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Land-based Salmon Aquaculture in Japan

A study on how a new supply of salmon from land-based salmon facilities in Japan may affect imports in the Japanese salmon market

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Abstract

This study's research question is how a new supply of domestically sourced salmon from land-based facilities in Japan may impact imports to the Japanese salmon market. By using import statistics and domestic data from the Tokyo wholesale market, I estimate the Armington elasticity between foreign and domestic salmon. This elasticity provides an estimate of the level of substitution of different products of salmon from several countries, which provides insights to how the different imports will react to domestic changes in volume and price. My findings show that there are significant differences in the Armington elasticity between different imports, especially between fresh and frozen salmon. Furthermore, I modelled how two imports displaying a different level of substitution, fresh Atlantic salmon from Norway and Australia, may be affected by the domestic changes differently. These projections found that Norway, with a lower estimated Armington elasticity, is much more resistant to domestic changes compared to Australia.

Acknowledgements

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Contents

Contents

1. Introduction

Japanese consumers were first introduced to the prospect of consuming raw salmon as *sashimi*, thinly sliced raw meat, towards the end of the 20th century. This was initially the result of an extensive marketing campaign from Norway, called “Project Japan”, where they were successful in bringing farmed Norwegian Atlantic salmon to the Japanese market (Odden, 2020; Norwegian Seafood Council 2022). Since that time, salmon consumed as sashimi, like in popular dishes such as sushi, has become increasingly popular both in Japan and worldwide. According to a recent consumer report conducted by Maruha Nichiro (2022), salmon is by a substantial margin the most popular fish for sushi across conveyor belt sushi restaurants in Japan, after it surpassed the popularity of tuna a few years ago. Now, some businesses are looking to introduce a new type of salmon into the Japanese market, in the form of salmon farmed from land-based facilities located within Japan. If the projected production from these facilities becomes reality, Japan may experience a substantial increase in supply of domestic salmon. In addition to these new land-based facilities, there is also a general movement of new fish farms being built in Japan, which may further increase the quantity of Japanese salmon. This study seeks to explore how this new influx of domestically farmed salmon may impact the import market of salmon in Japan.

To start, it should be emphasised that land-based aquaculture is not some new, unproven technology. Norway has as an example been using land-based hatcheries for more than 20 years for smolt, and the same technology has also been utilized for several species of fish internationally, for both smolt and adult fish (Benjaminsen, 2021). A large increase in demand for seafood, combined with a reduction in wild stocks, has led to an increase of 527% in global aquaculture production between 1990 and 2018 (Choudhury et al., 2022). As a result of the increase in demand, some fish farmers have moved towards utilizing land-based facilities capable of more intensive production, which has led to better financial results for many fish farmers (Choudhury et al., 2022). An important advantage that land-based facilities have over traditional fisheries in the ocean, which naturally contributes to its financial benefits as well, is the mitigation of lice and other infectious diseases amongst the fish (Benjaminsen, 2021).

In terms of land-based farming of salmon specifically, excluding the smolt hatcheries mentioned above, previous facilities in both Iceland and Norway have not proven financially sustainable due to the higher cost compared to that of traditional fisheries (Lekang et al., 2016). It should be noted that these land-based facilities utilized flow through water systems, while newly built or planned facilities will generally utilize recirculating aquaculture systems (RAS) (Summerfelt & Christianson, 2014). This technology could be more financially viable than the use of flow through water systems, though the initial investment cost is considerably greater (Lekand et al., 2016). As the use of these new facilities for land-based salmon production is quite new, it still remains to be seen to what degree they will be financially viable.

A few companies are currently in the process of constructing land-based facilities in Japan, one of them being the Norwegian company Proximar Seafood. They are trying to utilize the popularity of fresh Norwegian salmon by raising Atlantic salmon in onshore facilities in Japan. From these facilities they will be able to deliver fresh Atlantic salmon to the Japanese market, without the need of air transportation from Norway (Proximar Seafood, 2022). They expect their first harvest to happen in the first half of 2024, and once full capacity is reached, they are targeting to produce about 5300 metric tonnes of salmon each year. Another company that will also be delivering Atlantic salmon from land-based facilities is Soul of Japan. The company is expecting to start their first deliveries in 2025, with a volume of about 10 000 tonnes once the farm is running at full capacity (Soul of Japan, 2022). In addition to these two foreign companies, there are also a few domestic companies that are looking to pursue land-based salmon ventures. Companies like FRD Japan have already even been successful in early test projects with small production volumes and are looking to expand their production further in the coming years (FRD Japan 2022; Chris Loew, 2020). Table 1summarizes the current or targeted production volume of salmon from each company that have announced their plans to pursue land-based aquaculture in Japan as of writing.

Announced production from each company, in MT	2022	2023	2024	2025	2026	2027	Not dated	Sum
Proximar Seafood		5300						5300
Soul of Japan				10000				10000
FRD Japan	30						1970	2000
Mitsubishi Corporation & Maruha Nichiro						2500		2500
Kyushu Electric Power et al.	300						2700	3000
Tottori Kotoura Gran Salmon							600*	600
Announced total targeted production								23400

*Table 1: Production numbers pulled from each company's website or press releases. The year listed is the first expected delivery, and the companies will likely not deliver at full capacity at launch *Tottori Kotoura is already producing a small amount of salmon, but 600 MT is the targeted production once expansions are finished (Honda 2018; Loew 2020; Kyuden 2021; FRD Japan 2022; Proximar Seafood 2022; Soul of Japan 2022; Mitsubishi Corporation 2022)*

Though a few test projects and smaller scale land-based salmon facilities have already been constructed in recent years in Japan (Loew 2020; FRD Japan 2022), the interest in land-based aquaculture for salmon is somewhat of a recent trend. Apart from being a major market for salmon, one could point to several different reasons as to why companies have an interest in starting their ventures in Japan specifically.

For foreign companies, the most attractive benefit of producing salmon in Japan instead of in their own country is more than likely the abolishment of the air freight cost. Talking the perspective of Norway, DNB Markets (2017) calculated that the cost of air freight from Norway to the US or Asia was about 14 NOK/kg. They calculated that the total cost of the salmon before transportation was 35.5 NOK/kg HOG (head-on-gutted), rendering the air freight cost to amount to about 28% of the total cost. By constructing land-based aquaculture in Japan itself, fish farmers can establish themselves in close vicinity to their respective markets, forgoing the need of expensive transportations. Furthermore, one can avoid disturbances in the air fright route, an example being the Russian airspace closing in 2022 which has led to longer flights and increased cost of transportation between Europe and Asia (Norwegian Seafood Council, 2022).

Another reason for establishing land-based farms in Japan is that of environmental sustainability. Transporting fish across the world to Japan, especially with airplanes, causes a footprint of emissions. These types of emissions will naturally not occur if the production facilities are in close proximity to the market. Though this in itself may not directly benefit the companies, the focus on sustainability can be used in branding to attract customers. We are already seeing signs of this from Proximar Seafood (2022) and Soul of Japan (2022), where sustainability is a key part of their marketing. It should be noted that land-based facilities do require an extensive amount of energy to operate compared to that of traditional fisheries (Nistad, 2020). For this reason, and the level of sustainability may depend on the amount of energy required and the source of this energy. That being said, research suggests that the new facilities utilizing RAS technology, a technology that keeps seeing continuous improvement, should be able to operate in a sustainable manner (Bergman et al., 2020). It is nonetheless an important issue to consider, especially considering the rather turbulent energy market as of late.

The perspective of the Japanese businesses pursuing land-based is likely somewhat different to the foreign prospect, as the whole dynamic of moving production in proximity to the market is not present. Even though fish farms with proper facilities may negate the problems of parasites and other diseases infecting the salmon, Japan also faces the issue of high ocean temperatures in many months of the year. SOURCE This leads to fish farming in the oceans surrounding Japan becoming a much more seasonal activity, for example compared to that of Norway (Evans, 2018). This is likely one of the main benefits that Japanese companies have of starting land-based aquaculture, as you would both negate the issue of diseases found in the ocean, as well as not being forced into a seasonal production pattern that could render the business less financially viable.

Outside of these new land-based facilities, domestic salmon farming in general seems to be gaining some traction inside Japan. One of the largest producers of farmed salmon in Japan actually dates back to the 1970s, where coho salmon became popular to farm in Miyagi

Prefecture (Asahi Shimbun, 2022). Back in that time however, the coho salmon was similarly to wild salmon, not consumed raw. But after the earthquake in 2011 destroyed much of the farm facilities, the farms have been rebuilt and improved. This has led to the introduction of a coho salmon branded as “Silver salmon” or “Silver King” which is also sold as sashimi, of which they produce some 465 tonnes annually (Ocean Outcomes, 2022). Furthermore, several new fish farms have been established and entered the sashimi market in just the last few years (Asahi Shimbun, 2022). They hope that domestic branded Japanese salmon may be able compete in the Japanese salmon market for sashimi, especially as salmon seems to gain more and more popularity (Honda, 2018; Maruha Nichiro 2022). Salmon produced in these farms includes a variety of species, such as rainbow trout and cherry salmon.

Considering the projected output of salmon from land-based facilities, and the recent trend of new aquaculture in general, it seems imminent that domestic supply will increase considerably in the coming years. Considering this, my research question is the following: ***How will the potentially large increase of farmed domestic salmon impact the import market of salmon in Japan***. To answer this question, I use an econometric model to estimate the *Armington elasticity* between domestic and imported goods. The Armington elasticity, as proposed by Armington (1969), builds on the assumption that a foreign and domestic good, that are otherwise equal in nature, may be differentiated solely by their country of origin. I apply this theory to see how the substitution rate of goods changes depending on elements such as species of salmon, product type and origin country. Though many studies have estimated the Armington elasticity across several industries and sectors, estimation of the elasticity in Japanese fishery industry has not been done. As such, this thesis presents the first estimations of the Armington elasticity in this market.

The thesis consists of seven parts in total. In the next chapter, chapter 2, I present an overview of the Japanese import marked for salmon. Proceeding the market overview, I review the relevant literature in chapter 3. Chapter 4 shows how the data is collected, and how the sample is built. I also describe the variables that are to be used in the analysis. Chapter 5 shows the results of the different econometric models used to estimate the Armington elasticity under different sets of variables and scenarios. Following, in chapter 6 I use the results from chapter 5 to make some projections on how imports may change in selected countries under different assumptions of price levels. In Chapter 7 I further discuss the results found in chapter 5 and chapter 6. Finally, chapter 8 summarises the findings of the paper and concludes the thesis.

2. Imports in the Japanese Salmon Market

Japan is considered one of the largest markets for salmon, estimated being the 10th largest market in 2021 (Mowi, 2022). It is viewed as one of the main markets for a number of salmonoids such at Atlantic salmon, large trout and coho. When discussing the import market, it may make sense to split the salmon into two broader categories. On one side we have salmon that participate in the sashimi market, where the salmon is either exported fresh and chilled, or frozen. Major exporters here include Norway, who exports most of the fresh salmon used in sashimi, and Chile, who exports most of the frozen salmon that is used for sashimi (Tsai & Tominaga, 2016). On the other side you have salmons that are more processed or treated, such as salted or smoked, or salmons that are otherwise meant to be heated before consumption. Major exporters of such salmon products include the United States, Russia and Chile.

Prior to the introduction of Norwegian Atlantic salmon, salmon was generally not consumed raw in Japan (Norwegian Seafood Council, 2022). Pacific salmon from Japan was at that time more or less only caught in the wild, and the meat had to be cooked before consumption due to parasites prevalent in the Pacific Ocean (Sollesnes, 2018). As a result, the vast majority of salmon consumed as sashimi has historically been imported from overseas. The two main exporters of salmon of this type to Japan have been, and continues to be, Chile and Norway. According to import data provided by the Japanese Ministry of Finance, salmon from Chile and Norway accounted for about 65% and 18% of the total salmon import to the sashimi segment, respectively (Japan Customs, 2022). Other countries also contribute to the salmon sashimi market in varying degrees, for example Australia and Canada who both exported more than 1500 tonnes of fresh Atlantic salmon in 2020.

Since its introduction to the Japanese market, Norwegian salmon has been an important product in the sashimi market. The main salmon being imported from Norway is Atlantic salmon, but there is also a considerable amount of salmon trout being imported. In 2020 around 85% of the salmon imported from Norway was Atlantic salmon, while 15% was salmon trout (Japan Customs, 2022). In 2020, 95% of the Atlantic salmon imported from Norway was fresh, which is a key feature of the Norwegian salmon. As not freezing the fish better retains the taste of the meat, salmon from Norway has received an image of quality in the Japanese market (Tsai & Tominaga, 2016). This is also reflected with a higher price point of Norwegian salmon compared to that of other products such as Chilean salmon, which is mainly exported frozen. Furthermore, both Atlantic salmon and salmon trout is either exported semi-dressed, a less processed product, or as fillets. While semi-dressed Atlantic salmon has historically been imported in larger volumes than fillets, there has been a steady increase in the volume of fillets in the previous years. The main reasons for this development are said to be a substantial reduction in the ability to process the fish in Japan, due to a decrease in processing facilities and workers (Tsai & Tominaga, 2016).

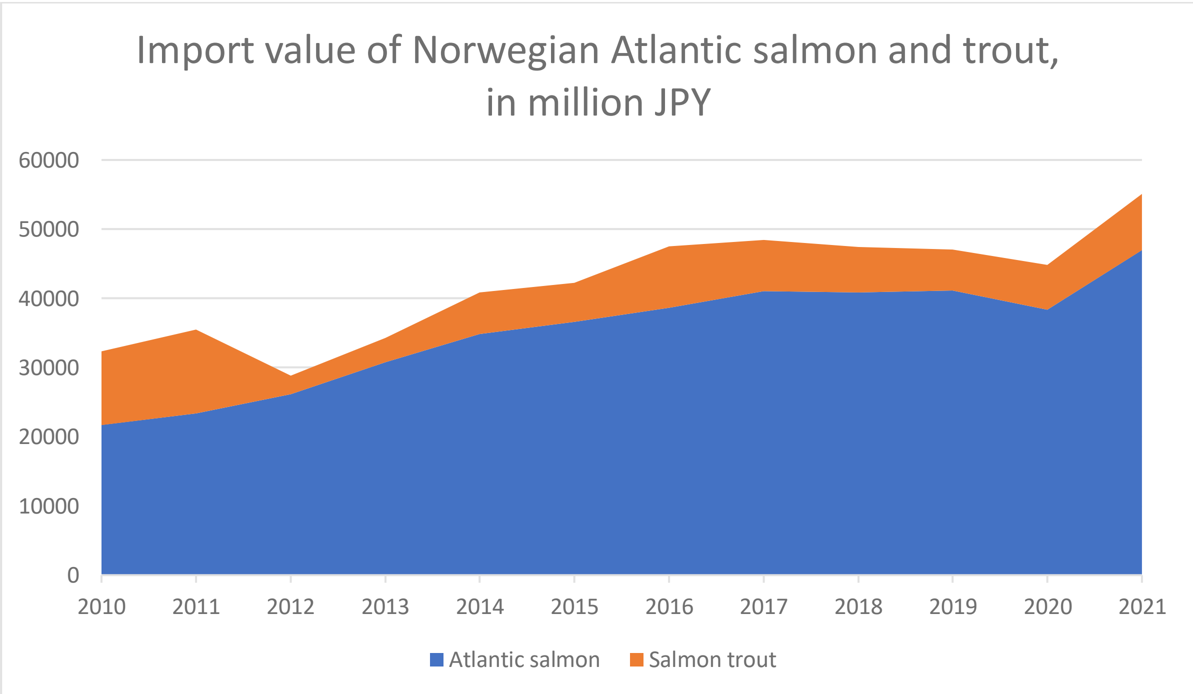

Figure 1 Yearly import value of Atlantic salmon and salmon trout from Norway to Japan. Data is collected from the Japanese Ministry of Finance (2022).

The largest exporter of salmon to Japan is Chile, who exported around 160 000 tonnes of salmon in 2021 (Japanese Customs, 2022). A substantial amount Chilean salmon export is frozen coho salmon, which is generally considered a product meant for cooking (Tsai & Tominaga, 2016), Chile also transports a considerable volume of salmon trout, though the volume of trout has been declining in the last few years. The main reasons for this reduction are toxic algae bloom, higher production costs, and diseases that hit salmon trout production in Chile around 2014 (Poblete et al., 2019). As Chilean trout is often sold as sashimi (Tsai &

Tominaga, 2016), it may look like salmon imports from Norway are substituting the drop of salmon import from Chile to the market segment of sashimi. Chile also exports some Atlantic salmon, though at far lower levels compared to that of coho and trout (Japanese Customs, 2022). Almost all salmon from Chile is exported frozen, and most of both Atlantic salmon and salmon trout are shipped as fillets.

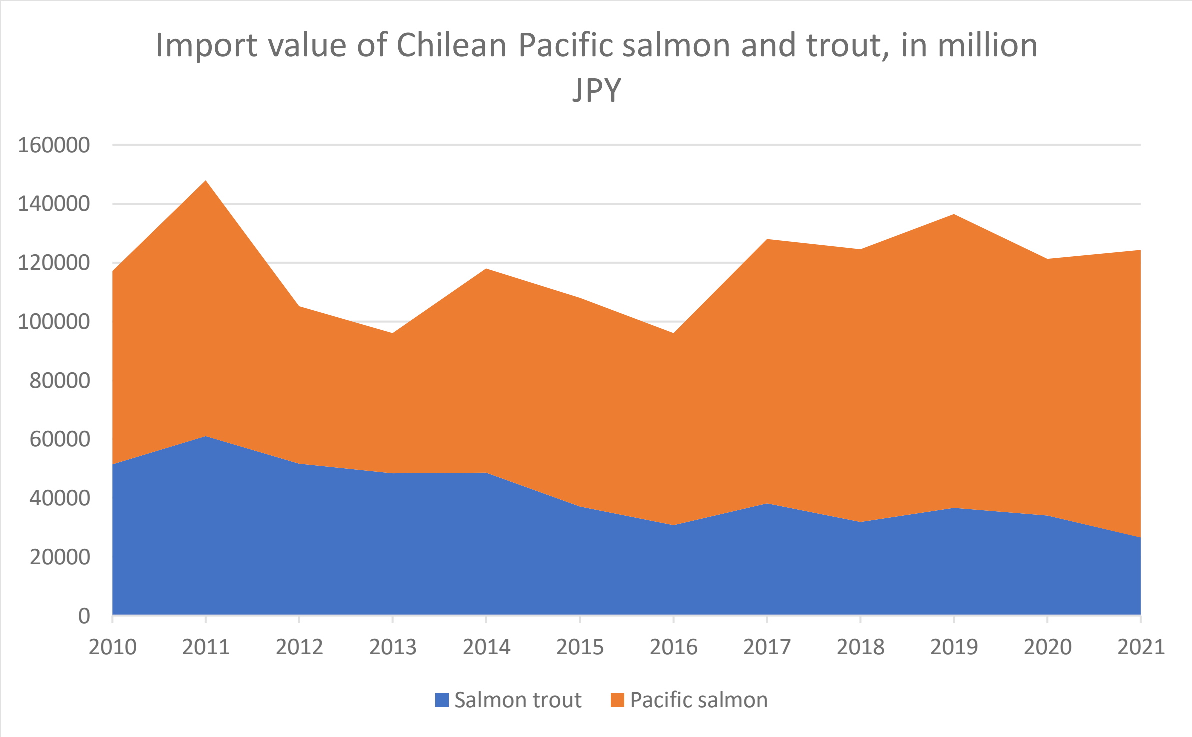

Figure 2 Yearly import value of Chilean salmon and salmon trout from Chile to Japan. Data is collected from the Japanese Ministry of Finance (2022).

From both Russia and the US, the major salmon export is frozen pacific salmon, specifically sockeye salmon. In figure 3 we may observe how the import value of sockeye has changed from two countries since 2014. Interestingly, the yearly import value from the countries often seems to follow each other's movement. Furthermore, the value of import fluctuates substantially compared to that of Norwegian export and Chilian trout. This indicates that frozen salmon in general may be more subject to market changes, as we also observe similar levels of fluctuations in frozen Pacific salmon from Chile. In somewhat the same vein, the differences may also indicate a difference between salmon products that compete in the sashimi segment and those that do not, as Atlantic salmon and trout are common salmon used for this purpose

(Tsai & Tominaga, 2016). This makes sense considering that the domestic competition in this market segment has to this date been severely lacking compared to that of frozen salmon.

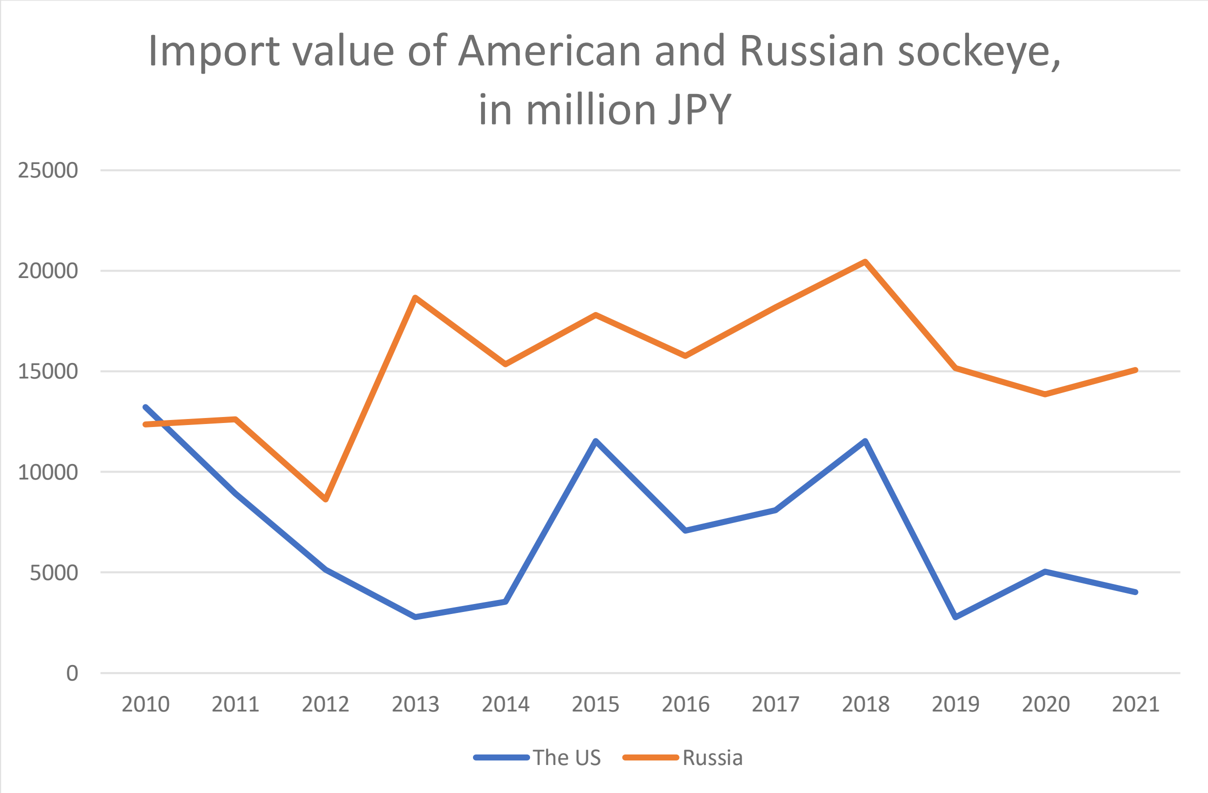

Figure 3 Yearly import value of sockeye from the US and Russia to Japan. Data is collected from the Japanese Ministry of Finance (2022).

3. Literature Review

In trying to answer how the new supply of domestically sourced salmon may affect the Japanese salmon market, it is crucial to look at the relationship between the price of Japanese salmon to that of imported salmon. A common way of studying this relationship is to estimate the Armington elasticity. The Armington elasticity is a measure of the level of substitution between foreign imported good and domestically produced goods. It builds on the assumption presented by Armington (1969) that the demand and price of a good does not only necessarily depend on typical elements such as the type or state of the good, but that the origin country of the good can also have a significant effect on demand. As an example, leaving everything else equal, two similar salmon products from Chile and Japan are assumed to experience a difference in demand just based on the producing country alone.

There has been done extensive research in trying to estimate the Armington elasticity across different sectors and countries for several years. A recent study by Bajzik et.al (2020) tries to explain what the cause of the great variation in the elasticity-estimation by analysing papers that have attempted the estimation. They find several elements that they believe to provide a significant contribution to the variation between papers, such as the estimation technique or the origin country in question, but the most apparent contributor to the variance is the nature of the data and how it is used. This includes variables such as the size of the data, the dimension of the data or whether the data is monthly, quarterly, or annual. The great variation among previous research and results emphasises the importance of being careful when analysing and discussing the results of an estimation of the Armington elasticity, and that it may be wise to compare with previous papers that may have utilized other research methods. The paper by Bajzik et.al (2020) is as a great source to compare this study's estimations with, by the nature of their analysis being based on a substantial number of previous studies.

In general, there are two main methods used to estimate the Armington elasticity. The first method is to regress the bilateral trade flows, while the other method entails regressing the ratio of imports to domestic consumption on the ratio of domestic prices to import prices (Bajzik et. al, 2020, p.3). While both methods have their own benefits and drawbacks, the first method yields a result that can be more interpreted as a comparison of elasticity among foreign goods, while the second method maintains a stronger interpretation of the elasticity between foreign and domestic goods. Considering the research question of this study, and also the availability of data, I pursue the second approach in this paper.

Though several approaches of estimation exist within the methodology above, this study will base its model on a somewhat simplified model presented by Reiner and Roland-Host (1992). Their model was originally used to estimate the Armington elasticity in the American mining and manufacturing sector. Their model specification has since been utilized in many studies, such as an extensive study conducted by Blonigen and Wilson (1999) that researched the Armington elasticity across several different sectors. In accordance with Armington (1969) and literature that since followed, the model is first built on the following constant elasticity of substitution (CES) function that models the demand for foreign and domestic for a good in a given sector or industry (Reiner and Roland-Host, 1992; Blonigen and Wilson, 1999):

$$U(M,D) = \left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where U represents the consumer utility between a combination of imported good *M* and domestic good *D*, *M* and *D* is the quantity of imported goods and domestic goods respectively, β is a parameter representing the weight between foreign and domestic goods, and σ is the constant elasticity between the two goods and represents the Armington elasticity. Solving the first-order condition from this equation finds yields the solution to the consumer's optimization problem:

$$\frac{M}{D} = \left[\left(\frac{\beta}{1-\beta}\right)\frac{P_D}{P_M}\right]^{\sigma}, \tag{2}$$

where P_D is the price of domestic good and P_M is the price of imported good. The function states that the ratio of imported and domestic goods is a product of a fraction of the weight parameter β and the relative price between the goods. By transforming equation (2) in its logarithmic form, you end up with a formula that is commonly used in the literature as a basis for studying CES:

$$ln\left[\frac{M}{D}\right] = \sigma * ln\left[\frac{\beta}{1-\beta}\right] + \sigma * ln\left[\frac{P_D}{P_M}\right] \tag{3}$$

The implication of equation (3) is that the less the domestic and foreign products act as substitutes to each other, σ will take a lower value, while a higher value of σ indicates a stronger relative level of substitution between the goods. By rephrasing this equation with additional seasonal dummies and an error term, we get the following model that can be used to calculate the elasticity σ:

$$log\left[\frac{M}{D}\right] = \alpha + \sigma * ln\left[\frac{P_D}{P_M}\right] + \sum_{y=1}^{n} m_y D_y + \varepsilon \tag{4}$$

This model is almost equal to the one used to estimate the Armington elasticity σ in the aforementioned studies, the only difference being that the above model has a general seasonal term instead of strict quarterly one as used by Reiner and Roland-Host (1992) and Blonigen and Wilson (1999). α is the intercept, D_y represents the seasonal dummies and ε is the error term. This model serves as a baseline for models of this paper, but I will make some alterations of it as my research scope differs somewhat compared to previous studies that are generally performed at a more sectoral or industrial level.

While there are not currently any exact estimations of the Armington elasticity of salmon between Japan and foreign countries specially, there are number of studies conducted that tries to estimate the elasticity in different sectors and for different product types. On such paper is a study conducted by Gallaway et. all (2002) which estimated the Armington elasticity of several import to the US. They calculate an average estimate of 0.95 and 1.55 for the short and long-run elasticity respectively, and the estimates ranges from 0.15 to 4.85. Bajzik et.al (2020), who analysed several studies estimating the elasticity found that the primary sector in general experienced lower levels of than other sectors. The study features both unweighted and weighted estimates of the elasticity, where the weighted estimated are weighted by inverse number of reported in the studies researched. In the "agriculture, forestry and fishing" the unweighted mean of the Armington elasticity is estimated at 0.92 and 0.77 for unweighted and weighted estimations respectively. While this certainly indicates a higher home bias of domestically sourced good in this sector, Bajzik et.al (2020) emphasizes that the sample in the category is dominated by estimates in the sector of agriculture, causing the interpretation of the fishery sector be somewhat reduced. A study conducted by Donnelly et al. (2004) may also provide some insights on the Armington elasticity of fish. They estimate a category of "prepared fresh or frozen fish and seafoods" to have elasticity of 1.7, while a even more processes product type of "canned and cured fish and seafoods" feature a high price elasticity of 5.0. When comparing this to the mean estimate found by Bajzik et.al (2020), it might indicate that frozen or more processed products experience a higher substitution rate, which does seem naturally logical. Estimates of other products in the study may further indicate a general difference of substitution rate between fresh and frozen goods. For example, the Armington elasticity of "frozen fruit, fruit juices and vegetables" is estimated at 5.00, while the fresh goods of fruits and vegetable are estimated at 3.98 (Donnelly et al, 2004).

4. Data and Model Design

The following chapter describes the process of gathering necessary data and the construction of the data set, as well as the general model design with an overview of the variables.

4.1 Data and Sampling

To create a model to estimate the Armington elasticity and help answer the research question of the thesis, I create an unbalanced panel data set consisting of monthly time series data. To estimate the Armington elasticity as described in the previous section, data of quantity and price of both domestic and imported salmon must be collected. As domestic data is missing in several of the months 2013, 2014 serves as natural starting date for the panel data.

For the import data I use data provided by the Japanese Ministry of Finance (2022). The dataset is quite detailed, providing monthly import volume in kilograms and its value in Japanese yen, JPY, from each respective country exporting fish to Japan. Furthermore, the different salmonoids are well categorized into separate groups, both by species and conditions such as if the fish is fresh or frozen, making it generally easy to analyse the different salmon products. The monthly value of salmon divided by the quantity imported is created as a variable in the panel to compare the price of imported fish with the price of Japanese fish. Additionally, each observation includes the origin country, whether the salmon is fresh or frozen, and the exact species of salmon of the import. In some cases, countries export both semi-dressed and fillets in considerable numbers of the same salmon, such as Norway's export of fresh Atlantic salmon. While it would be interesting to analyse these separate products separately, some analytic value might also be lost due to mix of these product types changing being a result of the somewhat inverse relationship of their separate volumes. To make sure that no insight is lost in this, two separate panels are made of the import data. In the first version, the volume of semi-dressed and fillets within the same species and product type are combined. For the price, a weighted average price between fillets and semi-dressed is estimated. In the other version, the two are treated as separate products. In in the following and in general, I will apply the combined version. This data set is more balanced where countries with exports of several different species and types of salmon are not overwhelmingly represented in comparison to others.

As for volumes and prices of fish sourced inside Japan, it is difficult to acquire as specific data as with the import. The Tokyo Central wholesale market is a very important market for seafood in Japan, and from its website it is possible to retrieve daily sales data of salmon farmed in Japan[1]. The prices recorded each day are the highest and lowest selling price at the market that day. While price levels are listed for each respective species of salmon, the quantity provided is for the total quantity of all salmon species sold each respective day. Though this is unfortunate, the data could still be used to gain a proximation of the price and quantity of Japanese salmon. Similar to the import data, the wholesale data is also categorized by whether the different salmon species are frozen or fresh, with separate price and quantity data for each. Though it would be beneficial to compare the frozen and fresh salmon respectively with the import data, the specifications in the wholesale data suggests that the data of frozen salmon unfortunately includes an unknown amount of imported salmon. As this could potentially hurt the integrity of the model due to duplicate data being present amongst the import and wholesale observations, only the data of fresh salmon will be used as the reference of domestic quantity and price of salmon.

To better compare the domestic sales with the import data, it is necessary to transform the wholesale data to monthly estimates. Firstly, the daily sales data is aggregated in each month, and thereafter divided by the appropriate number of observations in order to estimate an average quantity sold at the wholesale market each month. Additionally, I wish to create an estimate of the national quantity of domestic salmon, that may compare better with the import data that is recorded at national level. In order to accomplish this, I try to locate some sort of approximation on how much Tokyo market represents of the national market size of fresh salmon. I do this by consulting the online agricultural databases from the Organisation for Economic Co-operation and Development (OECD)[2]. From their website is it possible to

[1] Data was pulled from the Tokyo wholesale market's website of trade statistics (in Japanese): https://www.shijou-nippo.metro.tokyo.lg.jp/SN/SN_Sui_Nengetu.html

[2] Data was collected from global agriculture and fisheries statistics produced from OECD databases: https://stats.oecd.org/

retrieve the production quantity of salmon from aquaculture in Japan, which is a natural proxy for the salmon production that is being sold fresh as wild salmon is normally not consumed raw. Trade statistics from the OEDC databases also confirms that Japan only exports a negligible amount of fresh salmon and will therefore not affect the estimate of domestic supply. The following table displays the ratio Tokyo wholesale supply against the national production of fresh salmon, which will be used scale each year's domestic quantity to a national level.

Year	Ratio
2014	20,68%
2015	22,46%
2016	20,66%
2017	17,28%
2018	17,07%
2019	21,73%
2020	21,61%

Table 2: Rounded ratio of quantity of fresh salmon sold at the Tokyo wholesale market versus the national production. We can observe that the ratio is quite constant over time, generally ranging between 17% - 21%.

Though a better estimate of the market size could be preferable, the absence of more appropriate Japanese data makes this a good a proximation with the available sources. Similar approaches have been used before to estimate this value, such as by Reinert and Roland-Holst (1992). Next, I calculate the average price each month, for both the highest and lowest daily prices. The mean between these two variables is then calculated to act as an estimate of the average price. The two data sets are then finally joined together by each month, creating a panel data containing time series import data matched with the appropriate domestic data.

Finally, the few select countries are selected to act as the sample for the analysis. The first countries selected are Chile, Norway, the US, and Russia. These countries have in common that they have a considerable amount of export to Japan, and more importantly a consistent one. But by only selecting these countries, the sample would only contain one country exporting a consistent supply of fresh salmon, being Norway. As it is desirable to evaluate the differences between frozen and fresh salmon, considering that much of the new domestic supply is fresh salmon, a few other countries will be added to the model. These will be the three countries exporting most fresh salmon after Norway, namely Australia, Canada and the UK. It should be noted that these countries export considerably less salmon that the rest of the countries in the sample, which may or may not affect the analytic results. This leaves an unbalanced panel data, where some countries are more represented more than others due to exporting several different species of salmon of different product type.

4.2 Descriptive Statistics

Figure 3 shows an overview of the number of each observation in the listed categories. Most countries in the sample have only one export, resulting in 84 observations. Chile exports a considerable amount of both frozen trout and frozen coho, which are both included. Likewise, Norway also exports relatively large amount of frozen trout, in addition to its more major export of fresh Atlantic salmon and trout. Though Norway and Chile both export some amount of frozen Atlantic salmon as well, the export of both are rather inconsistent and hence dropped from the analysis. All fresh exporters of salmon export Atlantic salmon, resulting in a higher frequency of that species in the model.

Figure 4 Frequency of observations from each respective country, species and whether the salmon is fresh or frozen. The figure is based on the general model that combines semi-dressed fish and fillets.

Table 3 displays statistics for the key variables in the model, namely the quantity of import and domestic sales, and the price for both. Unsurprisingly, there are some considerable variations in the variables, due to the variables containing data from countries with vastly different level of export and that frozen and fresh salmons are not separated.

	Mean	Gmd	Min	Max
Amount Imported, kg	1633972	2329115	3058	24602603
Import Price	990	256	465	1603
Domestic Quantity	4425474	2797929	1075222	13796301
Domestic Price	1238	467	613	2703

Table 3 General statistics for variables in panel data, rounded. Includes mean, Gini's Mean Difference (Gmd), and the minimum and maximum values observed. Domestic quantity is scaled to as previously described.

Table 4 further explores the statistics for each respective country. The means and mean difference values makes sense according to previous discussion. We observe that Norway and Chile, who exports a higher variety of salmon, also experience a higher variation than the other countries. It is somewhat interesting that Norway has a lower variance than Chile, considering that Chile only exports frozen fish in contrast to Norway who exports both frozen and fresh salmon. The average highest price point among exports is Norwegian salmon, which may be considered even more impressive considering that part of the Norwegian data contains lover-valued frozen salmon. An even higher price average is found amongst the Japanese fresh salmon. This price also experiences a relatively high variance, which is more than likely correlated to the aforementioned seasonal production patterns present in Japanese fisheries today.

	Mean	Gmd	Min	Max
Norwegian Import Quantity	1022878	1160571	33144	4005396
Norwegian Import Price	1141	193	695	1603
Australian Import Quantity	73198	40299	22119	261581
Australian Import Price	1074	109	867	1219
Canadian Import Quantity	123859	75395	19831	314666
Canadian Import Price	987	108	818	1313
English Import Quantity	43666	20208	10308	93590
English Import Price	1086	94	886	1227
Chilean Import Quantity	5201817	4703723	167682	24602603
Chilean Import Price	887	312	465	1495
American Import Quantity	830672	1033142	3058	4931880
American Import Price	760	174	525	1146
Russian Import Quantity	1796057	1759376	22171	6338258
Russian Import Price	801	164	531	1546
Fresh Domestic Quantity	2273969	686869	1075222	3550152
Fresh Domestic Price	1479	624	613	2703
Frozen Domestic Quantity	6576979	1916498	3578578	13796301
Frozen Domestic Price	998	109	859	1187

Table 4 Statistics for each respective country, including domestic, rounded. Domestic numbers are scaled to national levels. Includes mean, Gini's Mean Difference (Gmd), and the minimum and maximum values observed.

Figure 4 displays the volume changes of fresh domestically sourced salmon in Japan and fresh Norwegian Atlantic salmon since 2014. From the figure we may observe great variation in both volumes within each year. There are clear seasonal effects. The domestic supply increases from the winter months before most often peaking in October, after which it declines rapidly towards the winter months. Though Norwegian salmon does not experience as drastic of a yearly variation as the Japanese salmon, there is a clear peak each year in December. This seems to be correlated with the corresponding drop in domestic supply towards the winter months. In the same vein, Norwegian imports generally seem to drop as the domestic supply is peaking. This seems to indicate a natural inverse relationship between the two volumes, which makes sense as they are both subject to the Japanese demand of fresh salmon.

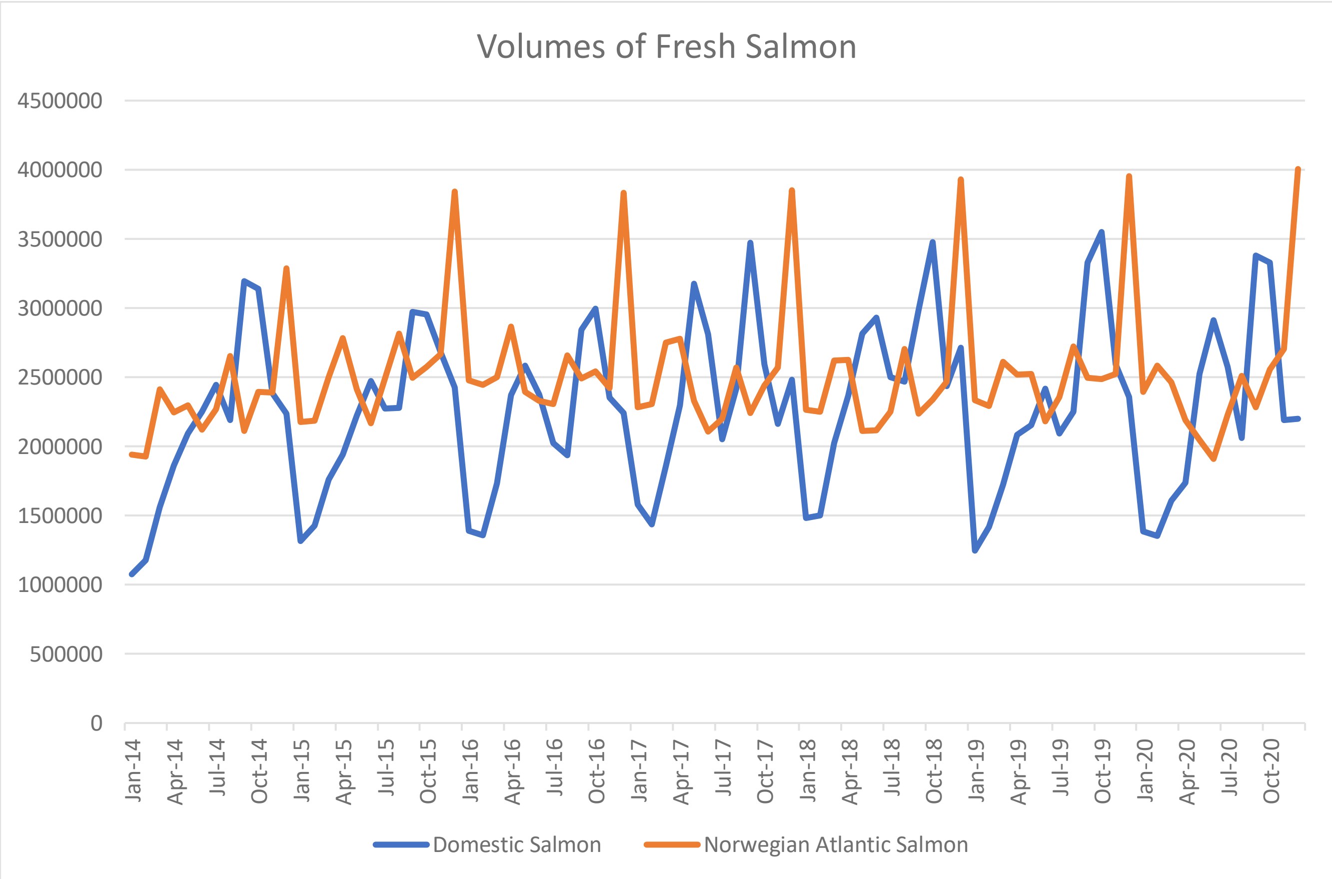

Figure 5 Domestic quantity of fresh salmon from January 2014 to December 2020, scaled to national levels.

4.3 Variables in the Models

Following the literature, the dependent variable in the model will be the logarithmic function of the ratio of imported quantity to domestic quantity. It is important to stress that due to the nature of the data, there will be a higher variance in the imported quantity compared to that of the domestic quantity. While imported quantity will vary between species and countries in each observation, the domestic quantity will only change depending on the fish being fresh or frozen. This means that within the two main groups of fresh and frozen data in a given period of time, the dependent variable will only vary by the imported quantity between the different salmon imports. as the domestic quantity will be equal. Accordingly, imported salmon quantity Q^M_{tcsf} varies by time *t*, country c, species s and *f*, which states whether the import is frozen of fresh. Due to the potential issue of frozen salmon data containing an unknown amount of imported salmon, two versions of domestic quantity Q^D are defined. For the models using both fresh and frozen domestic observations, import quantity Q^D_{tf} varies by time *t* and the state of the salmon *f*. For the models using only domestic quantity of fresh salmon, import quantity Q^D_t will naturally only vary by time *t*.

On the right side of the equation, the first variable is the logarithmic function of the ratio of domestic price to import price. This variable follows the notations and logic as previously discussed variable. The import price P^M_{tcsf} varies by time *t*, country *c*, species *s* and state of fish *f*. In models with both fresh and frozen domestic data, domestic price P^D_{tf} varies by time *t* and state of fish *f*. In the models using only fresh domestic data imports price P^D_t varies by time *t*.

As there seem to be strong seasonal effects present in both the previously discussed variables, a seasonal dummy variable d_m for each month will be to capture any seasonal affects. From the descriptive statistics we observe great variations between observations depending on country, species and whether the fish is fresh or frozen. As such, country λ_c, species τ_s and whether the salmon if frozen or frozen δ_f will also be added as dummy variables to capture any fixed effects across time in the panel data. Additionally, there is likely to exist some linear trends across the time horizon for at least some of the salmon, such as the negative trend observed of Chilean trout in figure 2. To capture such effects, a continues variable increasing in value by 1 by each period is used to estimate any linear trends. These variables, together with the coefficient and error term, will make up the general model for the analysis.

5. Model Specifications and Results

The following section describes the different model specifications, in addition to the main results of the regressions. As previously stated, the frozen domestic quantity and price may be affected by an unknown amount of imported frozen salmon being part of the domestic data. One potential solution to this issue is to use the domestic fresh data, which does not include any import of salmon, as the reference for domestic values to compare to both fresh and frozen import. Though this alleviate the concerns of import and domestic data being mixed, it may also lead to a weaker and less precise model. Frozen imported salmon and fresh domestic salmon may be too differentiated, or at least more so compared to that frozen domestic salmon. In order to not lose any potential insights that can be derived from the following models, I will compute the results using both versions of the panel data. I will apply a linear OLS regression model to the panel data to estimate the variables of interest. I will also include the control variables mentioned in 4.3 to capture any fixed effects. In the following I only report the estimations of the intercept α, the Armington elasticity σ and the linear trend μ_t in the table themselves, as the estimates of the variables are not of too much interest to this study.

5.1 General Model

The first model will be an estimation of price the elasticity across the whole panel data. The specification will resemble the model discussed in the literature, with the addition of some dummy variables to capture fixed effects within the panel data.

The empirical model for model (1):

$$ln\left[\frac{Q^M_{tcsf}}{Q^D_{tf}}\right] = \alpha + \sigma * ln\left[\frac{P^D_{tf}}{P^M_{tcsf}}\right] + \sum_{y=1}^{11} m_y D_y + \lambda_c + \tau_s + \delta_f + \mu_t + \varepsilon_{tcsf}, \qquad \textit{Model 1}$$

Where t = 1, …., T is the time index, D_y are seasonal dummies to capture monthly seasonal effects, λ_c is the fixed effect of countries chosen by the model with c = 1, …., C country index, τ_s is the fixed effect of species chosen by the model with s = 1, …., S species index, δ_f

is a dummy variable stating whether the salmon is frozen or fresh, while ε_{tcsf} is the error term to the above specifics. Finally, a continues variable, μ_t, is added to model in order to capture any potential linear trends. Bear in mind that Q_{tf}^D and P_{tf}^D will be changed to Q_t^D and P_t^D in the altered model, where they will only be defined by the fresh data. In the following, model 1a represents model 1 using Q_{tf}^D and P_{tf}^D, while model 1b represent model 1 with Q_t^D and P_t^D.

	Model 1a	Model 1b
α	-3.78***	-3.45***
	(-0.13)	(-0.14)
σ	1.01***	0.74***
	(-0.11)	(-0.12)
µ	0.01***	0.00**
	(0.00)	(0.00)
N	840	840
R2	0.77	0.83

*Table 5 reports results from the fixed-effects OLS regression of model 1. The sample includes the whole panel data, with different observations used for domestic quantity in model 1a) and model 1b) as described in chapter 5.1. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

To start, we can observe that all the estimated coefficients are statistically significant at least at the 5 percent level, with most of the coefficients being significant at the 0.1 percent level. Not surprisingly, the price elasticity σ is estimated higher in model 1a. This is more than likely a result of frozen import displaying a higher level of substitution with the frozen domestic fish, which a higher level of σ entails. Though as previously stated, the higher level of substitution may be a result of some imported goods being sold in the domestic market.

The trend is calculated to take a coefficient of about 0.01 in the first model in the first model. As the model, with its basis in equation (4), is derived from equation (2) by talking the natural logarithmic function, the linear trend of import quantity to domestic quantity is found to be around 1 percent by time in the panel data. A much lower trend is computed in the model 1b, talking a value of about 0.003.

From the monthly dummies, we can observe significant effects from about the first half months of the year. This indicates significant differences in the ratio between import and domestic quantity during the first half of the year, especially during late spring and early summer. A likely explanation to this would be that the Japanese salmon production displays a high level of seasonality, with larger part of the harvest happening in the aforementioned months compared to that of the exporting countries. Furthermore, the inclusion of fixed effects where important to explain the variation in the ratio of imports to domestic quantity. To analyse the difference between countries and products, I will in the following model them separately, starting with looking at fresh versus frozen salmon.

5.2 Comparison of Fresh and Frozen Salmon

For model (2) I estimate a model using the frozen and fresh data separately in order to better observe potential differences between them. The model will be quite similar to model 1, the difference being that the dummy variable for frozen and fresh salmon, δ_f, will be excluded.

The empirical model for model 2:

$$log\left[\frac{Q^M_{tcsf}}{Q^D_{tf}}\right] = \alpha + \sigma * log\left[\frac{P^D_{tf}}{P^M_{tcsf}}\right] + \sum_{y=1}^{11} m_y D_y + \lambda_c + \tau_s + \mu_t + \varepsilon_{tcsf}, \quad \textit{Model 2}$$

	Frozen a	Frozen b	Fresh
α	-1.44***	0.51	-3.56***
	(0.25)	(0.28)	(0.09)
σ	2.98***	1.13***	0.20*
	(0.35)	(0.20)	(0.09)
μ	0.01***	-0.00	0.01***
	(0.00)	(0.00)	(0.00)
N	420	420	420
R2	0.62	0.59	0.94

*Table 6 reports results from the fixed-effects OLS regression of model 2. The samples are separated by fresh and frozen salmon. The different observations used for domestic quantity in Frozen a) and Frozen b) are as described in chapter 5.1. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

Table 6 shows that all the estimations of coefficient σ are significant at least at the 5 percent level, in both versions of the frozen model and in the fresh model. The estimations follow the same logic as in model 1, where model frozen a) displays a higher level of substitution than model frozen b), more than likely due to the frozen import being regressed on the fresh domestic in the latter. Perhaps more interesting is the rather stark difference in the frozen and fresh models' estimate of σ, where the fresh model has a calculated coefficient of 0.20, which is substantially lower than the frozen models. This indicates that the fresh salmon in general are more differentiated to their Japanese counterparts than the frozen salmon.

Seasonal effects in the frozen models are quite like those in model 1, with significant monthly seasonal effects generally present during the first half of the year. The fresh model, however, displays significant seasonal effect in almost all months. This makes sense, considering that fresh salmon is more than likely to be subject to more seasonality than frozen produce, which is in nature easier to steadily distribute throughout the year. We again can observe that the inclusion of country fixed effects where important to explain the variation in the ratio of imports to domestic quantity.

5.3 Country-specific Elasticities of Frozen Salmon

To better explore the seemingly large differences between countries, a view on each separate country's elasticity would be beneficial. Firstly, I estimate a model for each respective country with frozen export from the general model. Dummies for countries λ_c and fresh or frozen salmon δ_f will naturally be redundant. The dummy for species τ_s is also removed as the countries in general do not have separate species to analyse within the frozen category. This leaves only the monthly dummies and continues the trend variable left in the model. As before, I will use two different samples based on what data to represent the domestic quantity and price with.

The empirical model for model 3:

$$log\left[\frac{Q^M_{tcsf}}{Q^D_{tf}}\right] = \alpha + \sigma * log\left[\frac{P^D_{tf}}{P^M_{tcsf}}\right] + \sum_{y=1}^{11} m_y D_y + \mu_t + \varepsilon_{tcsf}, \qquad \textit{Model 3}$$

Version a	Chile	US	Russia	Norway
α	-0.16	-5.01***	-2.78***	-2.51***
	(0.36)	(0.50)	(-0.30)	(0.22)
σ	1.31***	5.69***	2.30***	1.82***
	(0.82)	(0.97)	(0.09)	(0.37)
µ	0.01**	0.01*	0.01***	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
N	84	84	84	84
R2	0.75	0.64	0.79	0.43

*Table 7 reports results from the fixed-effects OLS regression of model 3. The samples are made from the frozen import from the separate countries in panel data, with this sample using frozen domestic salmon. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively*

Version b	Chile	US	Russia	Norway
α	1.09 ***	-3.56***	-0.71	-1.13***
	(0.35)	(0.55)	(0.37)	(0.25)
σ	0.94***	2.06***	0.32	0.90***
	(0.30)	(0.44)	(0.32)	(0.23)
µ	-0.00	0.00	0.00	-0.01
	(0.00)	(0.01)	(0.00)	(0.00)
N	84	84	84	84
R2	0.78	0.53	0.71	0.62

*Table 8 reports results from the fixed-effects OLS regression of model 3. The samples are made from the frozen import from the separate countries in panel data, with this sample using fresh domestic salmon. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

From table 7 we can observe that each country has a significant calculated price elasticity σ. Salmon from the United States it estimated to have the highest level of substitution with the Japanese sourced salmon, while Chile has the lowest. A part of the reason for Norwegian and Chilean salmon displaying lower level of substitution, is likely due to the species exported being different. Norwegian and Chilean import includes trout in the sample, while the US and Russia only imports Pacific salmon, which is also sold domestically in Japan in relatively high numbers. From the second model we again observe a reduction in σ among all countries, which is more than likely due to similar reasons as before.

As both Chile and Norway export a considerable amount of frozen trout, we also have the opportunity to more thoroughly compare these important exporters of salmon to the Japanese market. As the frozen trout from Norway and Chile is sold both semi-dressed and as fillets, I will in the following model these two product types separately. As the elasticity may differ between the two product types, this will assure a fairer comparison between the countries as the mix between whole products and fillets are more than likely to differ throughout the time horizon between the two countries. The models are otherwise identical to model 3, though only data of trout is included. As trout is categorized separately in the frozen domestic data, we may confirm that imported trout is not present in the Japanese data set. For this reason, I may run the following regressions using frozen domestic data without the prior concerns.

	Chilean Trout Semi-dressed	Chilean Trout Fillet	Norwegian Trout Semi-dressed	Norwegian Trout Fillet
α	-2.29***	-0.79***	-2.56***	-3.94***
	(0.24)	(0.18)	(0.41)	(0.38)
σ	1.03**	1.29***	1.09	1.31*
	(0.36)	(0.35)	(0.70)	(0.50)
μ	-0.01**	0.00*	-0.02***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
N	84	84	84	84
R2	0.36	0.41	0.33	0.40

*Table 9 reports results from the fixed-effects OLS regression of model 3. The samples are exclusively made of Chilean and Norwegian frozen trout, separated by semi-dressed and fillet products. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

Interestingly, the models estimate the coefficients of the price elasticity σ very similarly. In the model only estimated with fillet data, the estimated difference of σ between Norway and Chile is only 0.02, and both are statistically significant at least at the 5 percent level. Though the estimated elasticity of Norwegian trout does is not significant the 5 percent level, the coefficients are also here very similar. The models may imply that the substitution level between imported frozen trout and Japanese frozen salmon may not be that different depending on the origin country of the imported trout. Additionally, we can note that the level of substitution of frozen trout in general seem to be lower than that of frozen salmon in general. We may attribute the difference in trend between semi-dressed and fillet to an increase of fillet coupled with a decrease of semi-dressed salmon. This trend seems to be present in both Norwegian and Chilean export, though the effect is estimated greater from the Norwegian observations.

5.4 Country-specific Elasticities of Fresh Salmon

The following model is identical to model 3, but I will now look at the difference between countries exporting fresh salmon instead of frozen. As all the countries exporting fresh salmon except for Norway only exports Atlantic salmon in any meaningful or consistent volume, I will estimate models using only Atlantic salmon data from Norway in order to better compare the countries.

The empirical model for model 4:

$$log\left[\frac{Q^M_{tcsf}}{Q^D_{tf}}\right] = \alpha + \sigma * log\left[\frac{P^D_{tf}}{P^M_{tcsf}}\right] + \sum_{y=1}^{11} m_y D_y + \mu_t + \varepsilon_{tcsf}, \qquad \textit{Model 4}$$

	Norway	Canada	UK	Australia
α	0.50***	-3.29***	-3.77***	-3.66***
	(0.05)	(0.23)	(0.19)	(0.14)
σ	0.13*	-0.26	-0.05	0.85***
	(0.06)	(0.25)	(0.22)	(0.15)
μ	-0.00	0.02***	0.01**	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)
N	84	84	84	84
R2	0.89	0.50	0.38	0.71

*Table 10 reports results from the fixed-effects OLS regression of model 4. The samples are made of the fresh import from the separate countries in panel data. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

Firstly, we may observe that both Canada and the United Kingdom have a negative estimated price elasticity σ, albeit not statistically significant at the 5 percent level. As a negative rate of substitution in itself does not make theorical sense within the model, the observations from both of these countries are seemingly unfit to draw any meaningful conclusions from. What is interesting though, is the seemingly large difference between Australia and Norway.

According to the estimations, it seems as though Australian Atlantic salmon has a higher level of substitution with the Japanese salmon than the Atlantic salmon from Norway. This may indicate that salmon is differentiated by country of origin, in support of the Armington assumption. There also seem to be a difference in linear trend between Norway and Australia, where Norway has an insignificant estimated coefficient close to 0. Australia on the other hand, has an estimated linear trend of about 0.006. We may observe the growth of Australian Atlantic salmon in figure 6.

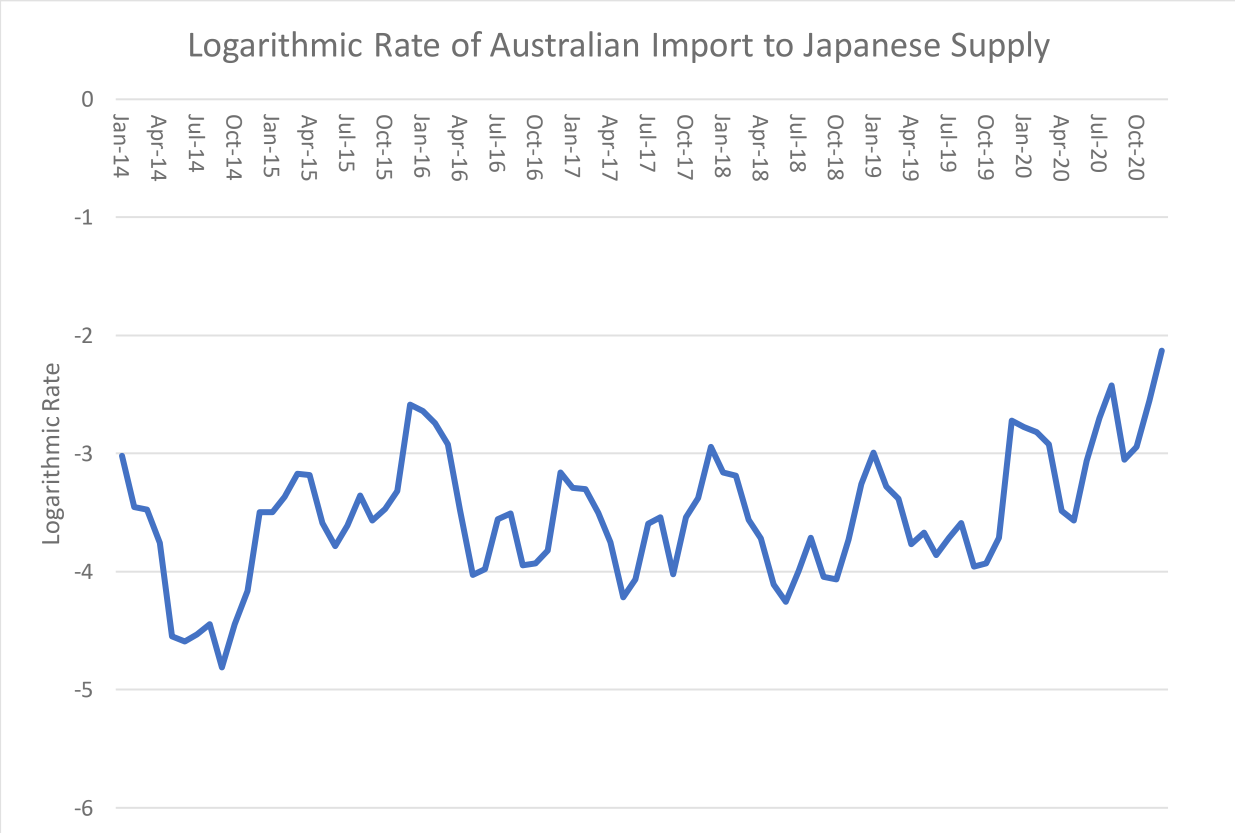

Figure 6 Changes in of the ratio of Australian Atlantic salmon over Japanese fresh salmon. Estimated linear trend is about 0.006.

As the data of Atlantic salmon from Norway includes both fillets and whole fish, we may similarly to model 3 estimates these separately to make sure that the mix of fillets and whole salmon is not the main cause of the difference observed between Norway and Australia.

	Norwegian Semi-dressed	Norwegian Fillet	Australian Semi-dressed
α	0.11	-0.58***	-3.66***
	(0.06)	(0.05)	(0.14)
σ	0.16*	0.13*	0.85***
	(0.06)	(0.06)	(0.15)
μ	-0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)
N	84	84	84
R2	0.88	0.89	0.71

*Table 11 reports results from the fixed-effects OLS regression of model 4. The samples are exclusively made of Norwegian and Australian fresh Atlantic salmon, with the Norwegian import being separated by semi-dressed and fillet products. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

We may observe from table 11 that there is little difference between Norwegian whole fish and fillets when considering the price elasticity σ, and that they are both still very different from the estimated σ of Australian salmon.

5.5 Quarterly Estimates

Finally, I wish to estimate the fresh country specific model again with a quarterly time unit instead of monthly. It could be valuable to see how such an estimation affects the relatively low calculated substitution rate of Norwegian salmon, and also the negative estimated price elasticities of Canada and the UK. Longer-term sales contracts are quite popular in countries such as Norway, which could contribute to potentially stronger estimations of price elasticity σ when using a more aggregated unit of time. This would also be in line with previous literature, as Bajzik et.al (2020) found that using data with longer time units such as annual and quarterly typically yields a higher estimation of the price elasticity. Model 5 will be quite similar to model 4, the difference being that it will naturally include quarterly dummies instead of monthly ones. The sample will also use observations from 2004, and hence have a much higher time horizon that will likely also have an effect on the estimations.

The empirical model for model 5:

$$log\left[\frac{Q_{tcsf}^{M}}{Q_{tf}^{D}}\right] = \alpha + \sigma * log\left[\frac{P_{tf}^{D}}{P_{tcsf}^{M}}\right] + \sum_{y=1}^{3} m_y D_y + \mu_t + \varepsilon_{tcsf}, \qquad \textit{Model 5}$$

	Norway	Canada	UK	Australia
α	-0.49**	-3.10***	-3.56***	-3.44***
	(0.14)	(0.51)	(0.24)	(-24)
σ	0.64***	-1.35*	0.33	1.16**
	(0.18)	(0.65)	(0.33)	(0.35)
μ	0.01***	0.02*	-0.01	-0.01
	(0.00)	(0.01)	(0.00)	(0.00)
N	63	63	63	63
R2	0.66	0.14	0.21	0.40

*Table 12 reports results from the fixed-effects OLS regression of model 5. The samples are made of the quarterly panel data, using fresh Atlantic salmon observations. Variables listed are the intercept α, Armington elasticity σ and the linear trend μ. *, **, and *** indicates statistical significance levels of 5%, 1% and 0.1%, respectively.*

We can observe that using quarterly data, Norwegian Atlantic salmon indeed gains a substantially higher coefficient σ. Similar effects can also be seen from the Australian salmon. Though the British salmon does no longer have a negatively estimated price elasticity, it is still not statistically significant at the 5 percent level. Furthermore, the Canadian salmon is still estimated to have a negative coefficient σ.

6. Effect of Land-based Facilities on Import Volume

In order gain some insight on how the import volume might change in reaction to the increase of domestic volume, we might return to the first-order equation (2) that equation (4) and the regression models were derived from. By using the estimations of the price elasticity σ and the other variables, we may solve for import quantity M in equation (2) when increasing domestic volume D by the projected production numbers from land-based facilities as presented in table 1:

$$\frac{M}{D} = \left[\left(\frac{\beta}{1-\beta}\right)\frac{P_D}{P_M}\right]^{\sigma} \tag{2}$$

For the purpose of this analysis, I will be using the Norwegian and Australian regressions from model 4. As the study wishes to answer how an increase of salmon caused by domestic land-based facilities, which should mostly be fresh salmon, it will be interesting to look at the how this affects countries exporting fresh salmon. By looking at Norway and Australia specifically, we can also compare two foreign goods of the exact same product type, being fresh Atlantic salmon, and observe how the difference in price elasticity between them may impact their future export.

The parameter β may be calculated by using the estimation of the intercept from the regression models, by using the following equation for the intercept as derived from equation (2):

$$\alpha = \ln \sigma \left(\frac{\beta}{1-\beta}\right) \tag{5}$$

‘

The β parameter weighs the imported good relative to the domestic good (Blonigen & Wilson 1999). By adding the estimated seasonal effects to the intercept, we may interpret how this relationship between imported and domestic good changes throughout the year. α in month 1 will equal the estimated intercept, while α in month 2 will equal the intercept in addition to the estimated seasonal effect and so on. In this way, we may interpret the seasonal effects as shifters of the parameter β throughout the year. The linear trend estimated in model 4 will also be included.

The main reason for opting to do the following projections using the monthly estimates instead of the quarterly estimates, is the change in linear trend. Model from 2004, causing the linear trend terms to quite different from all of the monthly estimations. Norway as an example has an estimated positive trend if estimating from the sample from 2004, while the trend has been more or less stagnant in the monthly models from 2014. Australian Atlantic salmon would also have a negative estimated term, despite there seemingly being a growth its ratio to domestic salmon from 2014. Additionally, the results will better compare with the previous models that are calculated using monthly samples from 2014.

The final topic to consider before running the analysis, would be how the forecasted domestic production should be allocated throughout the years. Under just a standard increase in production, a reasonable avenue would be to allocate the new output following the present seasonal pattern of production. But, considering that one of the main benefits of land-based salmon farming is the ability of year-round production of the fish (Masser et.al 1992), simply allocating the new production evenly in each month might be a better and more realistic approach. The new production will more than likely not be equally distributed throughout the first year in the market, and that the starting data of deliveries will also greatly affect how much of the new production is delivered in the starting year. To somewhat compensate for this, the new production will be divided between the planned year of deliveries and the following year. On that note it should also be emphasized that the following estimations should not be treated as a formal economic forecast. As only the demand side of the market is calculated and not the supply side, and some assumption on how the price evolves will have to be made.

For the first view at imported volume, I assume that prices stay at the same level for the coming years. Figure 7 showcases potential changes in volume, using the estimated values and leaving everything else equal:

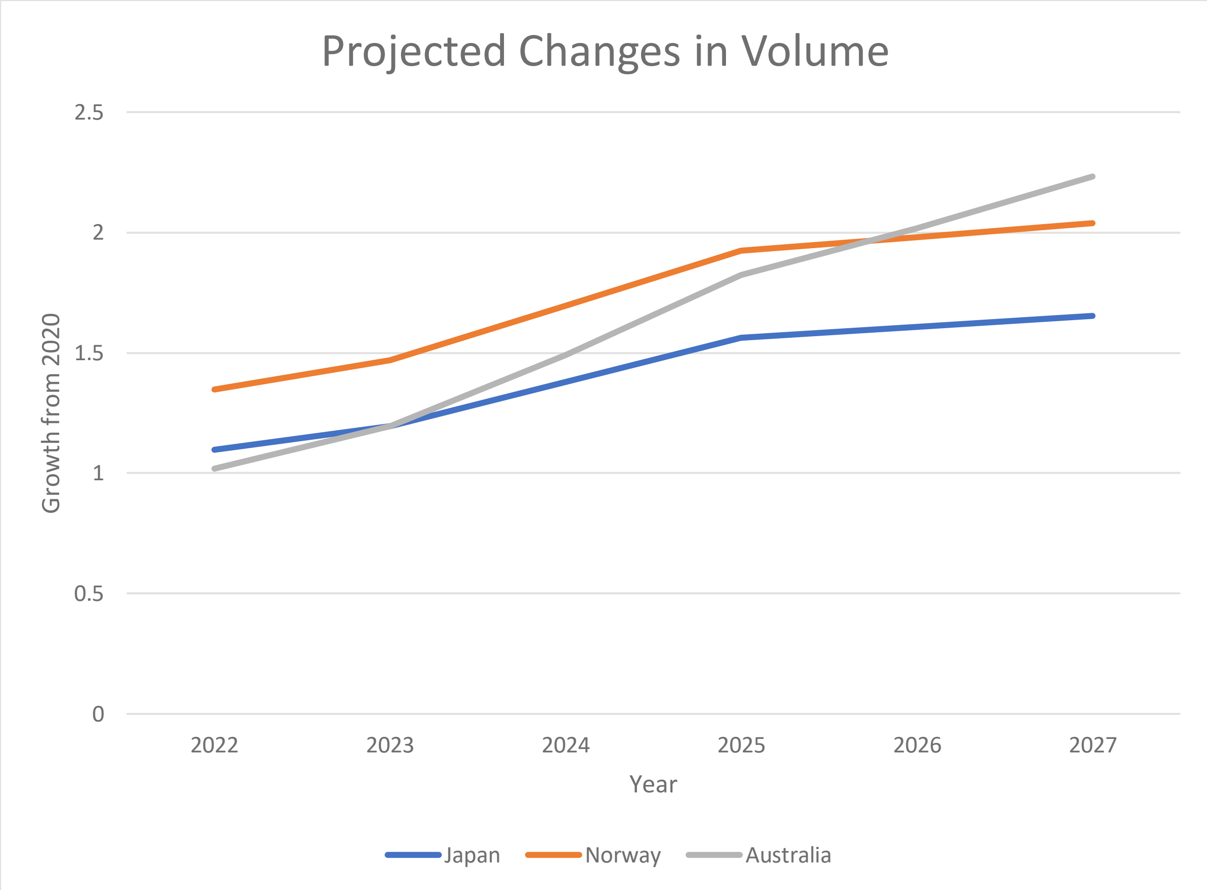

Figure 7 Projected changes of import volume from Norway and Australia respectively, using parameters as estimated in model 4. The projected volume for Japan is based on announced output from new land-based facilities as seen in table 1.

We observe some clear differences in projected volume between the two countries. Australia, having a considerably higher estimated Armington elasticity compared to Norway, initially witness a lower projected volume compared to that of Norway. Around 2026 though, Australia surpasses Norway's projected volume, due its significant positive linear trend term as seen in model 4. Both Norwegian and Australian salmon seems quite resistant against the new supply of domestically sourced salmon. The projected changes are rather large, where Norwegian volume is estimated to more than double while Australian salmon is projected a bit higher by the end of the forecast. Considering the growth of Norwegian salmon witness in figure 1 this could perhaps in theory be close to possible, but that figure also used a time horizon of 12 years. Australian import could be considered to have a higher growth potential though, due to its current low volume compared to Norwegian import, which is also apparent from its estimated trend. That being said, the more interesting takeaway from figure 7 and the following figures is the relative differences between the two imports.

Next, we may see what happens in a scenario where the domestic price decreases. After all, one of the main mentioned benefits of establishing land-based facilities in Japan is the removal of air freight cost. As a reference point, DNB Markets (2017) calculated that about 27% of the total cost of salmon shipped from Norway to Asia came from the cost of air freight. Many of the high prices observed in domestic salmon are also seemingly the result of the highly seasonal production pattern of Japanese salmon. As land-based facilities will be able to supply the domestic market more consistently, the average yearly prices are likely to drop. Several factors can dictate how the cost of land-based facilities may compare to that of air-transported salmon in the future, such as the price of fuel or the price of energy in Japan of which land-based aquaculture requires a considerable amount of to operate, making it difficult to predict the domestic price changes. But for the sake of seeing what will happen if the domestic price were to decrease, we may first imagine an average 15 percent drop in the price of Japanese fresh salmon for all years.

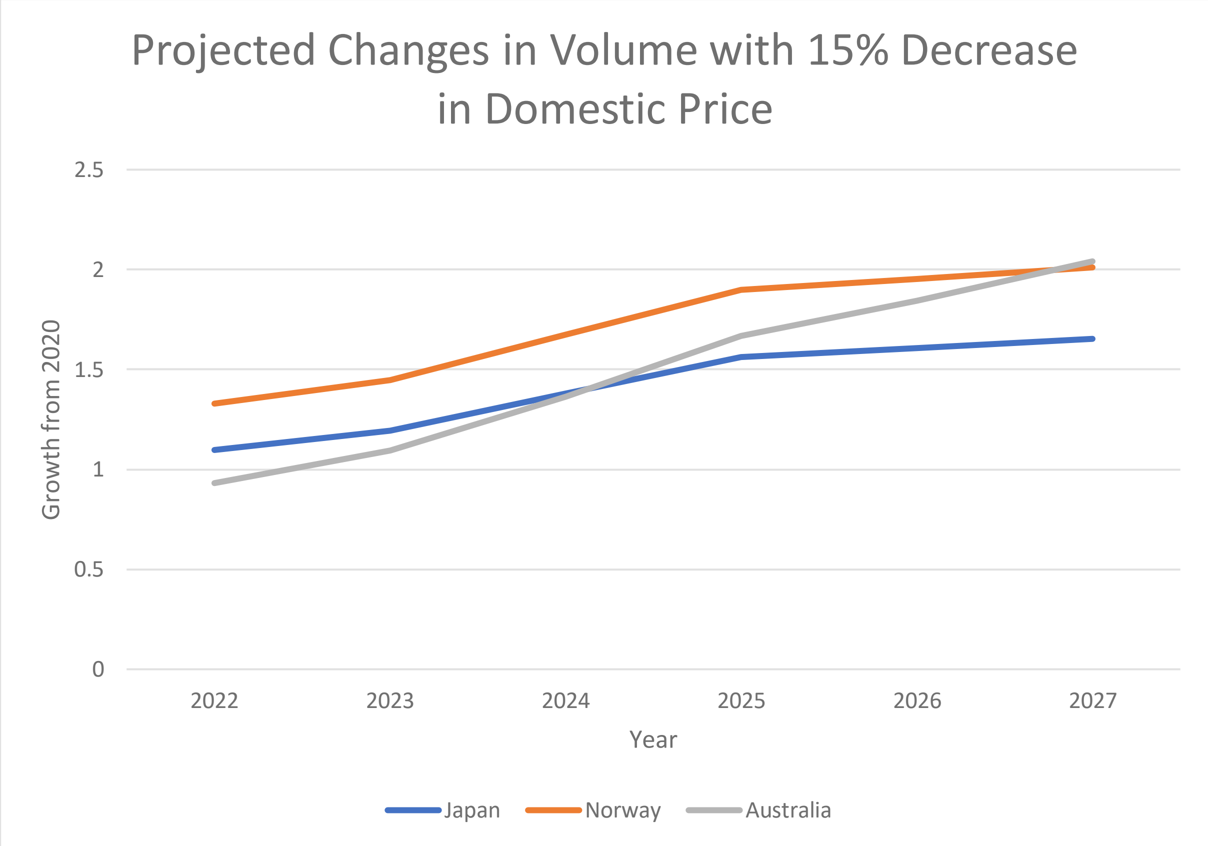

Figure 8 Projected changes of import volume from Norway and Australia respectively using parameters as estimated in model 4. The projected volume for Japan is based on announced output from new land-based facilities as seen in table 1. A 10 percent decrease in price of domestically sourced salmon in Japan is applied.

From figure 8 we may observe that a decrease of 15% in the domestic price will have quite the impact on the growth in export. We confirm that by having a higher substitution rate towards Japanese salmon, Australian salmon will react more dramatically than Norwegian salmon to any changes in price. Australian salmon is not in this scenario projected to surpass the growth rate of Norwegian salmon until 2027, and any further decrease in domestic price are likely to lead to a negative projected growth rates for a longer time before gaining momentum do the estimated linear trend term.

Furthermore, we may look at a scenario where exporters are able to respond to the domestic price reduction with a similar price reduction. Figure 9 displays a scenario where Norwegian salmon is reduced by the same amount as the domestic price reduction, while figure 10 displays the same for Australia. We again can observe that the Australian salmon is in much higher degree than the Norwegian salmon subject to price changes.

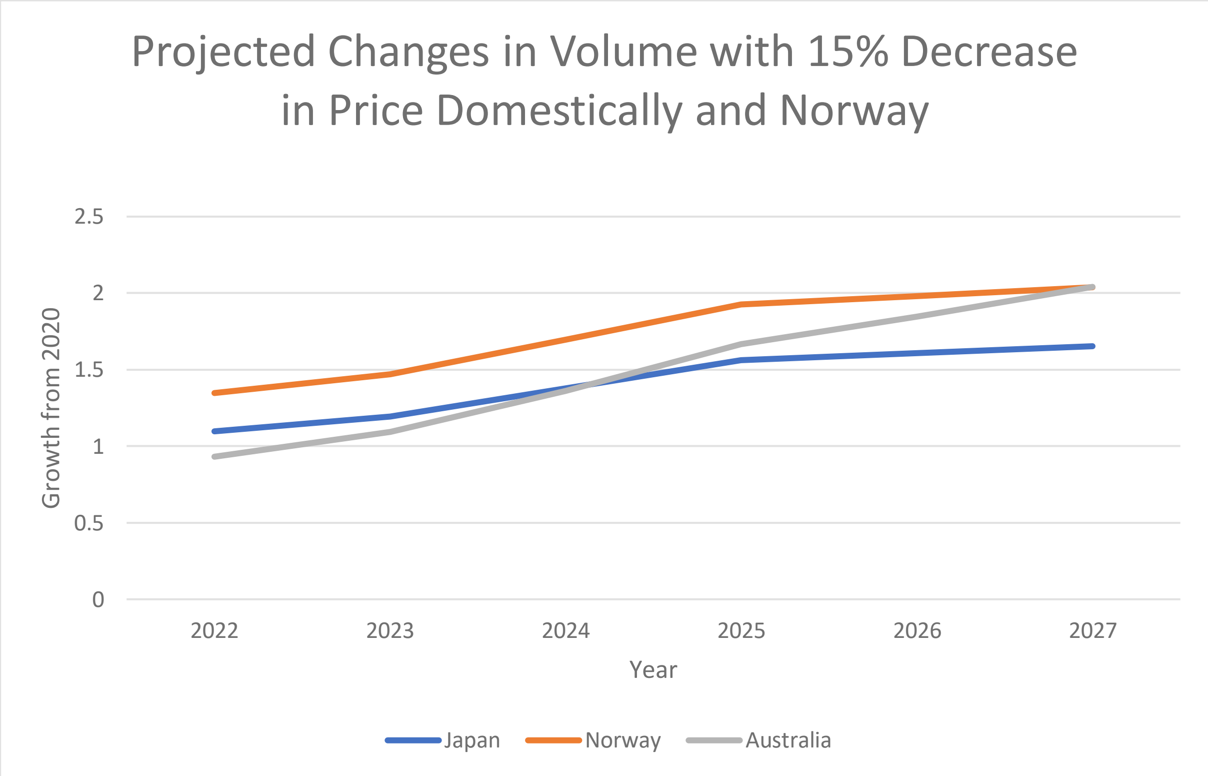

Figure 9 Projected changes of import volume from Norway and Australia respectively using parameters as estimated in model 4. A 10 percent decrease in price of domestically sourced salmon in Japan, and for imported Norwegian salmon is applied.

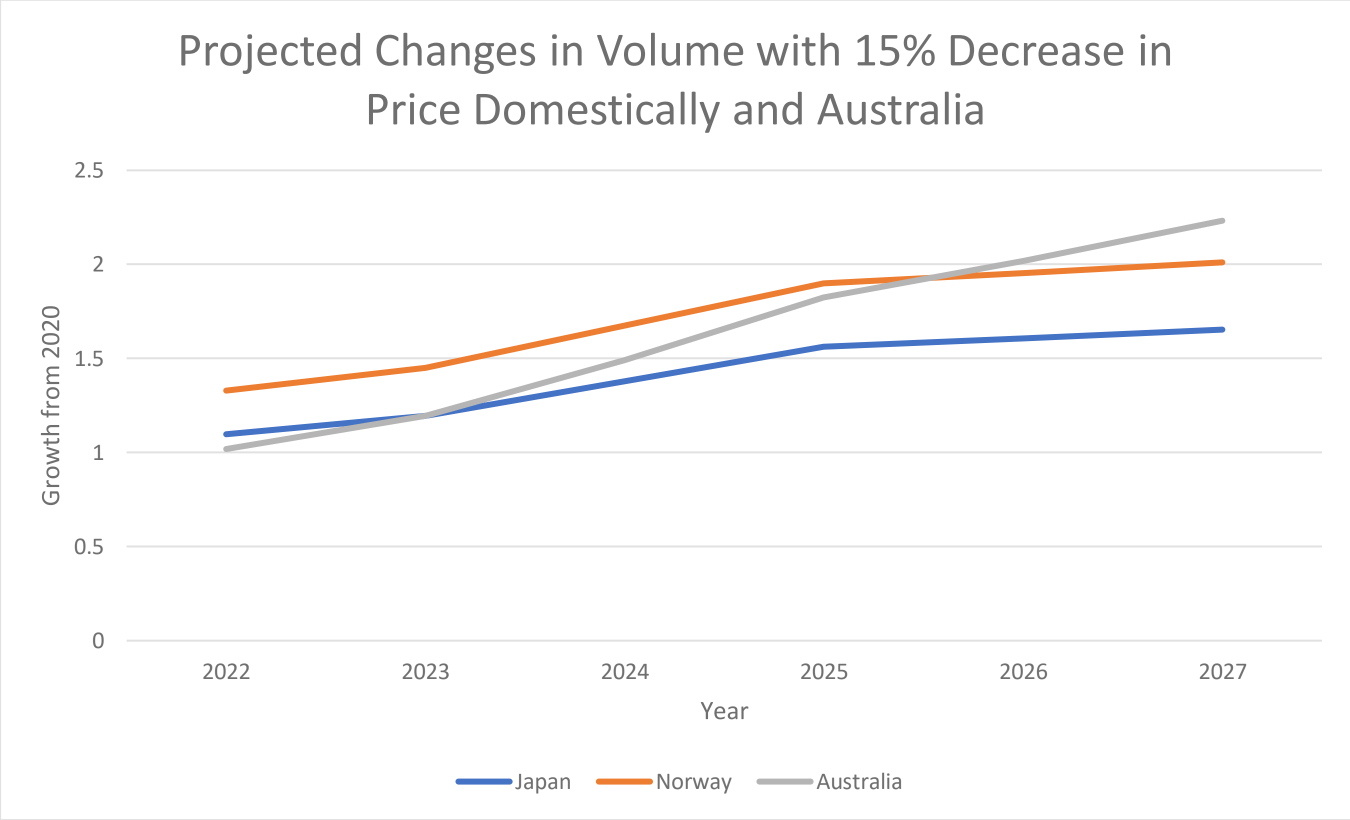

Figure 10 Projected changes of import volume from Norway and Australia respectively using parameters as estimated in model 4. A 10 percent decrease in price of domestically sourced salmon in Japan, and for imported Australian salmon is applied.

Another likely scenario, and perhaps more realistic, is that the domestic price will gradually decrease over time. After the initial launch, production from the new facilities may become more cost effective and efficient, as producers gets more established in the market and gain more knowledge. Additionally, future technology may also make the production cheaper, though such changes to technology is most probably further away in time than the scope of this forecast. For the final projection, we may imagine a domestic price decrease of 10% in the first month, with a gradual drop of an additional 2.5% each year. I assume that import prices are constant.

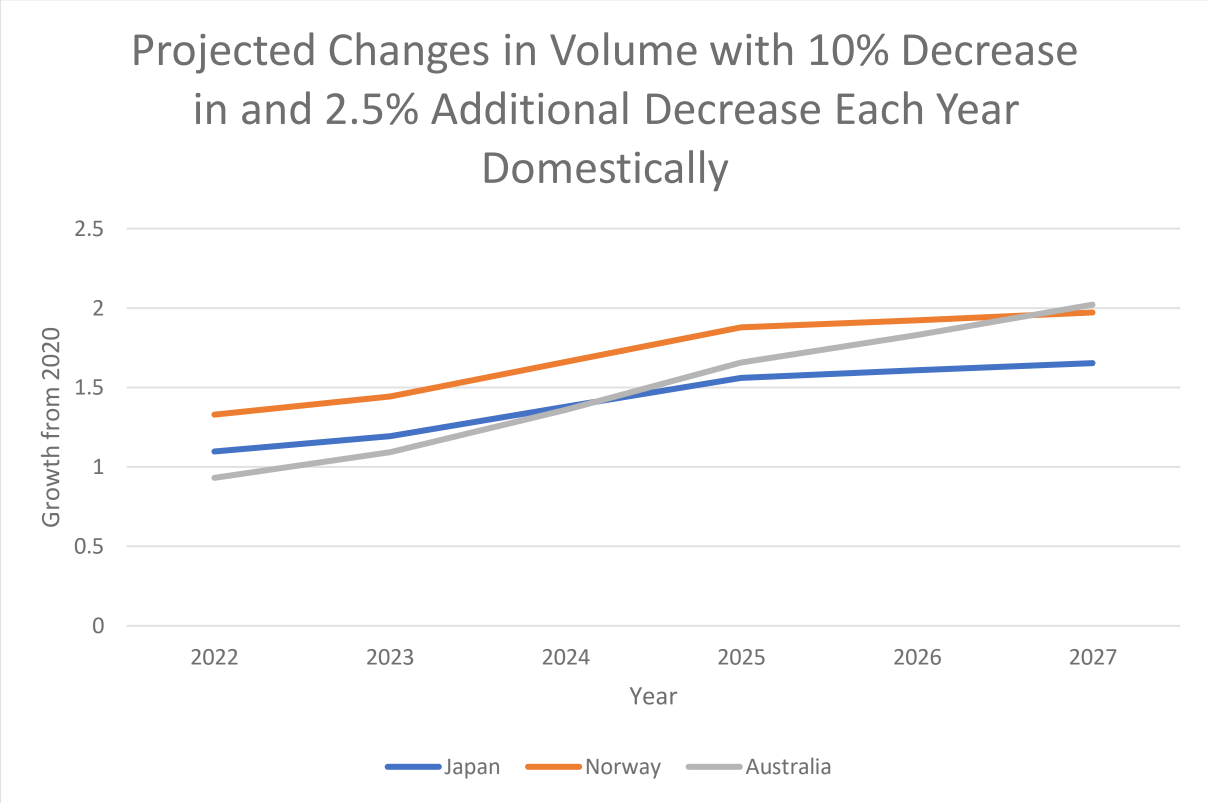

Figure 11 Projected changes of import volume from Norway and Australia respectively using parameters as estimated in model 4. A 10 percent decrease in price of domestically sourced salmon in Japan in 2020, with an additional 2.5% decrease each year after

Comparing figure 11 with figure 8, we observe very similar projections. Australia is again most affected by price changes. While Australian import is somewhat more affected by the gradual price decrease, as evident by its decrease in growth rate from 2024 compared to figure 8, is still surpasses growth of Norwegian import by the end of the time horizon due its estimated trend.

7. Discussion

One of the most apparent effects that can observed from the analysis is the difference in substitution rate between frozen and fresh salmon imports to Japan, where frozen salmon experience a higher substitution rate across the board. This points towards a notion that Japanese consumers consider frozen salmon less differentiated than fresh salmon, and that they likely care more about the origin of the salmon when purchasing fresh salmon. Additionally, the species of the frozen salmon and its origin country is seemingly important to the estimates. This is especially the case for salmon exported from the United States, which has the highest elasticity estimated in the whole analysis, with an Armington elasticity of 5.69 as seen in model 3a). While this may indicate that frozen salmon exports are differentiated by country of origin, other elements could also be the explanation of the estimated differences. One of the more probable factors to explain some of the differences observed between countries is the mix of salmon present in the domestic data. While we cannot confirm with the available data the amount of each separate species of frozen salmon in the domestic, we do know that much of Japanese salmon is caught in the wild and sold as a frozen product meant for cooking. Considering that the US exports a substantial amount of frozen wild pacific salmon that is also mainly a product meant for cooking, the Japanese and American salmon may naturally be considered closer substitutes. Chile, who has a considerably lower estimated Armington elasticity than the US, export a lot of salmon raised in aquaculture. As this product often can be used in sashimi products as raw fish, consumers may be more aware of the country of origin and the products will be more distinguished from Japanese frozen salmon.

As stated, differences in the Armington elasticity are not only apparent between the countries within frozen export, but also between the species of frozen salmon. An unfortunate element of this part of the analysis is the fact that it can be difficult judge how much of the differences of elasticity is affected by country of origin and how much is affected by species as these are often tied together. Luckily, both Norway and Chile both export several species of frozen fish, and they are both exporting frozen trout as analysed in model 3. From this model we could observe that frozen trout was estimated to have a much lower level of substitution than the other species, and they were estimated strikingly similar between Norway and Chile. The general lower level of estimated elasticity seen in trout from both Norway and Chile, indicates a clear difference among species, which are also more than likely partly due to other species of salmon having a higher domestic presence than trout. As previously mentioned, the fact that trout is often used as sashimi (Tsai & Tominaga, 2016), may also contribute to this effect. Perhaps the more interesting result from this model is the similarity of estimated Armington elasticity between Norway and Chile, which is seemingly even true when running separate models for semi-dressed trout and trout fillet. This serves as a possibility that frozen salmon of the same product type and species face a similar level of substitution with Japanese salmon, even though the salmon have different origins. This also somewhat emphasizes the notion of frozen salmon being less differentiated than fresh salmon in general, as the model may indicate that freezing the fish causes the products to be less differentiated in the market.

The notable differences between fresh and frozen salmon could have an impact on the future of the Japanese salmon import. Though the main forecast of this paper is based on the new wave of land-based facilities, which are more than likely only targeting the fresh segment, there has been a wave of increasing salmon production in general as discussed in chapter 1. Additionally, model 2 did estimate a significant Armington elasticity for most of the countries against the fresh domestic salmon, albeit at a lower level compared to the substitution with frozen domestic salmon. If Japanese salmon production continues to grow, with an increase in supply of both frozen and fresh fish, the higher observed Armington elasticity estimate may indicate harsher domestic competition in the coming years among frozen exports. Additionally, one may assume that consumers in general have a higher preference towards fresh salmon than frozen salmon. If then the price of domestic salmon will decrease in the future, some consumers may choose to substitute frozen imported salmon with fresh domestic salmon if the price moves towards more comparable levels between the two products.

An increase in domestic supply is likely to affect the exporting countries differently. Assuming an increased level of competition in the frozen segment relative to the fresh, some producers may be tempted to start exporting fresh salmon instead of frozen. This will of course mostly be an option for those already raising their salmon in aquaculture facilities, so that the salmon is safe for raw consumption. This will naturally not be an option for those harvesting wild salmon, such as the many of the exporters in the US. Chilean producers on the other hand could very well be likely candidates for such a change, as they are already raising salmon for raw consumption in considerable volumes. It should be emphasized that this would require a large change to the method of distribution, and it would be accompanied by a substantial increase in cost that could potentially render this a not financially sustainable option for producers. However, if such a change where to find place, both in Chile and other countries such a Norway, it could in turn increase the competition in the market segment of fresh salmon. This would be an interesting development, where the current state of the sashimi market where Chilean salmon is generally sold as cheaper thawed sashimi, compared to the more expansive fresh Norwegian sashimi, could potentially be altered.

Looking beyond frozen salmon there are also some interpretations about the fresh salmon that can be made. The data basis of fresh salmon is very different from that of frozen salmon, where Norway exports a large majority of the salmon. This causes the basis of the analysis to be somewhat weaker when trying to compare results between different countries. This can be seen with model 4 and model 5, where neither a sensible or significant Armington elasticity is estimated for salmon from UK and Canada. The Armington elasticity is estimated at significant levels for Australia though, making it possible to make comparisons with Norway. The Armington elasticity of fresh Atlantic salmon from Norway and Australia is estimated at 0.13 and 0.85 respectively. Both estimates are considerably lower than the estimates of frozen salmon, showcasing the differences between frozen and fresh imports.

Though the two countries export the same product, being fresh Atlantic salmon, we can observe a large difference of the estimated price elasticity between the two countries. This is contrast to what was observed when comparing frozen trout from Norway and Chile to each other, where very similar estimations of the Armington elasticity were observed between the two countries. This may serve as yet another sign of a systematic difference between fresh and frozen salmon imports. The market does not only seem to have a higher substitution rate of frozen salmon in general, but there may be a comparatively higher difference in the level of substitution rate found among fresh salmon themselves.

The effect on how the difference in substitution rate among fresh salmons was showcased in in chapter 6, where there were clear differences in how Norwegian and Australian salmon may react to the new volume of fresh salmon from land-based facilities in Japan in the close future, with or without price changes. Though the results should not be treated as a formal economic forecast, the insight gained from looking at the differences between the two countries themselves could be valuable. It shows how the same salmon species, sold as the same and otherwise equal product, may be subject to different levels of domestic competition from both an increase in demand and a reduction in prices. This may indicate that Norwegian salmon indeed has gained some sort of special status among Japanese consumers, which should maybe not be too surprising considering the history of the product in the Japanese market as described at the start of the paper. Norwegian salmon also displaying the highest average price point in the panel data, despite having lower-valued frozen trout among its observations, could also point towards this notion. It should also be emphasized that the Australian salmon, being a fresh salmon, also had a relatively low estimated Armington elasticity. Considering how quickly Australian salmon reacted to changes in the domestic market, it is of interest to consider how the increase of domestic supply may affect the countries or products with higher estimations of the Armington elasticity. These imports would be subject to an even higher level of domestic competition and react even more strongly to a decrease in the price of domestically sourced salmon.

7.1 Robustness of Analysis

One of the more unfortunate parts of the analysis is the somewhat lack of detailed domestic Japanese data. While the import data of salmon is separated by species for both volume and price, all domestic volumes for either fresh or frozen salmon is aggregated. Domestic prices for salmon is also generally as the minimum and maximum price of all fresh or frozen salmon. This potentially leads to many of the Armington estimates being skewed. If one imported species or type of salmon is more present in the domestic market than other imports, that import is likely to display a higher estimated Armington elasticity as the products likely acts more as substitutes. If it would be possible to estimate the elasticities by modelling the specific import products against their respective domestic counterparts, the results would likely quite differ from my analysis and perhaps be more realistic. This is especially an issue when trying to project volumes of future imports. At the forecasts apply an Armington elasticity estimated from the historic aggregated domestic data of all species, the forecast will not take future changes to the mix of domestic salmon species into consideration. As the new salmon production from land-based facilities in a large degree will be Atlantic salmon, it is natural to assume that imports of Atlantic salmon likely will display a higher level of substitution in future compared to what is estimated from the general historic Japanese supply. Considering this, the analysis is likely a bit too optimistic from the perspective of Atlantic salmon exporters. It will be interesting to the market again in the future after the large new influx of domestic Atlantic salmon has entered the market, to observe how the estimates of the Armington elasticity may differ from the estimations of this paper.

8. Conclusion

This paper studied the potential effect of the new supply of domestically sourced salmon from land-based aquaculture that will enter the Japanese import market in the coming years. To gauge how the new supply will affect different imports, the studies estimated the Armington elasticity between Japanese salmon and different salmon imports from several countries, in order to observe the level of substitution among the different products. Furthermore, this is the first study that attempts to estimate the Armington elasticity in the Japanese fish industry.

To estimate the level of substitution, I created a panel data containing import data from several countries and Japanese sales data a general sample. By applying linear OLS regressions with fixed effect to different versions of the sample, I was able to estimate the Armington elasticity of several countries, species, and types of salmon. Estimation of the elasticity using the whole sample is estimated relatively low, at either 1.01 or 0.74 depending on the model, which seems to be aligned with previous literature that suggests a lower Armington elasticity in the primary sector (Bajzik et. al, 2020). Additionally, there seem to be stark differences in the level of substitution between frozen and fresh goods. This may seem intuitive as consumers are perhaps less likely differentiate between frozen goods compared to fresh consumes, and the notion is also supported by previous literature such as by (Donelly et. al, 2004). Though most of the new salmon production of land-based facilities is more than likely to be sold fresh, it is still valuable to consider the frozen salmon import. There are signs of a relatively high level of substitution between frozen import and fresh Japanese salmon as seen in model 3, and it would not be far-fetched to assume that many consumers would opt to favour fresh domestic salmon if that indeed becomes more cheap and readily available.

Furthermore, there are signs of significant differences between countries that exports equal products, following the Armington assumption that otherwise equal products are differentiated by origin country alone. Such a difference can be seen between fresh Atlantic salmon from Norway and Australia. In chapter 6 we observed how this may affect future volumes of import by considering different scenarios of how the price will change. Norway, with a lower estimated Armington elasticity, displayed a higher resistance to volume increases and price reductions of domestic salmon compared to Australia. The fact that such effects were observed on Australian Atlantic salmon, which had a relatively low estimated elasticity of 0.85, shows that an increase of domestic supply could have a potentially heavy on several exports. Overall, this leads to the conclusion that several imports may be heavily affected by an increase if the domestic supply if is it so increase as projected. This will be especially by the case, if the increase in Japanese supply of salmon is coupled with a decrease in price.

Finally, I note that the analysis is based on very aggregated data of the domestic supply of salmon. This may have skewed some of the results, where certain exports of salmon that has historically been less present in the mix of domestic salmon species may have displayed a lower Armington elasticity. I encourage future research, especially after the new supply of salmon has entered the market, to see if and how the estimations will change.

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