the constant term in the model equation (Parker, 2020). φ1yt-p is the coefficient associated with the lagged value of the dependent variable (Y) at time t-P. It captures the effect of the previous value of the dependent variable on the current value. θqxt-q is the coefficient associated with the lagged difference of the independent variable (X) at time t-q. It captures the effect or the impact of the lagged change in the independent variables on the current value of the dependent variables. ut is the standard error term (Parker, 2020)

One of the key advantages of the ARDL model is its ability to handle non-stationary time series data. By including lagged values of the dependent variable in the model, the ARDL approach can capture the dynamic effects from the lagged x's and the lagged y's and by including a sufficient number of lags of y and x, we can eliminate serial correlation in the errors (Yobero, 2017).

3.3 Dummy Variables

A dummy variable is a binary variable that takes a value of 0 or 1 that is used to include categorical data into a regression model (Date, 2023). One adds dummy variables to a regression model to represent factors, which are of a binary nature. This means they are either observed or not observed. For our research, the dummy variable is used to define a period of time where a price shock of the FPI is observed.

3.4 The Akaike information criterion (AIC)

When estimating prediction error, AIC is a useful tool in the selection of competing, alternative regression models. AIC estimates the relative loss of information in a model. It awards the lowest score to a model possessing the least loss of information or most predictive power, while minimizing the number of predictor variables (Claudio, 2022)

The formula of AIC is defined as:

$$AIC = 2k - 2\ln(L) \tag{3.2}$$

Where 2k is the number of model parameters plus the intercept, and the second term, 2ln(L) is the natural logarithm of the model's likelihood function value. The first term penalizes a greater number of parameters while the second rewards goodness of fit. The lower AIC score a model gets, the better it fits the data (Claudio, 2022).

4. Results

4.1 The Fish Pool Index

For this research, we have used the FPI as a benchmark for the price of Norwegian farmed salmon. FPI is a widely used and reliable indicator of market conditions, updated daily to reflect the current price of Norwegian farmed salmon. As already discussed, the prices for Atlantic salmon can fluctuate significantly, which can pose a risk to buyers, sellers, and other parties involved in the market. Fish Pool provides a risk management tool that can assist in minimizing the exposure to market volatility. Fish Pool is based on the FPI, allowing parties to agree on a fixed price for Atlantic Salmon at a future date (Fish Pool, 2023) As Fish Pool ASA does not offer physical trade of fish, a reference price reflecting the actual spot price of Fresh Atlantic Salmon is needed to settle the financial forward contracts.

The FPI is based on a weighted weekly average of the prices for sizes 3-6 kg of superior quality head-on gutted salmon, and it is composed of two index elements: Nasdaq Salmon Index, which reflects the exporter's selling prices, and SSB, which reflect Norwegian export statistics. These two index elements are related to the weekly spot price of buying and selling

Atlantic salmon. By using this index in our research, we can obtain a comprehensive understanding of how the Russo-Ukrainian war and other external factors have affected the market for Norwegian farmed salmon. The aim of the FPI is to give a correct reflection of the market price, be possible to re-examine/verify, not possible to manipulate, be transparent and available, and remain neutral to all parties (Fish Pool, 2023). The FPI provides a transparent and efficient way to trade salmon contracts, ensuring that market participants have access to accurate and timely information.

This information is essential for buyers and sellers to make informed decisions about when to buy or sell salmon contracts, and for researchers to analyze market trends and identify the impact of external factors. Because the FPI is widely regarded a reliable indicator of market conditions and provides a transparent and efficient way to trade salmon contracts, we have chosen to use it as a representative benchmark for the price of Norwegian farmed salmon. This enables us to obtain accurate and up-to-date information on market trends, making it easier to analyze how external factors have affected the price of Norwegian farmed salmon.

4.2 Statistics on The Salmon Export & Price

In addition to the data collected from Fish Pool, we also collected data on salmon price and export from SSB (SSB, 2023) for fresh farmed salmon. Looking at the data from both sources allows for a more comprehensive overview of the Norwegian farmed salmon market, and having data from multiple sources ensure the accuracy and reliability of our findings. The main event is defined as February 24, 2022, i.e., the start of the Russo-Ukrainian war (Week 8), and data from both sources shows a shock when the war started. The price of farmed salmon is illustrated in Figure 4-1 with data collected from the FPI price history, reflecting the market price. The SSB Time Series Data for Fresh Farmed Salmon is presented in Appendix III, and shows the same shock when Russia invaded Ukraine.

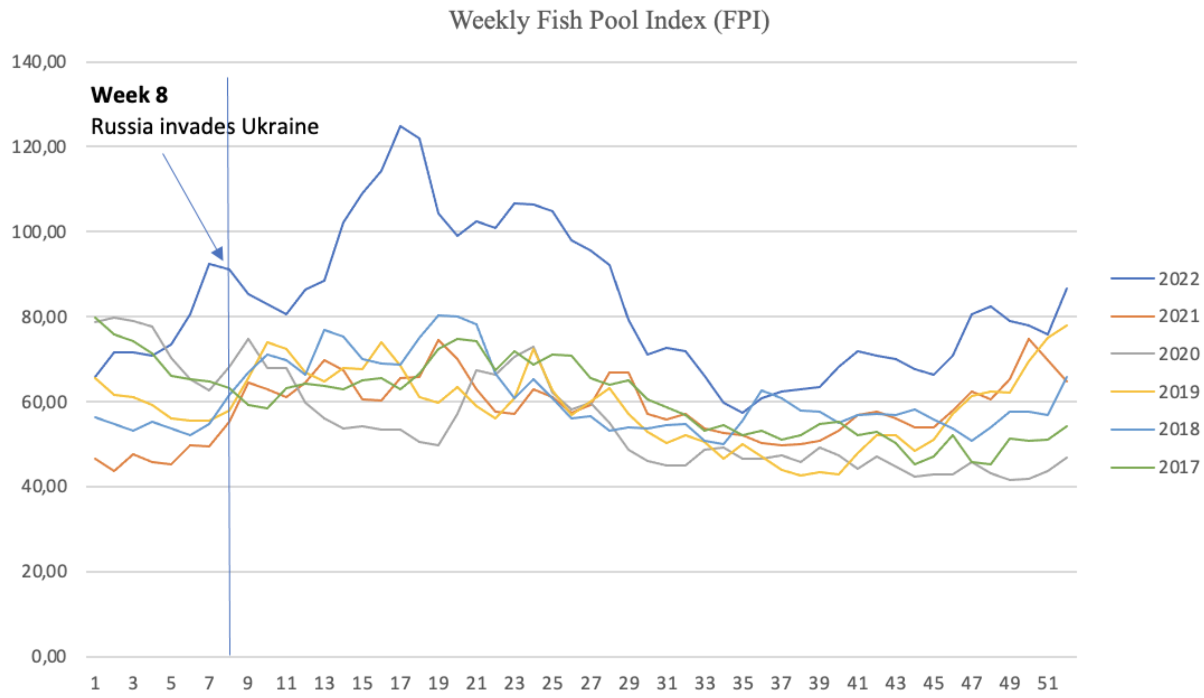

Figure 4-1: Weekly Fish Pool Index (FPI) January 2017 to December 2022

If we consider the last decade, the salmon price has been quite volatile, with some significant fluctuations over the years. Looking at the data, we see that the Fish Pool Index was relatively stable in the first few months of 2020, with some fluctuations but no significant decline. However, we notice a sharp decline in August 2020, which could be linked to the COVID-19 pandemic's impact on the seafood industry. The Fish Pool Index slowly started to recover in 2021, indicating some stabilization in the market. It is worth noting that several other factors could also influence the Fish Pool Index, such as climate change, global trade dynamics, geopolitical tensions, and technological advancements in the seafood industry.

The data for 2022 shows a significant increase in the Fish Pool index NOK/kg compared to the previous year, with the highest index recorded in May and a peak in April. The average price for the year is also higher than the previous years (see Figure 4-2). This increase could be attributed to several factors, including the impact of the Russo-Ukrainian War, which has caused significant disruptions in the global supply chain.

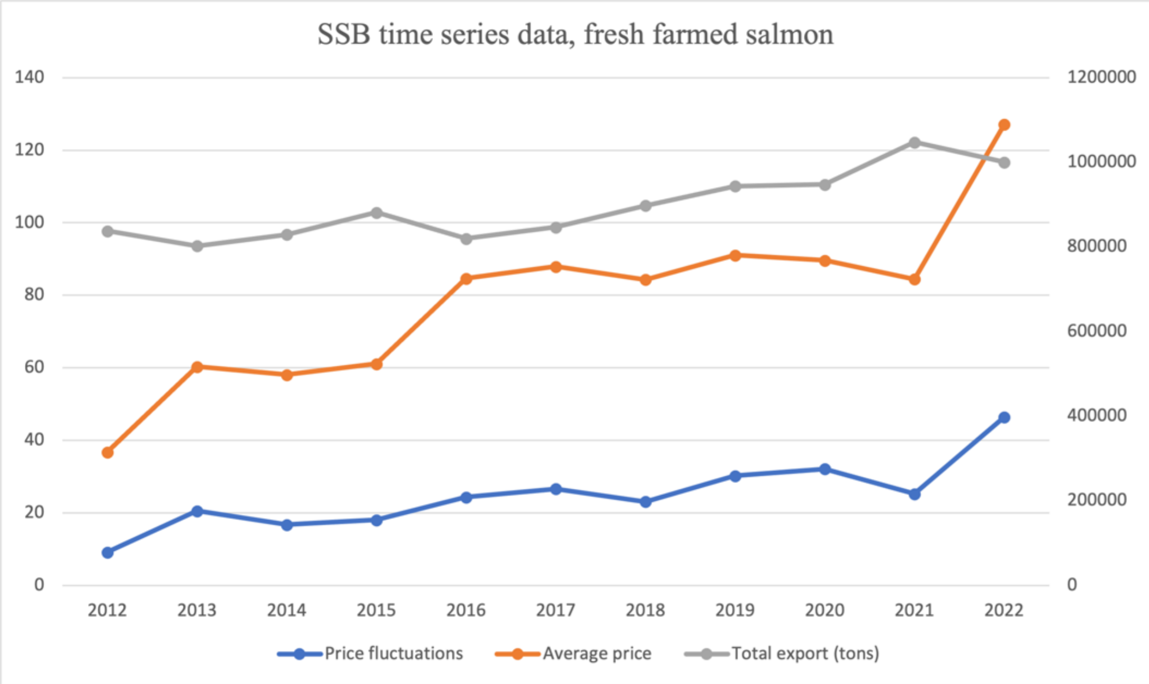

Figure 4-2: SSB time series data 2012-2022, fresh farmed salmon

Upon closer examination on the price fluctuations, average price, and total export for fresh farmed salmon from 2012-2022, there are some interesting trends to note, particularly in 2022. In terms of price fluctuations, there has been a significant increase in 2022 compared to previous years (see Figure 4-2). The average price of fresh farmed salmon in 2022 was 80.76 NOK, which is significantly higher than the average price in 2021 (59.23 NOK). Despite the significant increase in average price, the total export of fresh farmed salmon in 2022 remained relatively stable compared to 2021. It is worth noting that 2022 had the highest average price over the entire period analyzed, indicating that the fresh farmed salmon industry in Norway is continuing to thrive.

4.3 Explanatory Variables

Following the collection and organization of the data, we plotted the variables in RStudio to gain a better understanding of their relationships. In addition to the FPI, we included the explanatory variables. By examining the plots and correlations between these variables, it allowed us to identify any potential trends or patterns that may have influenced the salmon price during the period of interest. Overall, our analysis suggests that the impact of the Russo-Ukrainian war on Norwegian salmon prices is complex and multifaceted, and the inclusion of multiple explanatory variables in our analysis is crucial to capturing this complexity.

Figures 4-3 to 4-7 illustrates the plot of collected data for all explanatory variables. For the purpose of analysis in R, these variables have been assigned simplified names. Among the variables, only wheat price and meat price index exhibit significant deviations from their annual cycles. Specifically, wheat price demonstrates a 33% increase from February to May 2022, indicating a notable change beyond the expected pattern. Similarly, the meat price index undergoes an 11% shock in the transition from the beginning to the middle of 2022. However, it is worth noting that this shock occurs six months after a preceding increase of 26% observed from late 2020 to mid-2021.

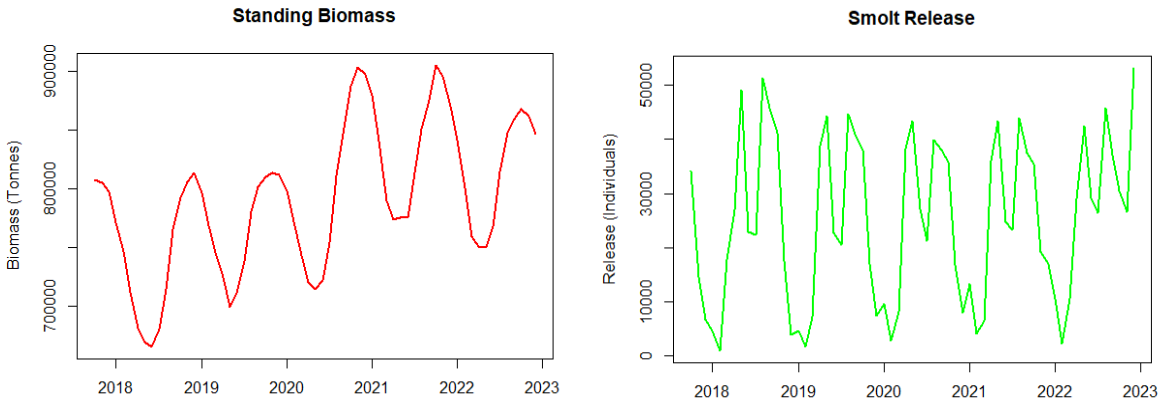

Figure 4-3:Time Series Data Standing Biomass (a, left) & Smolt Release (b, right)

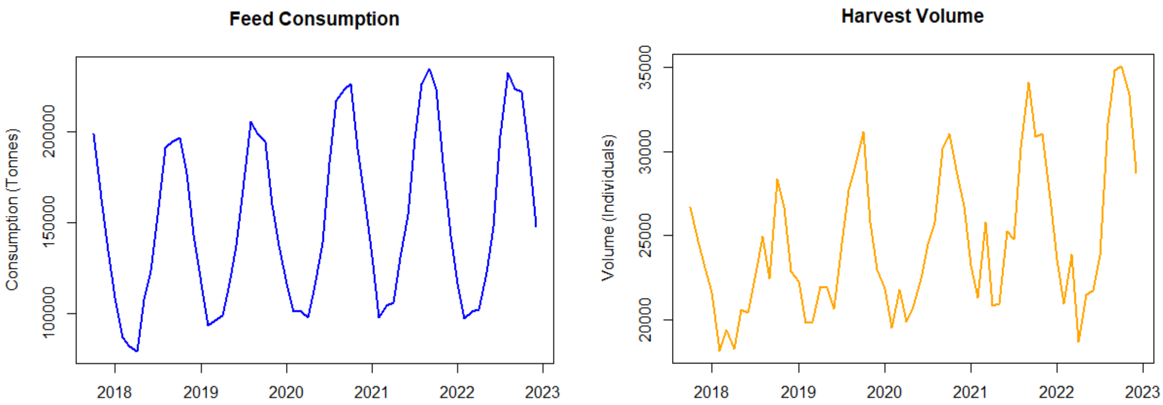

Figure 4-4: Time Series Data Feed Consumption (a, left) & Harvest Volume (b, right)

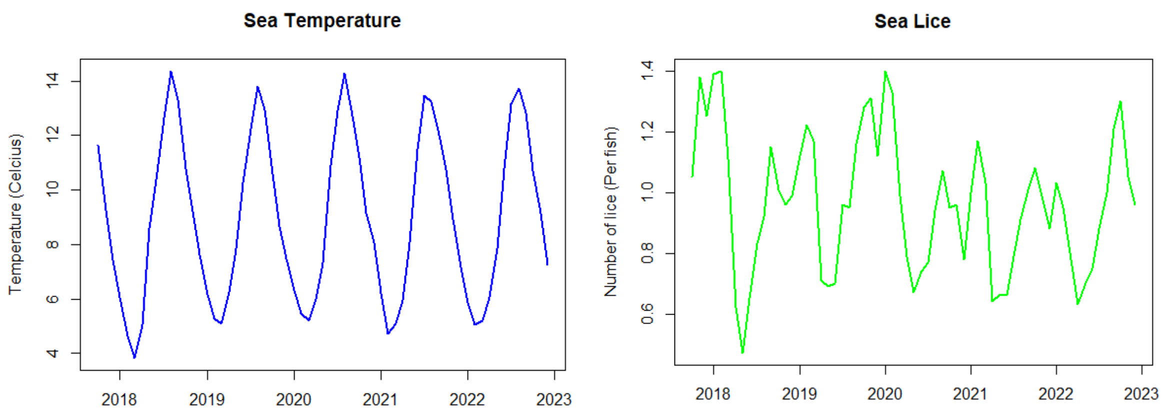

Figure 4-5: Time Series Data Sea Temperature (a, left) & Sea Lice (b, right)

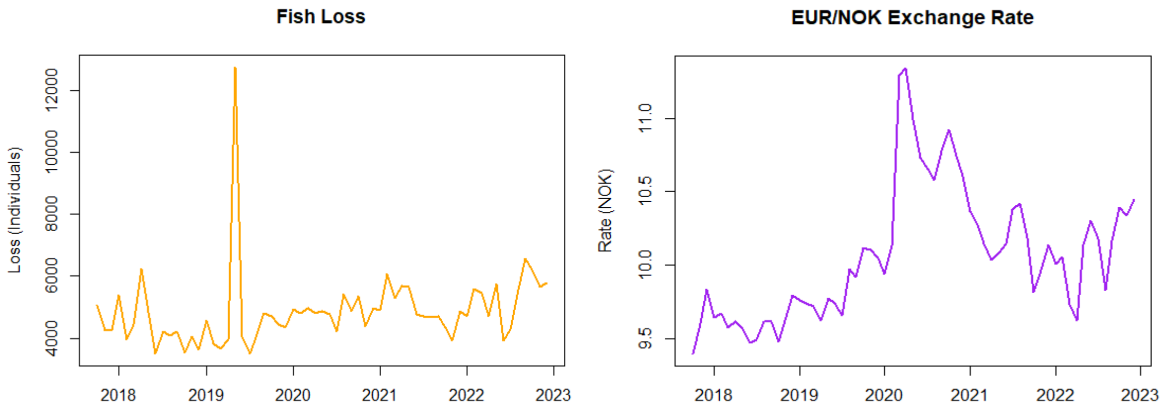

Figure 4-6: Time Series Data Fish Loss (a, left) & Exchange Rate (b, right)

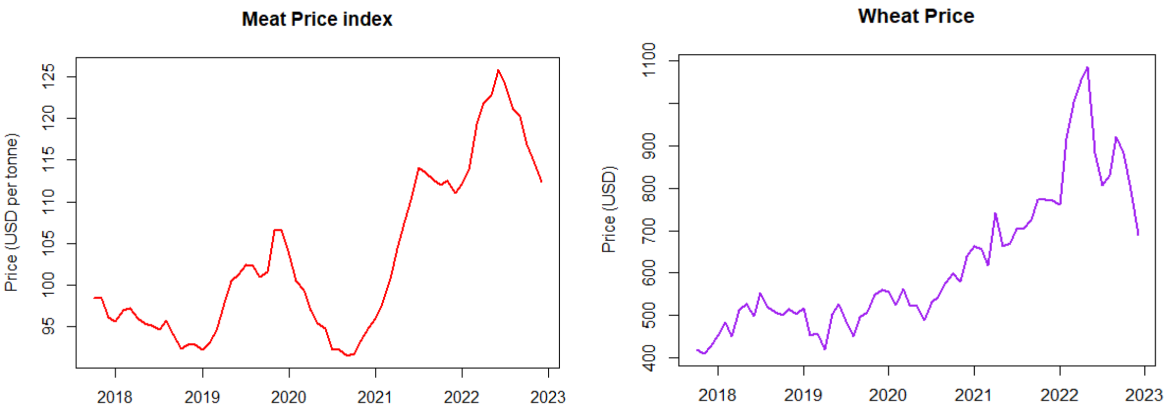

Figure 4-7: Time Series Data Meat Price Index (a, left) & Wheat Price (b, right)

Figure 4-3 presents the time series data for Standing Biomass and Smolt Release. Upon visual analysis, no noticeable abnormal results or anomalies are observed in these variables over the specified time period. Similarly, Figure 4-4 displays the time series data for Feed Consumption and Harvest Volume. These variables also exhibit a consistent trend without any apparent abnormal fluctuations or deviations from the expected patterns. Moving on to Figure 4-5, we observe the time series data for Sea Temperature and Sea Lice. Both variables show consistent patterns without any notable abnormalities or unexpected changes throughout the examined time frame. Figure 4-6 focuses on the time series data for Fish Loss and Exchange Rate. In the case of Fish Loss, a significant shock is observed at the beginning of 2019, which can be attributed to a widespread occurrence of algae toxins leading to the death of several million farmed salmon (Karlsen et al., 2019). As for the Exchange Rate, while a shock is observed at the beginning of 2020, no noticeable changes are observed in 2022.

Finally, Figure 4-7 presents the time series data for Meat Price Index and Wheat Price. Both variables exhibit a shock in 2022, similar to the Fish Pool Index (FPI), indicating a notable change in their respective values during that period. The analyzed figures provide an overview of the time series data for the variables in our dataset, indicating the absence of significant abnormalities in most cases. The exceptions include the Meat Price Index and Wheat Price variables, which displayed shocks in 2022, mirroring the observed patterns in the Fish Pool Index. The visual representations of these changes offer support and confirmation for the observed trends.

4.4 ARDL Model

Our ARDL model function is defined as equation (3.1), where α is an intercept value the model automatically estimates. The previous FPI values affect the current value in the expression ($\varphi_p y_{t-p}$). Each explanatory variable has its own expression ($\beta_t x_{t-s}$). u_t is the error term. This creates a model where the fish pool index (y) is explained by the other variables. The model cannot be plotted due to its complexity. The number of lags to each variable was added by utilizing a vector we created and assigned values to its respective order in the vector. These values were discussed in chapter 3.1.3. The dummy variable is included in the model, but does however, not fit into the model like the variable expressions ($\beta_t x_{t-s}$). It represents an exogenous variable that does not influence the dependent variable within the model, but rather observes and is included as a predictor. Its values are set to 1 in the period March through July 2022, and 0 for all other months before and after. The objective with the dummy variable is to see if there has been an extra unexplained price increase that cannot be explained by the other explanatory variables (Natsiopoulos & Tzeremes, 2023).

4.2.1 AIC model selection

The model is then sorted using a command to identify the top orders of best fitting models. This generates a list of the same model using different lag combinations for each explanatory variable. The order that best fits our data is determined by the lowest AIC value. While testing different amounts of lags on the variables, we found that the only way to get different results on the AIC-test was by changing the lag amount for “fish loss”. An overview of AICs tested ARDL models is presented in Appendix IV. The dummy variable does not appear in the test because it has not been added as a variable with any lag possibility.

4.2.2 ARDL Model Summary

The coefficients estimated in Table 4-1 provide insights into the relationship between the variables and the salmon price. A summary of the best fitting model was given by a command to provide us with regression information. The coefficients along with their corresponding standard errors, t-values, p-values, and significance level help us understand the factors influencing the price of Norwegian farmed salmon. Several noteworthy observations emerge from the coefficients. The values most relevant to us are the P-values (significance values), more specifically the P-value for the dummy variable (dummy). At 0.7, it is not significant at any level. On the other hand, we find several other significant values. There are values given for each variable and lagged variable.

The variable "Standing Biomass" demonstrates a positive relationship with the salmon price, suggesting that an increase in biomass tonnage is associated with higher prices. However, the lagged term displays a negative relationship, indicating a more complex dynamic. Feed consumption and harvest volume exhibit significant relationships with the salmon price. Higher feed consumption and harvest volume are associated with lower prices, as evidenced by their negative coefficient estimates. The MPI variable shows a negative relationship, implying that an increase in the meat price index corresponds to a decrease in salmon prices. Conversely, the "wheatusd" variable, which represents the USD/Bushel price of wheat, displays a positive relationship. Wheat had an immediate impact but not as a lagged variable. This suggests that higher wheat prices have a positive impact on salmon prices, potentially due to the importance of wheat as an ingredient in fish feed. As the wheat price increase, the fish price increase. The variable "eurnok" (NOK/EUR exchange rate) does not exhibit a significant relationship with the salmon price, as indicated by a p-value above the threshold of 0.05. Biomass, feed consumption, harvest volume and the meat price index (MPI) are significant at the 0.001 level. Wheat price (wheatusd) and lice per fish are significant at the 0.01 level.

Table 4-1: Regression Coefficients for best fitted model

Coefficients	Estimate	Std_Error	t_value	p_value	Significance_Level
Intercept	184.2019	33.0074	5.5800	0.0000	***
L(fishpoolindexnokkg, 1)	-0.1765	0.1129	-1.5600	0.1275	
biomasstonnes	0.0009	0.0002	3.9100	0.0004	***
L(biomasstonnes, 1)	0.0000	0.0004	0.0900	0.9305	
L(biomasstonnes, 2)	-0.0009	0.0003	-3.3200	0.0022	**
L(biomasstonnes, 3)	-0.0001	0.0001	-0.5800	0.5663	
smoltrelease	-0.0001	0.0001	-1.6800	0.1025	
feedconsumption	-0.0008	0.0002	-3.4000	0.0018	**
L(feedconsumption, 1)	-0.0010	0.0003	-3.7500	0.0007	***
harvestvolume	0.0040	0.0011	3.5900	0.0011	**
L(harvestvolume, 1)	0.0040	0.0014	2.9500	0.0058	**
seatemp	-1.1258	1.4558	-0.7700	0.4448	
liceperfish	-1.1547	6.4805	-0.1800	0.8597	
L(liceperfish, 1)	-4.3830	7.7884	-0.5600	0.5774	
L(liceperfish, 2)	24.5925	7.6543	3.2100	0.0029	**
L(liceperfish, 3)	-21.1061	8.1125	-2.6000	0.0138	*
mpi	-1.6215	0.4795	-3.3800	0.0019	**
L(mpi, 1)	1.8777	0.5230	0.0019	0.0011	**
wheatusd	0.0404	0.0161	2.5100	0.0171	*
L(wheatusd, 1)	0.0159	0.0213	0.7500	0.4604	
L(wheatusd, 2)	0.0248	0.0177	1.4000	0.1701	
eurnok	-2.9855	3.0612	-0.9800	0.3365	
L(eurnok, 1)	-6.0685	3.3380	-1.8200	0.0781	.
fishloss	0.0003	0.0008	0.3700	0.7168	
L(fishloss, 1)	0.0017	0.0007	2.3800	0.0235	*
dummy	1.2678	5.8487	0.2200	0.8297	
L(dummy, 1)	3.4222	5.0529	0.6800	0.5030	

5. Discussion

The volatility of salmon prices, as highlighted in previous studies (discussed in chapter 2.2), has been a subject of interest due to its potential association with the Russo-Ukrainian war. Our study confirms that the presence of price fluctuations during the period under investigation is a significant outcome. The fluctuations can be attributed to both internal and external factors such as key industry indicators and, indirectly as suggested by our analysis, the impact of geopolitical disruptions. In light of our findings, the confirmation of price fluctuations supports the premise that the Russo-Ukrainian war, being a significant geopolitical disruption, could have had indirect effects on the Norwegian farmed salmon price. While we cannot draw definitive conclusions about the direct causality between the war and price fluctuations, the confirmation of price dynamics highlights the market's vulnerability to external factors, including geopolitical disruptions. Therefore, our study's confirmation of price fluctuations contributes to addressing the problem outlined in our thesis by shedding light on the potential impacts of the Russo-Ukrainian war on the Norwegian farmed salmon price. It underscores the importance of considering broader contextual factors when analyzing and interpreting the observed price dynamics. By incorporating this finding into our analysis, we can further explore the interplay between geopolitical events, market dynamics, and pricing in the Norwegian farmed salmon industry.

5.1 General findings of the ARDL Model

What we can assert from our result with an insignificant dummy variable in our ARDL model is that there has been no additional unexplained increase of gross salmon price directly affected by the Russo-Ukrainian war. This is the case for the abnormal changes in the period from March 2022 through July 2022, where the price first saw a 60% increase until May, and then a 60% decrease until July. Implementing a dummy variable into the ARDL model containing the variables most important for salmon price forecasting means our research has covered almost all but unpredictable systematic risk. Observing that the dummy variable was insignificant at all levels, we cannot say that there has been anything affecting the price outside of what has been covered by our model.

If we look at how the results from our ARDL model fits into the equation 3.1, $\varphi_p y_{t-p}$ represents the effect of the previous values of the Fish Pool Index on the current value. This implies that an increase in the lagged value of the index leads to a similar increase in the current value of the index. The estimate of -0.1765 indicates an inverse relationship between the lagged and current values of the index.

$\theta_q x_{t-q}$ consists of the coefficient estimates presented in the second column of Table 4-1, where (t-q) lagged variables are presented as L (Variable, nLags). The lagged value of the explanatory variable (X_{t-p}) analyzes the influence of the previous period's value of each of the explanatory variables on the current values. The coefficient estimate (θ_p) represents the strength and direction of that influence. For some variables, we find positive (φ_pXt-p) estimates with a significant p-value. This means that an increase in the lagged value of the explanatory variable leads to a similar increase in the current value of the Fish Pool index, while the variables that are negative and significant indicate inverse relationships. While the dummy variable representing the war was found to be insignificant in our ARDL model, it is important to note that our chosen set of explanatory variables comprehensively covered the systematic risk associated with salmon prices.

5.2 Analyzing the processed dataset

As previously mentioned, the analysis conducted by Oglend (2013) suggests that the volatility of farmed salmon prices can be attributed to the overall trend observed in the prices of various food commodities relevant to salmon production, including meats. These findings indicate a common underlying pattern in the pricing dynamics of these commodities. Furthermore, it is evident that the Russia-Ukraine conflict has had a substantial impact on the volatility risk of commodity markets. The war has introduced additional uncertainties and fluctuations in the global market, affecting various industries, including agriculture and seafood.

The significant p-value for the wheat price index (see Table 4-1) indicates that changes in current wheat prices have an impact on the baseline level of the salmon price. This means that when there are fluctuations in wheat prices, the initial level of the salmon price is affected, even when other factors are held constant. This relationship is likely due to the fact that wheat is a key component in salmon feed, and changes in wheat prices influence the production costs of salmon. On the other hand, the non-significance of the lagged wheat p-value suggests that the impact of past wheat prices on the salmon price is not statistically significant. In other words, the historical levels of wheat prices do not have a significant direct effect on the current salmon price once the current wheat prices are considered. This result implies that the relationship between wheat prices and the salmon price is more immediate and sensitive to the current market conditions rather than being influenced by past prices. It suggests that market participants, such as salmon producers and buyers, are more responsive to the current price levels of wheat when setting the baseline price of salmon, rather than relying on historical price patterns. Overall, the significance of the wheat intercept indicates the importance of considering current wheat prices as a determinant of the baseline level of the salmon price, while the non-significance of the lagged wheat intercept suggests that historical wheat prices do not have a significant direct influence on the current salmon price.

In our study the analysis on the relationship between the meat price index and the price of Norwegian farmed salmon revealed a significant association between these variables. It is worth noting that our analysis only focused on the Norwegian farmed salmon price, but it is interesting to observe that the wheat price and MPI also experienced a significant increase in the same period as the salmon price.

5.3 Further interpretations of the results

The presence of an insignificant dummy variable in our ARDL model suggests that the selected explanatory variables have effectively accounted for the majority of systematic risk influencing the salmon price. This outcome is encouraging as it indicates the robustness of our model and its ability to generate reliable forecasts. Despite significant price fluctuations observed throughout the specified period, our model successfully captured the majority of systematic risks impacting the salmon price. This finding implies that the salmon market displays a relatively low sensitivity to external shocks. In other words, the salmon market demonstrates a certain level of resilience and stability, as it is not heavily influenced by external factors beyond those already included in the model. This insight further strengthens confidence in the predictive power and validity of our ARDL model in analyzing salmon prices.

The war has created geopolitical disruptions and heightened uncertainty, leading to fluctuations in various commodity markets, including wheat prices (discussed in chapter 2.3.2). As wheat is an essential ingredient in fish feed, the rise in wheat prices could lead to increased production costs, subsequently affecting the salmon price. This finding aligns with existing literature on the significance of input costs in the seafood industry and the increase in commodity price, including wheat, due to the war. It highlights the complex interplay of various factors, such as feed ingredients, global commodity prices, and market dynamics, in determining salmon prices. However, further research would be needed to confirm this hypothesis and determine the specific factors that may have contributed to the increase in the wheat price. Nonetheless, this observation highlights the importance of considering the wider economic context when analyzing the price movements of specific commodities.

5.4 Limitations

While our study aims to provide valuable insights into the impact of the Russo-Ukrainian war on the Norwegian salmon price, it is important to acknowledge its limitations. The limitations of the study may impact the interpretation and applicability of our findings and could uncover potential avenues for future research.

Data Limitations

Given the temporal scope of our study (January 2022 to August 2022), it is important to acknowledge that the results would not capture the long-term implications of the war on the salmon price. Our study relies on the availability and quality of data related to the Norwegian salmon industry, which may have limitations in terms of accuracy, completeness, and timeliness. There may also be other important variables that were not included in our analysis due to data constraints. While these variables may have a significant impact on salmon prices, their exclusion from our analysis does not invalidate the results we obtained. We acknowledge that our model provides a simplified representation of the complex dynamics that affect salmon prices.

Methodological limitations

Our study utilizes a specific model (ARDL) to analyze the relationship between the Norwegian salmon price and the Russo-Ukrainian war, which may have limitations in terms of for instance stationary assumption, endogeneity, and model misspecification. The ARDL model requires determining the appropriate lags for the variables, which can be challenging. Choosing an incorrect lag length may lead to biased parameter estimates and incorrect inference. Different lag specifications may produce different results, making the model sensitive to the researcher's choices. To address this limitation, we tested different amounts of lags on the variables as explained in chapter 4.2.1. Notably, we observed that changing the lag amount for “fish loss” was the only variable that resulted in varied outcomes of the AIC test.

There may be alternative models or methods that could be used to analyze the same data and produce different results. While we include a dummy variable to account for the impact of the Russo-Ukrainian conflict on the Norwegian salmon price, it is important to acknowledge that this approach also has its limitations. The use of a dummy variable assumes that the impact of the war on the salmon price was sudden and temporary, which was not necessarily the case.

By assuming that the impact was sudden and temporary, we may oversimplify the complex dynamics and duration of the war's influence on the salmon price. In reality, the effects of geopolitical events can be multifaceted and have varying durations. The use of a dummy variable can be effective for capturing abrupt and short-term shocks to the dependent variable. However, if the impact of the war was more gradual or had a prolonged influence on the salmon price, the use of a single dummy variable may not fully capture the nuanced relationship. By acknowledging this limitation, we recognize the need for further research and a deeper understanding of the dynamics between the war and the salmon price.

External Limitations

Our study focuses on a specific time period and a specific context, which may limit the generalizability of our findings to other contexts or time periods. Additionally, our study did not consider other external factors such as global economic trends or environmental factors that may also affect the salmon price. Another limitation is the use of secondary data sources, which may not be as accurate or reliable as primary data. Our study uses an ARDL model that assumes stationarity of variables, which may not be entirely appropriate for non-stationary data such as the salmon price. Finally, the use of a dummy variable to capture the impact of the war may not fully capture the true effect of the conflict on the salmon price.

Causal limitations

Our study aimed to analyze the relationship between the Norwegian salmon price and the Russo-Ukrainian war, but it cannot establish causality. There may be other underlying factors that could contribute to the observed correlations, such as changes in industry regulations or the impact of climate change. Despite these limitations, we believe that our study provides valuable insights into the impact of the Russo-Ukrainian war on the Norwegian salmon price and can serve as a basis for further research on the topic.

5.5 Suggestions for future research

Although our study has shed light on the influence of the Russo-Ukrainian war on the price of farmed salmon, there are several avenues for further research in this area. One potential area for future research is to focus on exploring the extent of the indirect impact of the Russo-Ukrainian war on the global seafood market, particularly in relation to the Norwegian salmon price. This could involve investigating the effect of economic sanctions and political tensions on the demand for Norwegian salmon in key markets such as Russia and China, as well as the impact of exchange rate fluctuations and transportation disruptions on the Norwegian salmon export industry. Additionally, further research could examine the potential long-term effects of the war on consumer behavior and demand for seafood, as well as the role of alternative protein sources such as plant-based or cell-cultured seafood products in shaping the future of the seafood market. By addressing these areas of inquiry, future research could provide valuable insights for policymakers, industry stakeholders, and consumers regarding the sustainability and resilience of the Norwegian salmon industry in the face of geopolitical and economic challenges. Our study is limited to a specific time period and set of variables, and there may be other factors and channels of influence that could be explored in future research.

Overall, while the impact of the Russo-Ukrainian war on Norwegian salmon price is complex and multifaceted, our findings suggest that indirect effects, such as fluctuations in global wheat prices, may play a role in shaping the market dynamics. This underscores the need for a comprehensive understanding of the factors influencing salmon prices and emphasizes the interconnectedness of the seafood industry with global commodity markets.

6. Conclusions

The Norwegian salmon industry is a major player in the global seafood market, contributing significantly to the country's economy. However, the industry is vulnerable to factors that can have a substantial impact on the price of farmed salmon. The Russo-Ukrainian war, which escalated February 24, 2022, has affected trade and economic activity worldwide. The conflict has created uncertainty in the global market, leading to changes in the price commodities, including wheat, which might indirectly have affected the price on farmed salmon through the price of fish feed. The presence of price fluctuations, as revealed in our study, indicates that the Norwegian farmed salmon market is influenced by various factors that can affect pricing and profitability, and that there are new and potentially significant drivers of price changes that have emerged. This paper investigated the impact of the Russo-Ukrainian war on the Norwegian farmed salmon price. The objective was to determine whether there is a significant relationship between the Russo-Ukrainian war and the Norwegian farmed salmon price.

Therefore, we set out to answer the following problem description: *How has the Russo-Ukrainian war impacted the Norwegian farmed salmon price?*

We created an ARDL model that included ten different variables additional to the dependent variable (FPI), and then implemented a dummy variable to the model. With the inclusion of a dummy variable in our ARDL model, we were able to account for any additional unexplained increases in the salmon price directly affected by the Russo-Ukrainian war. The insignificant coefficient on the dummy variable suggests that the variables included in our model were able to capture most of the systematic risk affecting the salmon price. The study showed that the Russo-Ukrainian war did not have a significant direct effect on the Norwegian farmed salmon price, as that the chosen set of explanatory variables in the ARDL model was able to capture most of the systematic risk affecting the salmon price.

While our study is focusing on the impact of the Russo-Ukrainian war on the price of farmed salmon, we acknowledge that there may be other factors that could have contributed to the changes in price observed during the study period. The confirmation of price fluctuations strengthens the validity of our research and reinforces the relevance of our problem statement. It establishes a basis for examining the potential indirect effects of the Russo-Ukrainian war on the Norwegian farmed salmon price and sets the stage for a comprehensive analysis of the contributing factors and their implications. Due to the complexity of the market, it is difficult to isolate the effects of individual factors on price. One of the main limitations of our study is that it only covers a specific period of time (i.e., from January 2022 to August 2022), and thus the results would not be able to capture the long-term effects of the war on the salmon price. The use of a dummy variable to capture the impact of the war may not fully capture the true effect of the conflict on the salmon price. Further research, when access to later data is available, could contribute to better understanding of the various factors that can impact prices in this important industry.

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Appendix

I. Farmed Salmon Price Time series

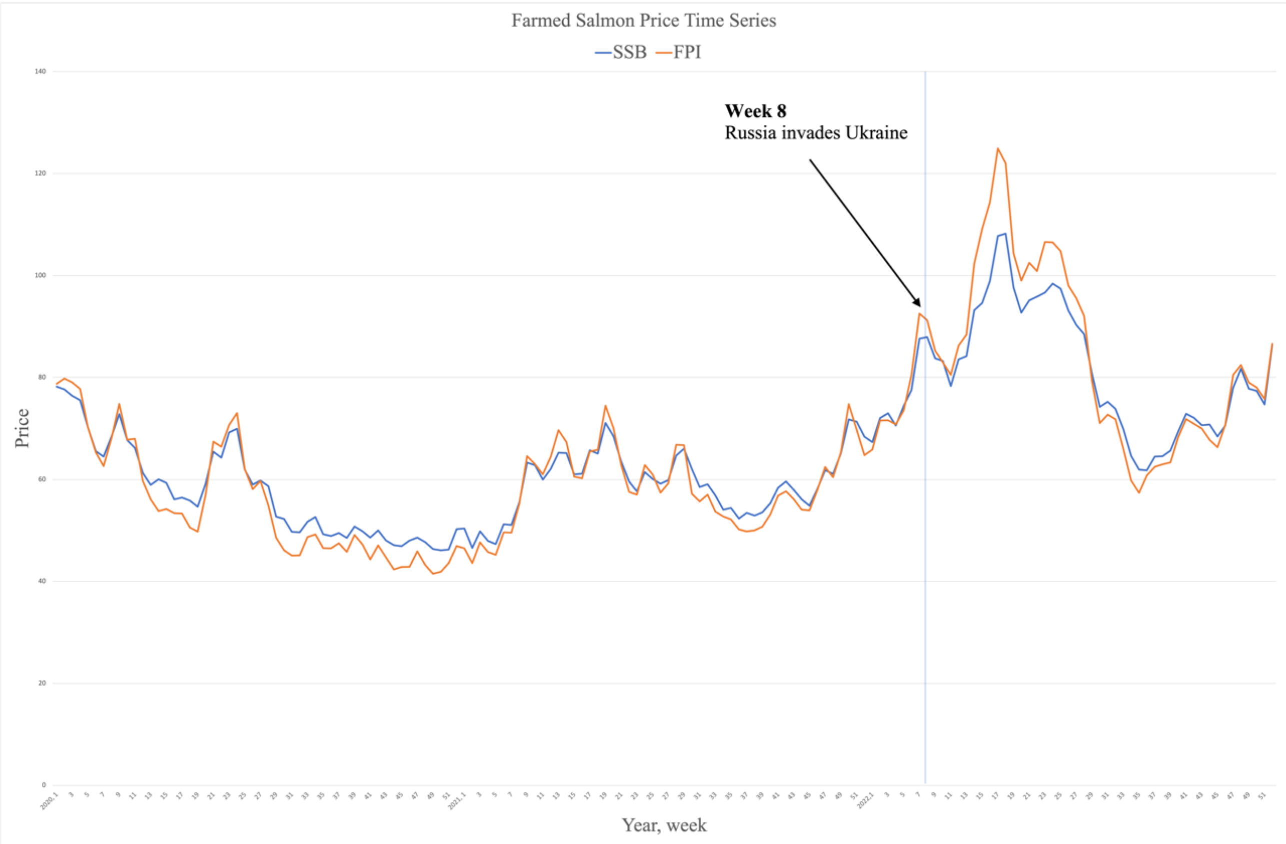

Figure 0-Price SSB & FPI January 2020 - December 2022

II. Overview of Data Sources

Table 0-1: Overview of Sources all variables

Variable	Source
Fish Pool Index	(Fish Pool, 2023)
Standing Biomass	(Directorate of Fisheries, 2023)
Smolt Release	(Directorate of Fisheries, 2023)
Feed Consumption	(Directorate of Fisheries, 2023)
Harvest Volume	(Directorate of Fisheries, 2023)
Sea Temperature	(Ocean Data Collector, 2023)
Sea Lice	(Ocean Data Collector, 2023)
Meat Price Index	(FAO of the UN, 2023)
Wheat Price	(Tradingeconomics, 2023)
NOK/EUR Exchange rate	(Norges Bank, 2023)

III. SSB Time Series Data

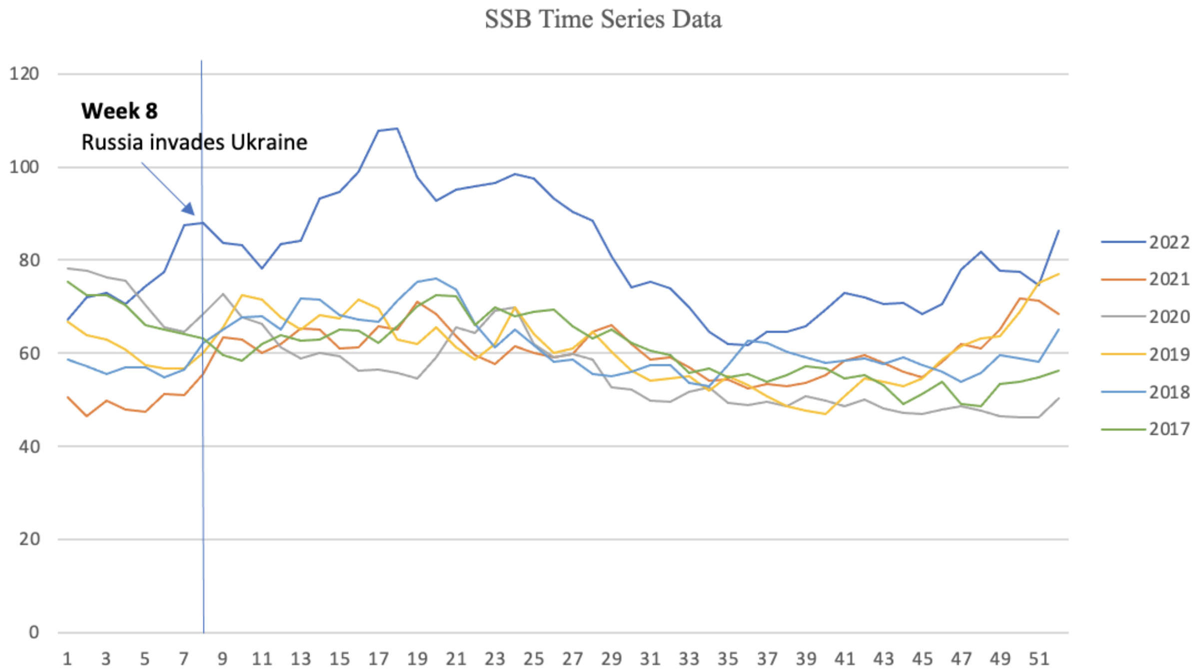

Figure 0-1: SSB Time Series Data, Fresh Farmed Salmon

IV. Overview of AICs tested ARDL models

Table 0-2: Overview of AICs tested ARDL models

	Fish Pool Index	Biomass	Smolt Release	Feed Consumption	Harvest Volume	Sea Temperature
1	1	3	0	1	1	0
2	1	3	0	1	1	0
3	1	3	0	1	1	0
4	1	3	0	1	1	0
5	1	3	0	2	1	0
6	1	2	0	1	1	0
7	1	2	0	1	1	0
8	1	2	0	1	1	0
9	1	2	0	1	1	0
10	1	2	0	1	1	1
11	1	2	1	1	1	1
12	1	2	0	2	1	1
13	1	1	1	1	1	1

	Sea Lice	Meat Price Index	Wheat Price	EUR/NOK Rate	Fish Loss	AIC
1	3	1	2	1	1	372.0981
2	3	1	2	2	1	372.3104
3	3	1	3	1	1	373.6707
4	2	1	2	1	1	381.3026
5	2	1	2	1	1	383.2353
6	2	1	2	1	1	386.2636
7	2	1	2	2	1	388.2110
8	2	1	1	1	1	390.8407
9	1	1	1	1	1	393.7937
10	1	1	1	1	1	394.9735
11	1	1	1	1	1	396.7391
12	1	1	1	1	1	396.9678
13	1	1	1	1	1	411.6944