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To the Graduate Council:

I am submitting herewith a thesis written by Christina D. Greer entitled "A Disaggregated Analysis of Beef Import Demand in Japan." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural and Resource Economics.

Andrew Muhammad, Major Professor

We have read this thesis and recommend its acceptance:

Karen DeLong, Jada Thompson, Charlie Martinez

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

A Disaggregated Analysis of Beef Import Demand in Japan

A Thesis Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Christina Dian Greer

May 2022

Abstract

Japan is an important partner for the U.S. beef industry and a major beef importing country. In 2020, Japan was the world's third-largest importer of beef products (USDA, 2021). Although the Japanese beef market has been studied, research on the importance of product characteristics in determining import demand has been limited. The goal of this research is to provide a detailed analysis of how U.S. beef products compete in the Japanese market relative to other exporting countries based on prices, product form (chilled versus frozen), and product characteristics (boneless versus bone-in). This study will focus on three key factors affecting beef import demand in the Japanese market. The first factor is the importance of country of origin, the second is the importance of product attributes in determining demand, and the third is the importance of the first two combined. These three factors will be examined by using the generalized dynamic Rotterdam model developed by Bushehri (2003). Results suggest that country of origin and product characteristics are important factors when determining Japanese demand for imported beef. The estimates found in this study can be used to examine the effects of recent trade agreements and tariff policy at the detailed product level and to project U.S. exports to Japan moving forward.

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CHAPTER 1: INTRODUCTION

Beef is a highly traded global commodity. It is a product that many around the world consume regularly. It might not matter to all, but to some, the source of their beef and how it is processed effects their decision to purchase that product. Choices like these are made at the consumer level, but also are made at the wholesale level where global commodities are traded. Given the importance of global markets for beef sales, producers need to know preferences in importing countries so that they can sell in the most efficient way possible.

The desire to know foreign preferences raises a very important question. How important are country-of-origin and product attributes to the global beef trade? Country-of-origin is referring to where the beef originated (e.g., the United States, Australia, Canada). Country-of-origin is important because each country could have different production practices such as grain-based versus grass-based feeding systems, different cattle breeds, and government regulations on production practices. Additionally, geopolitical concerns and trade policy could also affect country-of-origin preferences in an importing country. Whitten et al., (2020) studied how relationships between China's top trading partners have affected trade flows from 1981 to 2019. They found that when China experienced a shock or change its relationship with a trading partner, trade flows also changed depending on the political climate. The factors mentioned above and many more can cause firm and consumer perceptions to be very different across supplying countries, even when importing the same product. For instance, some consumers may view beef from Country A as a premium product while at the same time consider beef from Country B as an inferior good. Along with country-of-origin, product attributes can also play a role in importing and consumption. Product attributes, in this instance, describe how the beef is processed and in what form (e.g., chilled, frozen). In some countries, buyers might prefer beef that was never frozen, associating chilled or fresh beef with overall freshness and quality. While everyone around the world views products differently, a large majority of the people in a country might want their products in a certain way. Studying characteristics like country-of-origin and product attributes could provide beneficial details for global beef producers going forward.

Japan is an ideal country for studying how country-of-origin and product attributes can affect imports. According to the USDA's Product, Supply, & Distribution database, in 2020, Japan imported 832,000 metric tons (MT) (carcass weight equivalent) of beef products. This made Japan the largest importer of beef products behind China and the U.S. (USDA, FAS, 2021a). Imported beef in Japan is mostly supplied by two countries: Australia and the U.S. Other countries also supply beef to Japan; however, their contributions are minimal compared to the U.S. and Australia (Trade Data Monitor, 2021). Details on the importance of the U.S., Australia, and other countries will be given in Chapter 3.

Traditionally, Japan has been a leading destination for U.S. beef exports. However, from 2004 to 2006, U.S. beef exports to Japan plummeted due to the outbreak of bovine spongiform encephalopathy (BSE) (USDA, FAS, 2021b). From December 2003 to December 2005, Japan banned all U.S. beef products. After December 2005, restrictions were eased, but not fully lifted until April 2017 (USDA, 2019). In 2013, Japan became the top importer of U.S. beef once again. Since then, Japan has continued to be the largest importer of U.S. beef products (USDA, FAS, 2021b). Using the most recent data, Japan accounted for 25 percent of all U.S. beef exports in 2020 (UN Comtrade Database, 2021).

Although the Japanese market has been studied extensively, research on the importance of product characteristics (e.g., frozen boneless beef versus chilled boneless beef) to demand has been limited. To ignore these characteristics in analysis implies that beef products are the same regardless of product traits. For instance, this would imply that consumers consider frozen boneless beef and chilled bone-in beef to be the same product, which is likely not the case. As the U.S. beef sector seeks to expand global sales, U.S. exporters need to have a better understanding of how factors, such as price, expenditures, country-of-origin, and product characteristics affect demand in foreign markets. The goal of this project is to provide a more detailed analysis of how U.S. beef products compete in the Japanese beef import market relative to other countries based on price and product characteristics. To achieve this goal, the effects of beef prices and product characteristics will be examined using a demand system approach where I consider how U.S. beef competes with competing countries like Australia in the Japanese market.

Purpose of Study

This study will focus on three key concepts affecting beef import demand in the Japanese market. The first concept being the importance of country-of-origin. As stated earlier, country-of-origin refers to the source country of production. It tells us the country where the beef products originate. As Kawashima and Puspito Sari (2010) note, country-of-origin or source-country of production affects Japanese demand for imported beef. The beef exporting countries that will be examined in this study are Australia, the U.S., and New Zealand. The second concept is the importance of product attributes in determining demand. The product attributes that will be studied in this research are product form (i.e., chilled, frozen) and whether the product is boneless versus bone-in. Muhammad et al. (2018) considered product form but did not consider boneless versus bone-in, which could also influence demand. Lastly, it is important to know how the country of origin and product attributes combined affect product demand. Saghaian and Reed (2004) examined how source and product quality affect the Japanese beef import market.

Although quality and country-of-origin were studied, product form, i.e., chilled, or frozen beef, were not taken into consideration for Japanese consumer demand.

In this study, I use a demand system approach to examine Japanese demand for imported beef. Generally speaking, a demand-system framework and analysis will allow for examining how prices and other factors determine the quantity and type of beef purchased from different countries. By using a system wide approach, I can examine all products simultaneously. An added feature of this study is that the demand model used for the analysis is dynamic. Pollak used a dynamic demand model to determine if present consumption of a product is influenced by past consumption of that same product, as well as competing products (Pollak, 1970).

This study will examine Japan's demand for imported beef based on a particular product form, beef cut, and country of origin (e.g., Japan's demand for U.S. frozen boneless beef). Implicit in this approach is that products are imperfect substitutes for one another based on the above-mentioned factors. From there, we will be able to determine Japan's demand for imported beef. The Generalized Dynamic Rotterdam Model developed by Bushehri (2003) will be applied to analyze Japanese demand for imported beef differentiated by country of origin, product form, and cut. By using this model, we will be able to determine how certain factors affect the demand for imported beef. Some factors include own price, price of beef from a competing country, and past and present consumption. Being able to determine the effect of past and present consumption depends on the dynamic aspect of the model.

Overview of Research

The remainder of this paper proceeds as follows. The next chapter will review the previous literature on demand analysis applications to import demand (country of origin), demand systems and product attributes, and international beef trade. Next, I will provide background, discussing the relationship that has been built between the U.S. beef sector and Japan. To show this relationship, import, export, and price trends will be examined. This will be followed by a discussion of past and current trade agreements and how these agreements have affected current relations. Following this, I will give an in-depth description of the empirical model. This will show how the model was made on the foundation it is based upon. The next chapter will be dedicated to the data used for the estimation. This will include details about where the data was obtained, summary statistics, and any anomalies that were found. The next chapter will examine the results. This chapter will include a discussion of the estimation results along with the various elasticities. This chapter will then conclude with a comparison of the two approaches (disaggregated versus aggregated products).. Finally, this study will conclude with a summary of my findings and how policymakers might find this study useful.

CHAPTER 2: LITERATURE REVIEW

International Beef Trade

This section discusses previous research on international beef trade. Past studies on international beef trade have been conducted by Wahl et al. (1991), Weatherspoon and Seale (1995), Miljkovic et al. (2002), Miljkovic and Jin (2006), and Soon and Thompson (2020). Wahl et al. examined the impact of the Beef Market Access Agreement (BMAA) on the Japanese beef market. The purpose of their study was to know how BMAA would affect not only beef demand in Japan but also how it would impact Japan's livestock supply and meat markets. To study the long-term effects, Wahl et al used the almost ideal demand system (AIDS) to compare the BMAA with other policies such as import quotas and complete trade liberalization. Their results showed that complete trade liberalization would increase beef imports by 1.3 million metric tons by 1997. It was also found that under the BMAA, Japan's beef markets would be harmed. Both the Japanese Wagyu and dairy beef industry would see a decrease because of this new agreement (Wahl et al., 1991).

Weatherspoon and Seale examined the Japanese beef import market from 1970 to 1993. Like Wahl et al., they too wanted to see how new trade policies, such as BMMA, have affected imports from the U.S., Australia, New Zealand, and the rest of the world. Australians feared that Japan was favoring U.S. beef due to the large increase in import shares from 1970 to 1993. Weatherspoon and Seale used a system-wide approach and estimated import demand by source. In addition, three different models were tested to see which fit the data best. The CBS (Central Bureau of Statistics), Rotterdam, and general models were used in their analysis. They found that the CBS model fit the data set better than the other two. By using the results obtained by the CBS model, it was found that over the stated period, Japan did not favor one country over another. In addition, Weatherspoon and Seale found that the changes in imports were due to relative prices changes of U.S. and Australian beef (Weatherspoon and Seale, 1995).

Following Wahl et al. and Weatherspoon and Seale, Miljkovic et al. studied factors, such as changing trade policies, effecting Japanese beef demand. Unlike the other two studies, Miljkovic et al. also included how these factors affected Japanese pork demand. Miljkovic et al. had two objectives for their study. First, they wanted to know what factors are motivating the demand for U.S. beef and pork in Japan. Secondly, they wanted to study how changes in Japanese demand had affected U.S. livestock prices and meat exports. To estimate import demand for beef in Japan, they used an ordinary least squared (OLS) model. They found that U.S. beef and pork exports were affected by several Japanese factors such as trade restrictions, changes in currency value, and income growth. It was also found that U.S. livestock prices had an inelastic relationship when it came to factors that changed Japanese import demand. However, some economic events that had happened did reduce livestock prices at that time. Overall, they concluded that U.S. red meat producers would benefit from continuing tariff reductions and should have interest in Japanese trade liberalization policies (Miljkovic et al. 2002).

Like Wahl et al. and Weatherspoon and Seale, Miljkovic and Jin studied how Japanese trade liberalization effected different beef import markets. However, they believed that some additional effects may not been captured in previous studies. The type of trade liberalization policy they analyzed was the *ad valorem* tariff. The exporting markets of focus for this study were the U.S. and Australia. In addition to policies, Miljkovic and Jin also accounted for beef quality. A survey showed that in the Japanese beef market, U.S. beef is seen as a higher quality good over Australian beef in terms of taste, however, Australian beef is viewed as a fresher product. Miljkovic and Jin's results showed that that when the *ad valorem* tariff was implemented in the Japanese market, beef imports increased. In addition, their results confirmed what was found in the survey. Miljkovic and Jin's results showed that Japanese consumers viewed U.S. beef to be a higher quality product over Australian beef (Miljkovic and Jin, 2006).

In a more recent study, Soon and Thompson focused on how food scare events could affect demand for beef. For their investigation, they looked at how Japanese beef demand was affected by the 2003 BSE outbreak in the U.S. beef supply. They used a time-varying Armington Model for their analysis to examine the impact BSE had on the Japanese market. To achieve their goals, two experiments were tested. First, they examined how the elasticity of substitution and country-of-origin bias were affected by the outbreak. Next, they investigated what would have happened if there hadn't been the BSE outbreak. Extrapolated data was used to create the estimated beef demand. The difference between the extrapolated data and the actual data was taken to see how much BSE had affected beef demand. In the first experiment, they found that imported beef, specifically frozen imported beef, was more affected by the BSE outbreak than domestic beef. In the second experiment, they concluded that if the BSE outbreak had not happened, then U.S. beef imports would have been much higher and Australian imports would have been much lower (Soon and Thompson, 2020).

Overall, the studies conducted by Wahl et al., Weatherspoon and Seale, Miljkovic et al., Miljkovic and Jin, and Soon and Thompson discussed how implementing trade policies, such as tariff reduction, or food scare events, like the BSE outbreak, affected the demand for meat products in Japan. The next section discusses studies that have been done that include country of origin as a factor influencing demand.

Country of Origin

Previous literature regarding how country of origin has affected demand been conducted by Yang and Koo (1994), Kawashima and Puspito Sari (2010), and Greear and Muhammad (2021). Yang and Koo analyzed Japanese import demand for different meat products. The type of products considered in the study were beef, pork, and poultry. Each meat category was examined by country of origin. The purpose of their analysis was to know which country had the greatest potential in each meat market. The potential for each country was shown by how much a change in price would affect import expenditures. The countries chosen for each product depended on the amount imported into Japan. If the country exported more than 10 percent, then it was considered a source for that product. If the country's imported share was less than 10 percent, then it was lumped into the other/rest of world category. They used the U.S. and Australia in the analysis for beef, the U.S., Canada, Taiwan, and EC (European countries) in the analysis for pork, and the U.S. Thailand, and China in the analysis for poultry. To run the analysis, they used a source differentiated almost ideal demand system model. They found that the U.S. had the most potential in the beef market and a change in its price would affect import expenditures the most. Taiwan was found to have the greatest potential for the pork industry but also face a large substitution effect with pork products from European countries. Taiwan and China both had large expenditure effects (Yang and Koo, 1994).

Unlike Yang and Koo, Kawashima and Puspito Sari only looked at the beef industry. Their study had two objectives. Their first objective was to see if Japan's demand for imported beef had been affected by country-of-origin bias. The second objective looked at changes caused by trade liberalization and food scare events, such as the BSE outbreak. They wanted to know if these events related to country-of-origin bias and substitutability. They used an Armington demand model to conduct their analysis. Within the model, they separated beef products by place of production. The countries included in the model were the U.S., Australia, and the rest of the world. In addition, dummy variables were included to represent when BSE outbreaks had occurred in various countries. During the period of trade liberalization, they found that consumer preferences did not shift from domestic beef to imported beef and that country-of-origin bias remained constant. They also found that the U.S. and Australia could profit during this time by lowing their export price. In addition, the BSE outbreaks did affect beef exporting countries negatively. Countries that faced food scare outbreaks experienced an increased country-of-origin bias (Kawashima and Puspito Sari, 2010).

Greear and Muhammad also considered source as a determinate of demand. Unlike Yang and Koo and Kawashima and Puspito Sari, they studied Japanese demand for imported wine. They wanted to know how Japanese wine demand has been affected by the implementation of bilateral trade agreements. In addition, they wanted to know how tariffs affected the competitiveness of U.S. wines. One of the main motivations behind this study is that the U.S. is significant trading partner for the Japanese wine industry, but, until recently, it faced a 15 percent tariff. It was thought that U.S. exporters were at a disadvantage because of this high tariff rate. To conduct their analysis, Greear and Muhammad used a generalized dynamic Rotterdam model to estimate Japan's demand for imported wine. In their model, they treated goods from the following exporting countries as individual products: Australia, Chile, France, Germany, Italy, Spain, U.S., and the rest of the world. They concluded that the reduction of tariffs is affecting the demand for wine in Japan. However only the exporting countries involved in each individual trade agreements are the countries being affected. They also found that competing countries are only marginally being affected by bilateral trade agreements (Greear and Muhammad, 2021).

The studies done by Yang and Koo, Kawashima and Puspito Sari, and Greear and Muhammad all considered how country of origin might affect demand for a given product. In all three studies, source was found to be influencing demand in some way. Something these studies did not consider was product attributes such as product type or product cut. The next section includes studies that have been done that address how product attributes affect the demand for a product in a specific market.

Product Attributes

There have not been many studies done on the impact of beef product attributes on consumer demand. However, studies done by Muhammad and Hanson (2009) and Ufer et al. (2020) for other commodity markets show how product attributes affected demand. Muhammad and Hanson estimated the demand for U.S. catfish products. Product form and product cut was considered in the analysis, something that most catfish studies have not done. They wanted to know how consumers viewed fresh or frozen catfish cuts and if these different product forms are important enough to be considered two separate product groups. To estimate U.S. catfish demand, they used the absolute price version of the Rotterdam model. In addition, likelihood ratio tests were used to determine the importance of product form. The product cuts included in the model were whole, fillet, or other and the product forms were either fresh or frozen. They found that fresh and frozen catfish products were not seen as homogenous. In addition, the results show that catfish should not be analyzed as a single aggregated product (Muhammad and Hanson, 2009).

Ufer et al. did not study the beef industry. Instead, their research investigated how important product attributes were to U.S. demand for imported lamb products. According to their paper, previous research had not disaggregated lamb products. They believed that previous studies could possibly have bias and limited results because they aggregated the product categories. For their analysis, they used the absolute price version of the Rotterdam model. Each product used in the analysis was broken down by source and product attributes. The countries used as sources were Australia and New Zealand. The product forms considered were chilled, frozen, boneless, and bone-in. In all, they examined eight types of lamb products. Their results showed that weak separability was present when testing boneless versus bone-in lamb products. They further concluded that those two product types should be distinguished from one another when analyzing the lamb import market. However, they did not find evidence of separability among chilled and frozen lamb product (Ufer et al., 2020).

As stated earlier, few studies have examined how product attributes have affected demand for beef. In addition, there have been limited studies that have addressed how product attributes might affect demand in the Japanese market. The purpose of this study is to fill the gap in the literature and show how both product attributes and country of origin affect beef demand in Japan. Next, I will consider the few studies that have addressed this gap in the literature.

Combination of Country of Origin and Product Attributes

Limited studies have been done that connect the ideas of how country of origin and product attributes affect demand. Studies done by Saghaian and Reed (2004), Muhammad and Jones (2011), and Muhammad et al. (2018) have connected the ideas of country of origin and product attributes. In the study done by Saghaian and Reed, they considered country of origin, quality, and product differentiation when determining which type of beef Japanese consumers prefer. Their study had two parts. The first part was to obtain consumer demand functions for quality differentiated beef. The second part of their study estimated consumer demand for chuck, loin, ribs, and round beef from four sources. For their study, the four sources were broken down by domestic production in the categories of Wagyu and dairy and imported beef from the U.S. and Australia. The results showed that domestically produced beef was preferred over imported beef in Japan. When analyzed by cuts, Wagyu beef had a premium over all dairy cuts, dairy beef had a premium over all U.S. beef cuts except ribs, and U.S. beef had a premium over all Australian beef cuts expect ribs (Saghaian and Reed, 2004).

Like Saghaian and Reed, Muhammad et al. studied the impact country of origin and product form had on Japanese demand for imported beef. However, their main objective was to determine how tariff reductions have impacted the competitiveness of Japan’s largest beef suppliers. In this study, the competitiveness of Australia, the U.S., and other countries was evaluated. A large driver for their study was that the U.S. did not have an active trade agreement with Japan since the U.S. withdrew from the Trans-Pacific Partnership (TPP) in 2017. Because there was no trade agreement with Japan, U.S. beef was facing a large import tariff. One of the U.S.’s main competitors in the Japanese beef market, Australia, had an existing trade agreement, the Japan-Australia Economic Partnership Agreement (JAEPA). JAEPA was allowing Australian beef to come into Japan at a tariff rate lower than the most favored nation rate. To evaluate the import demand by product and source, Muhammad et al used the production version of the Rotterdam demand system. They concluded that the U.S.’s withdrawal from the TTP did have a significant negative impact on U.S. beef exports. Because Australian beef under the JAEPA experienced tariff reductions, there was significant gains for the Australian market. They found that Australia’s gains in the beef market will come at the expense of U.S. beef exporters. They also found that certain U.S. beef products will be directly affected by the JAEPA. For example, they calculated that U.S. chilled beef imports would fall by $70 million, and U.S. frozen beef imports would also fall by $139 million. (Muhammad et al., 2018).

Muhammad and Jones did not look at the beef market. Instead, they studied the U.S. salmon import market to determine if source was an important determinate for demand. Furthermore, they wanted to know if source was important enough for U.S. salmon preferences to be considered source independent. They used an absolute price version of the Rotterdam model in their study. They disaggregated imports by source, cut, and form. The exporting countries that were included in the study were Canada, Chile, and the rest of the world. The product cuts they considered were fillets and other salmon products. Each cut was also broken down by form, fresh or frozen salmon. In all, this model had 12 different salmon products being estimated. Their results showed rejection of source aggregation but could not reject source independence. It was found that source does affect U.S. salmon import preferences (Muhammad and Jones, 2011).

Literature Implications for this Research

In conclusion, the Japanese beef market has been studied intensively. However, very few of these studies have examined how product attributes and country of origin jointly affect the demand for beef. The studies conducted by Saghaian and Reed and Muhammad et al. have considered the effects product attributes and country of origin have on beef demand in Japan. Using their studies as guides, my research will build up their findings and show how both product attributes and country of origin affect Japanese beef demand.

CHAPTER 3: BACKGROUND

Over the years, the U.S. and Japan have been important trading partners to each other. Since 2013, Japan has been the leading destination market for U.S. beef (USDA, FAS, 2021b). The importance of the Japanese market to U.S. beef producers can be shown by comparing the value of products Japan imports by country of origin and product attributes. The background chapter will provide a more in-depth investigation into product preferences for Japanese consumers. By doing so, U.S. beef exporters will be provided with useful information that can be used in making strategic trade decisions.

Overview of the Japanese market

Over the last ten years, Japan has received its beef imports from three main countries. These countries are Australia, the U.S., and New Zealand. Figure 1 and 2 shows a comparison of how the average import share by country has changed over the last ten years. Figure 1 shows how much beef, on average, Japan imported from each country (in percentage terms) from 2012 to 2016. From 2012 to 2016, Australia supplied Japan with an average of 54 percent of its imported beef products. The U.S. was the next largest trading partner, accounting for 36 percent of Japan's beef imports. New Zealand was responsible for 5 percent of Japan's beef imports while the rest of the world (ROW) accounted for 6 percent altogether. In addition, it should be noted that the majority of Japan's imported beef coming from the ROW is being supplied by Canada and Mexico.

Figure 2 shows the breakdown for the next five-year period, 2017 to 2021. During this period, each country's rank according to import share did not change. What did change was the percentage each country accounted for. Australia lost part of its market share. During the last five years, Australia's average import share shrunk from 54 percent to 47 percent. The U.S.

supplied Japan with more beef and increased its import share. The U.S.'s import percentage increased from 36 percent to 42 percent. New Zealand's import share decreased during this period. New Zealand going from 5 percent to 4 percent. Lastly, the ROW's share of Japan's beef imports increased from 5 percent to 8 percent. In both periods, Australia and the U.S. combined accounted for nearly 90 percent of Japan's total beef imports.

Product attributes describe the specific cuts of beef (e.g., boneless, bone-in) and how the cuts are preserved (e.g., chilled, frozen). Six-digit Harmonized System (HS) codes are utilized to categorize each product. The first two numbers represent the chapter, the next two numbers represent the heading, and the last two numbers represent the subheading. For example, beef and other meat products (e.g., pork, poultry) are categorized under chapter 02 section. The heading and subheading numbers depend on other product characteristics.

Each country controls what type of beef is being imported based on its heterogeneous preferences. It is important to know what type of beef products Japan is importing. Table 1 shows the five-year average for Japanese beef imports by product attributes. Over the last five years, Japan has mostly imported chilled and frozen boneless beef. These two products account for almost 80 percent of the total share of Japanese beef imports. The top imported beef product, chilled boneless beef, had an average yearly import value of over $2 billion and accounted for 47 percent of Japan's imported beef supply. The next most imported beef product was frozen boneless beef. It had an average value of about $1.36 billion and accounted for 31 percent of Japan's imported beef. The next beef products don't even compare in size, however, two product categories had values shares greater than five percent. Those categories were chilled offal ($618 million) at 14 percent and frozen offal ($221 million) at 5 percent. The other seven beef product categories together barely make up 3 percent of Japan's total beef imports.

Not only can product importance be determined by product categories and country of origin, but it can also be determined by looking at the two combined. The combination of these two factors provides a detailed analysis into exactly what type of beef products Japan prefers. Figures 3 and 4 show Japan's boneless beef import trends by country and product attribute from 2008 to 2021. Australia, the U.S., and New Zealand were included in this figure because those are Japan's top beef trading partners. All other countries are captured under the ROW category. Monthly trade data was compiled to create these figures.

Figure 3 depicts the imports of chilled boneless beef from 2008 to 2021. Over the 14-year period, Australian chilled beef's monthly trade value rarely dropped below $60 million. From 2008 to 2013, its trade value with Japan was well above any other beef trading partner. In 2011, it hit a high of over $100 million in a single month. After 2013, Australian chilled beef began to see competition from the U.S. market. Since then, their trade values have remained close with an exception between 2014 and 2016. During this time, the value for U.S. chilled beef dropped. After this dip, U.S. chilled beef imports rebounded. In the more recent years, there have been several months where Japan imported more chilled beef from the U.S. than from Australia. Chilled boneless beef from New Zealand and the ROW have had low trade values. In 2019, there was a spike in beef from the ROW, however, this amount still doesn't compare to the value being imported from the U.S. and Australia.

The monthly trade values for frozen boneless beef are shown in figure 4. The trade values for frozen beef are not as consistent as the values for chilled beef. For frozen beef, Australia and the U.S. are still the top exporters to Japan. In 2013, there was a spike in the amount of U.S. beef being imported into Japan. During that month, the U.S. frozen beef had a trade value of $60 million, which was the highest amount seen during this period for U.S. frozen beef. That month was also one of the only times where the trade value for U.S. frozen beef was greater than the value for Australian frozen beef. Australian frozen beef's trade value spiked in 2015. During this month, Australian frozen beef had a trade value of over $130 million. The trade value for Australian frozen dropped soon after that but has consistently stayed the top frozen beef product. New Zealand and ROW frozen beef's trade value was more volatile. There was even a point in 2008 when New Zealand frozen beef rivaled that of U.S. frozen beef. Over the past 14 years, ROW and New Zealand frozen beef have constantly flipped when it came to who exported more to Japan. In the most recent years, ROW frozen beef has gained momentum and has consistently had a higher trade value than New Zealand.

Over the last fourteen years, Japan has seen a steady increase in the price of imported beef. Figure 5 shows the average world price of Japanese beef imports by product type from 2008 to 2021. The prices shown are represented by a unit value. Unit values are used as a proxy for actual prices, created by dividing value by quantity. Chilled beef has consistently been more expensive than frozen beef. The average price of frozen beef in Japan between 2008 to 2021 was $3.94 per kilogram, while the average price of chilled beef was $7.04 per kilogram. Prices for frozen beef have ranged from a low of $2.82 per kilogram in February of 2009 to a high of $5.46 per kilogram in December of 2021. Chilled beef saw an even wider distribution of price with a low of $5.08 per kilogram and a high of $9.36 per kilogram.

Several shocks to the beef market have occurred over the years. In 2008, there was a spike in the price for frozen beef and a drop in the price for chilled beef. The price increase in 2015 was for both frozen and chilled boneless beef products. The largest price increase happened in 2021 and it looks like the trend is continuing in the new year. The 2008 price spike could be explained by the Japanese ban on beef from the U.S. and Canada in late 2003. According to the

USDA ERS, Japanese consumption of beef decreased during and after the outbreak of BSE due to the low amount of beef entering the country. In addition, the low supply increased prices drastically. By 2008, prices had still not gone down to the levels seen before the BSE outbreak (USDA, ERS, 2010). As for the 2020-2021 price increase, the COVID-19 pandemic played a large role. The USDA ERS reported an increase in food prices across the board in 2020. In addition, 2020 saw the largest increase in all meat prices. The ERS report also includes that the consumer price index (CPI) for food had increased 7.8 percent from January 2021 to January 2022 (USDA, ERS, 2022).

Figure 6 goes beyond figure 5 and shows the average price of Japanese beef imports from 2008 to 2021 by country of origin and product type. Chilled beef outpriced frozen beef throughout the period no matter the country of origin. New Zealand had the highest average price for chilled and frozen beef. Those prices were $8.08 and $4.77 per kilogram, respectively. Chilled beef from the United States had an average price of $7.24 per kilogram and while frozen beef averaged around $4.20 per kilogram. On average, Australian beef had the lowest prices, with chilled beef averaging around $6.97 per kilogram and frozen beef averaging $3.84 per kilogram. The lowest price for Chilled beef was seen in April of 2009 for $4.82 per kilogram and it came from Australia. November 2021 saw the highest price for chilled beef. During this period chilled beef from New Zealand cost $10.27 per kilogram. In the case of frozen beef, New Zealand had both the lowest and highest price. In February of 2009, prices dropped to a low of $2.58 per kilogram while in August of 2017 prices soared to $7.18 per kilogram.

Overview of the United States Beef Market

U.S. beef exports have been consistently rising over the last twenty years. This can be shown through yearly data obtained through the USDA Foreign Agricultural Service's Global

Agricultural Trade System Database (USDA, FAS, 2021b). Figure 7 shows U.S. beef export trends for the top eight buyers and ROW from 2000 to 2020. From 2000 to 2003, Japan was the largest importer of U.S. beef and beef products. However, from 2004 to 2006, Japan imposed a total ban on U.S. beef due to the BSE outbreak and Mexico became the top importer of U.S. beef products (USDA, FAS, 2021b). Mexico remained the top importer from 2004 to 2010. For the next two years, Canada was the top destination for U.S. beef. In 2013, once beef restrictions in Japan began to relax, Japan became the top importer of U.S. beef products. This trend continued through 2020. South Korea, Hong Kong, Taiwan, China, and the Netherlands have also been major trading partners over the last twenty years (USDA, FAS, 2021b).

In the last five years, the U.S. has exported an average of $8.2 billion of beef products (UN Comtrade, 2021). Table 2 provides this total broken down by product (HS code). The table reflects a five-year average. It includes an average export value and value share in percentage terms for U.S. beef exports. The table is sorted by value with the largest export amount first. By looking at table 2, it is clear which products make up the bulk of U.S. beef exports. The top five exported beef products from the U.S. are chilled boneless beef, frozen boneless beef, frozen bone-in beef, frozen offal, and chilled offal. Chilled boneless beef accounted for 43 percent of the U.S.'s beef exports while frozen boneless beef made up 33 percent. Together, chilled and frozen boneless beef make up over 75 percent of total U.S. beef exports. The average export value for frozen boneless beef was $2.71 billion. Chilled boneless beef had an even higher export value of $3.52 billion. The next closest category is frozen bone-in beef. On average, the frozen bone-in beef category generates $750 million each year and accounted for nine percent of total U.S. beef exports. Frozen offal and chilled offal are also large beef categories generating values of $310 million and $280 million, respectively. Together these two categories made up about 13 percent of U.S. beef exports.

Relevant Trade Agreements

Trade agreements play an important role when two countries wish to strengthen their relationship. These agreements help facilitate and develop new or existing relationships and promote more liberalized trade. In 2020, Japan and the U.S. formed the U.S.- Japan Trade agreement (USJTA). This came after the U.S. pulled out of the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTTP). The USJTA covers many different industries. The goal of this agreement was to cut back on tariffs and non-tariff trade barriers. The unique aspect of this agreement is that it gives the U.S. the same market access as countries that trade under the CPTPP agreement. The USJTA plans to lower or eliminate tariffs for specific U.S. agricultural products, provide U.S. specific quotas, and preferential tariff access. For beef products specifically, Japan has promised to reduce tariffs on fresh, chilled, and frozen beef over the next 15 years (Office of the United States Trade Representative, 2019).

Japan is also a part of many other trade agreements. The Japan-Australia Economic Partnership Agreement (JAEPA) and the CPTPP both have provisions that directly relate to the beef sector. The JAEPA has been in place since January 2015. This agreement gave Australia better market access to its largest beef market, Japan. Results of this agreement include reducing the tariffs for frozen beef from 38.5 percent to 19.5 percent over 18 years, fresh beef from 38.5 percent to 23.5 percent over 15 years, removing the "global snapback" tariff for Australian goods, and setting an Australia- specific safeguard tariff of 38.5 percent with triggers based above current trade levels (Department of Foreign Affairs and Trade, 2018). The CPTPP is also a newer trade agreement. This agreement went into effect on December 30, 2018, with the countries of Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam being members. One of the goals of this agreement is to reduce tariffs on frozen and chilled beef to nine percent over 15 years. During the reduction process, members of the CPTTP will receive tariff rates below the most-favored-nation (MFN) rate. In addition, CPTPP countries will receive a specific safeguard rate on frozen, cheek, and head meat. The CPTPP-specific safeguards are more lenient than those given to MFN (USDA, FAS, 2018).

CHAPTER 4: EMPIRICAL METHODS

The foundation of my model will be based on Armington's (1969) Theory of Demand for Products Distinguished by Place of Production. As the title suggests, Armington expanded on the general theory of demand and showed that similar products are distinguishable by the country of origin. For instance, Japanese cars and French wine are two products distinguishable by its place of production. Armington further pointed out that "such products are distinguished from one another in the sense that they are assumed to be imperfect substitutes" (Armington, 1969). For this model, we are applying this concept of similar products being different based on country of origin to an agricultural sector, beef. In my model, beef products will be separated by place of production and each product will be treated separately. For example, U.S. beef will be treated as a different product from Australian beef and New Zealand beef. Treating beef products as different based on country or origin has been a common practice when estimating demand (Kawshima and Purspito Sari, 2010; Miljkovic and Jin, 2006; Muhammad et al.,2018; Saghaian and Reed, 2004; Yang and Koo, 1994).

Consumption patterns can be influenced by past purchases. For instance, if someone consumed and liked a certain food product in the past, then there is a strong possibility that they will continue to buy that product in the present (Pollak, 1970). This is considered habit formation. Pollak (1970) expanded on the idea of habit formation and created a model that incorporated how past behavior can affect present choices. In addition, he studied how short-run and long-run demand could differ over time and incorporated this dynamic concept into the theory of consumer demand (Pollak, 1970). This type of dynamic modeling framework will be implemented into this study by using a lagged quantity variable for each product. If the sign of the coefficient associated with the lagged quantity parameter is positive, then this is an indication of habit formation.

Given this information, here are some terms going forward. Assuming a beef importing country/destination market (e.g., Japan), let subscript i and j denote the production source or country of origin (e.g., U.S., Australia, etc.) and subscript g and h denote the type of beef product. For this study, there are two types of beef products being considered: chilled boneless beef (1) and frozen boneless beef (2). Only chilled and frozen boneless beef products will be used in this analysis because together these two products make up almost 80 percent of all Japanese beef imports and 99.58 percent of all beef when offal or highly processed products are excluded (Table 1). Price and quantity will be denoted as p and q, respectively. Let p_{gi} represent the price of product g from country i, and q_{gi} represent the quantity of product g from country i. Given these terms, we can define a country's expenditure on product g from country i as follows: $E_{gi} = p_{gi}q_{gi}$. By summing over E_{gi} we can get total expenditures on a certain product, total expenditures from a certain country, and total expenditures on all products.

The USDA's Economic Research Service defines conditional demand as demand based on "a subset of the consumer's total budget" and not total expenditures or income (USDA, ERS, 2021a). The conditional expenditure share for this model is defined as $w_{gi} = E_{gi}/E$, where E is expenditures on beef products from all exporting countries (as opposed to total expenditures on all food or products). This share (w_{gi}) represents the share of total Japanese beef expenditures allocated to product g from country i.

The demand model for this project assumes a system of equations where each equation is Japan's demand for a product (g or h) from an exporting country (i or j). The model specification for this study will be based on the Generalized Dynamic Rotterdam Model (Bushehri, 2003). The

Generalized Dynamic Rotterdam Model utilizes the concept of habit formation to produce a dynamic effect. Given the specified terms, Equation 1 is a representative equation from the demand system for product *g* from country *i*:

$$\bar{w}_{gi,t}\Delta q_{gi} = \gamma_{gi} + \sum_{h}\sum_{j}\gamma_{gi,hj}\Delta q_{hj,t-1} + \theta_{gi}\Delta Q_t + \sum_{h}\sum_{j}\pi_{gi,hj}\Delta p_{hj,t} \qquad (1)$$

The dependent variable is $\bar{w}_{gi,t}\Delta q_{gi}$. This represents the demand for product *g* from country *i* at time period *t*. The term $\bar{w}_{gi,t}$ is the two-period average expenditure share of product *g* from country *i* and is written mathematically as follows:

$$\bar{w}_{gi,t} = \frac{w_{gi,t} + w_{gi,t-12}}{2} \qquad (2)$$

The term $\bar{w}_{gi,t}$ is being multiplied by a log-difference term, Δq_{gi}. Δ represents the log-difference operator. This was done for both prices (*p*) and quantities (*q*). It can be written generically as:

$$\Delta x = \log x_t - \log x_{t-12} \qquad (3)$$

The *t*-12 notation represents a 12-period lag. Monthly data is used for the analysis and the 12-period difference is used to correct for seasonality (Greear and Muhammad, 2021).

The first parameter in the equation is γ_{gi}. This is a constant term that is specific to that product from a particular country. The next parameter is $\gamma_{gi,hj}$ which represents the impact of imports of product *h* from country *j* in the previous period on the quantity of product *g* from country *i* imported in the current period. Pollak (1970) found that if the own lag estimate (γ_{ii}) was positive then habit formation is present. For example, this would mean that past consumption of frozen boneless beef from country *i* positively affected the present consumption of frozen boneless beef from country *i*. This parameter is being multiplied by $\Delta q_{hj,t-1}$. This term is the lag variable. This variable was created by lagging the quantity log-difference term by one period. The parameter θ_{gi} is the marginal import share. This represents the amount that would be allocated to product *g* from country *i* if total expenditures increased by an additional dollar. $\theta_{gi}$is being multiplied by the parameter ΔQ_t. ΔQ_trepresents the finite version of the Divisa volume index which is a measure of Japan's real expenditures on all beef imports (Muhammad, 2018). This variable is calculated by summing across the dependent variable. It can be shown mathematically as:

$$\Delta Q_t = \sum_{g=1}^{m}\sum_{i=1}^{n} \bar{w}_{gi,t}\Delta q_{gi} \quad (4)$$

The parameter $\pi_{gi,hj}$ is the price coefficient. $\pi_{gi,hj}$ represents the impact the price of product *h* from country *j* has on the quantity of product *g* from country *i*. Following economic theory, the own price coefficient ($\pi_{gi,gi}$) for each product should be negative. The sign on the cross-price coefficients will determine the relationship between the two products. If the coefficient is positive, then the two goods are substitutes for one another. If the cross-price coefficient is negative, then the two goods are complementary.

Following Bushehri (2003), three parameter restrictions will be imposed on the model. The first restriction is adding up, which is satisfied automatically with this model (Muhammad and Jones, 2009). The next restriction is homogeneity. Homogeneity requires that all price coefficients sum to zero suggesting that if prices were to proportionally increase, then demand would not change (USDA, ERS, 2021a). The restriction of symmetry implies that the matrix of cross-price effects is symmetric. This implies, for instance, that the impact of Australian frozen beef price on U.S. chilled beef quantity is the same as the impact U.S. chilled beef price on Australian frozen beef quantity. These restrictions are specified as follows (Muhammad et al., 2018):

$$\sum_g \sum_i \theta_{gi} = 1, \sum_g \sum_i \gamma_{gi} = 0, \sum_g \sum_i \gamma_{gi,hjk} = 0, \text{ and } \sum_g \sum_i \pi_{gihi} = 0 \text{ (Adding up)} \quad (5)$$

$$\sum_h \sum_j \pi_{gihj} = 0 \text{ (Homogeneity)} \tag{6}$$

$$\pi_{gigj} = \pi_{gjgi} \,\forall\, g, \pi_{gihi} = \pi_{higi} \,\forall\, i, \text{ and } \pi_{gihj} = \pi_{hjgi} \text{ (Symmetry)} \tag{7}$$

Given Equation 1, the short-run expenditure, compensated price, and uncompensated price elasticities can be derived. The equations for these elasticities are as follows (Greear and Muhammad, 2021):

$$\eta_i^{sr} = \frac{\theta_i}{\bar{w}_i} \tag{8}$$

$$\eta_{ij}^{SRc} = \frac{\pi_{ij}}{\bar{w}_i} \tag{9}$$

$$\eta_{ij}^{SRu} = \eta_{ij}^{src} - n_i^{sr} \times \bar{w}_j \tag{10}$$

Equation 8 represents the short-run expenditure elasticity. This elasticity measures how demand for a good will change given a change in total expenditures in the short run. The short-run expenditure elasticity for good *i* is calculated by dividing the Divisa volume index by the average import share for good *i*. Equation 9 represents the short-run compensated price elasticity. It is calculated by taking the price estimate for good *i* from country *j* and dividing it by the average import share for good *i*. Equation 10 is the short-run uncompensated price elasticity. This elasticity is obtained by taking the short-run compensated elasticity and subtracting it from the product of the expenditure elasticity and the average import share for good *i*. Both the compensated and uncompensated elasticities measure how quantity demanded changes with a change in price. The response in quantity demand for the compensated elasticities is solely due to the substitution effect (real income held constant). The response in quantity demand for the uncompensated elasticities encompasses both the substitution and income effect (the full effect of a price change) (USDA, ERS, 2021a). To obtain the long-run elasticity estimates, we set $\Delta q_{hj,t} = \Delta q_{hj,t-1}$. By doing this, we can obtain the long-run expenditure, compensated price, and uncompensated price elasticities. These elasticities are as follows (Bushehri, 2003):

$$\eta_i^{LR} = \frac{\theta_i}{(\overline{w}_i - \gamma_{ii})} \tag{11}$$

$$\eta_{ij}^{LRc} = \frac{\pi_{ij}}{(\overline{w}_i - \gamma_{ii})} \tag{12}$$

$$\eta_{ij}^{LRu} = \eta_{ij}^{LRc} - n_i^{LR} \times \bar{w}_j \tag{13}$$

Equations 11 – 13 are similar to equations 8-10, respectively, but are the long-run outcomes.

CHAPTER 5: DATA AND ESTIMATION PROCEDURE

For this study, two models will be evaluated. The first model is the disaggregated model. The disaggregated model is based on country of origin and product characteristics. The second model is the aggregated model, which does not consider product characteristics, but only takes into consideration the country of origin.

Monthly data on all beef imports to Japan was used for the analysis. The data set included products such as chilled boneless beef, frozen bone-in beef, chilled offal, among others. For each product, monthly trade values and volumes (in kg) were included. After conducting a preliminary analysis, only two beef products were chosen (chilled boneless and frozen boneless beef) for the analysis. These two products make up most of Japan's beef imports. The other beef categories were too small to conduct analysis and contained too many zero observations. Australia, the U.S., and New Zealand are the only exporting countries; all other countries are represented by a rest of world (ROW) category. These three countries (Australia, the U.S., and New Zealand) together make up around 95 percent of Japan's beef imports. In total, eight products are used for the disaggregated analysis. For the aggregated portion of the analysis, imports were combined over product attributes where country of origin was the only factor resulting in four products for the analysis.

The time frame studied was from January 2008 to December 2021. Data collected before 2008 was being influenced by the BSE outbreak that occurred in late 2003 and the ban on imports through 2006. As mentioned prior, Japan imposed a total ban on beef imports from countries where the outbreak had occurred as a measure of food safety. To avoid the possibility of having skewed, unreliable results, the decision was made to begin the dataset in January 2008.

The raw data gave information on the value and quantity imported by country of origin. The value was measured in dollars and the quantity was measured in kilograms (kg). For the analysis, a unit value was calculated for each product by dividing its value by its quantity. This term was used as a proxy for the import price. Table 3 provides summary statistics for import prices, values, quantities, and expenditure shares for the disaggregated model. No matter the country of origin, chilled beef has a higher import price per kg. New Zealand chilled beef has the most expensive price with an average of $8.08 per kg. The next most expensive chilled product comes from the U.S. with an average price of $7.24 per kg. Australia and the ROW follow behind New Zealand and the U.S. with import prices of $6.97 and $6.99 per kg, respectively. The country with the largest difference between chilled and frozen beef prices is New Zealand. There is a $3.31 gap between the two. On average, Australia provides Japan with the cheapest frozen boneless beef at $3.84 per kg, while New Zealand has the most expensive frozen beef at $4.77 per kg. The ROW and the U.S. are in the middle with average import prices of $4.09 and $4.20 per kg for frozen boneless beef, respectively.

The expenditure share column represents, in percentage terms, how much out of total expenditures was spent on a specific product. On average, Australia chilled beef had the largest expenditure share (33 percent). The next largest category was Australian frozen beef (24 percent) followed by U.S. chilled beef (22 percent) and U.S. frozen beef (12 percent). The other categories for New Zealand and the ROW are very small and make up less than 5 percent each.

Table 4 provides the same type of summary statistics but for the aggregated model. U.S. beef is the most expensive product in this model with an average price of $5.80 per kg. Right behind it is beef from New Zealand. New Zealand has an average price of $5.79 per kg. It makes sense that these two products are the most expensive because both had higher prices when disaggregated by product type. Australia beef and ROW beef are slightly cheaper products in this market with average prices of $5.18 and $4.70, respectively.

The expenditure shares for the aggregated model are telling a similar story to what was found in the disaggregated model. Australian and U.S. beef make up most of Japanese beef imports. Australian beef alone makes up 56 percent of total expenditures on imported beef in Japan. U.S. beef is the next largest with an expenditure share of 33 percent. Together, these two countries capture almost 90 percent of Japan's beef import market. The last 10 percent is distributed between New Zealand and ROW.

To run the analysis, STATA statistical software will be used. The sureg (seemingly unrelated regression) function will be used to estimate the system of equations. In addition, the isure function will also be utilized. The isure function allows the model to iterate until the estimates converge (StataCorp, 2019).

CHAPTER 6: RESULTS

Log-Likelihood Results

To compare which parameter restrictions (homogeneity and symmetry) were valid, a log-likelihood ratio test was performed. This analysis was performed on both the disaggregated and aggregated models. The disaggregated results will be discussed first followed by the aggregated results. The log-likelihood ratio test was conducted using the lrtest command in STATA. The purpose of a log-likelihood ratio (LR) test is to see which model fits the data best. By doing so, one can tell if the additional restrictions are valid (Darnell, 1994). For this analysis, two different log-likelihood ratio tests are performed. The process is the same for both the disaggregated and aggregated models. The first test compares the unrestricted model to the model with homogeneity imposed. The second test then compares the homogeneity model to the model with both symmetry and homogeneity. For each test, two hypotheses need to be made: the null and the alternative hypothesis. For the first test, the null (H_0) and alternative (H_A) hypotheses are as follows:

H_0: The unrestricted model and the model with homogeneity imposed both fit the data equally, therefore the homogeneity constraint is not rejected.

H_A: The unrestricted model provides a better fit for the data. The homogeneity constraint should be rejected.

The second test has similar hypotheses. The main difference is the test being compared. The hypotheses for the second test are as follows:

H_0: The model with homogeneity only and the model with both symmetry and homogeneity both fit the data equally, therefore the symmetry constraint is not rejected.

H_A: The model with homogeneity only provides a better fit for the data. The symmetry constraint should be rejected.

The following results for the disaggregated model are given in Table 5. The log-likelihood value for the unrestricted model was 3,204.03, the model with homogeneity imposed was 3,198.05, and the model with symmetry imposed was 3,135.96. The next step is to obtain the LR statistic. According to Darnell (1994), this statistic is calculated by the following equation:

$$LR = 2\ln L(\hat{\theta}) - 2\ln L(\tilde{\theta})$$

For the first test, $\ln L(\hat{\theta})$ represents the unrestricted model's log-likelihood value and $\ln L(\tilde{\theta})$ represented the log-likelihood value for the model with homogeneity imposed. In the second test, $\ln L(\hat{\theta})$ represents the log-likelihood value for the model with homogeneity and $\ln L(\tilde{\theta})$ represented the log-likelihood value for the model with homogeneity and symmetry imposed. The test for homogeneity resulted in an LR statistic of 11.97. The LR statistic for the symmetry constraint is 64.17. The p-value for each test tells whether or not the null hypothesis is to be rejected. The homogeneity test has a p-value of 0.10. This means that we fail to reject the null hypothesis at the 0.05 level of significance. The interpretation of this result is that the homogeneity constraint fits the data. In the case of symmetry, the p-value is less than 0.05 so we can reject the symmetry constraint. Despite being rejected, both homogeneity and symmetry were imposed on the model. Kastens and Brester (1996) found that it is beneficial to impose these parameter restrictions even when they are rejected.

Table 6 depicts the log-likelihood results for the aggregated model. As stated earlier, the process for obtaining these results is the same as the process for the disaggregated model. In addition, the hypotheses are also the same.

The log-likelihood value for the unconstrained model is 1,154.18. The second model which has homogeneity imposed has a log-likelihood value of 1,150.42. The model with the symmetry restriction has a log-likelihood value of 1,147.28. The LR statistics for the aggregated model are much smaller than the values given in the disaggregated model. The LR statistic for the comparison of the unconstrained model to the model with homogeneity is 7.52. The LR statistic decreases when comparing the model with homogeneity to the model with both homogeneity and symmetry imposed is 6.27. The p-values (See Table 6) indicate that both homogeneity and symmetry should not be rejected.

Disaggregated Model Results

The demand estimates for Japanese boneless beef imports are shown in Table 7. The first column (expenditure coefficients or marginal share estimates) represents how much would be allocated to a specific product if total beef imports into Japan increased by one dollar. All expenditure coefficients are significant at the 0.01 level. Australian frozen beef has the largest expenditure coefficient (0.367) meaning that it would receive the largest allocation from an additional dollar in total beef imports. If beef imports into Japan increased by one dollar, then 36.7 cents would be allocated to Australian frozen beef. Products with relatively large expenditure coefficients include U.S. frozen beef (0.205), Australian chilled beef (0.161), and US chilled beef (0.133). The smallest allocation is for New Zealand chilled beef (0.003). This means that only 0.3 cents would be allocated to New Zealand chilled beef if total beef imports were to increase by one dollar.

The own price coefficients are along the diagonal line. Most of the own price coefficients are negative, which is to be expected. The two products that have positive coefficients, Australian frozen beef, and ROW chilled beef, are not statistically significant. Five products have own price coefficients that are both negative and statistically significant. These products are Australian chilled, New Zealand chilled, New Zealand frozen, US frozen, and ROW frozen beef. Positive cross-price coefficients indicate substitution between two products while negative cross-price coefficients indicate a complementary relationship. The following pairs are substitute goods: New Zealand chilled beef and Australian chilled beef, U.S. chilled beef and Australian chilled beef, U.S. frozen beef and ROW frozen beef, and ROW chilled beef and ROW frozen. In addition, New Zealand chilled beef and US frozen beef are both complementary to ROW chilled beef.

Table 8 shows the estimation results for the lag coefficients. Coefficients along the diagonal are the own-lag coefficients. Five own-lag coefficients are significant at the 0.01 level: New Zealand frozen beef, U.S. chilled beef, U.S. frozen beef, ROW chilled beef, and ROW frozen beef. The own-lag estimate for New Zealand chilled beef is significant at the 0.05 level. All significant own-lag coefficients are positive, which indicates habit formation for these imports.

Table 9 shows the compensated short run demand elasticities for Japanese beef imports. The first column shows each country's expenditure elasticity. Expenditure elasticities represent how sensitive a product is to changes in total Japanese expenditures on imported beef. All expenditure elasticities are significant at the 0.01 level aside from New Zealand chilled beef, which is significant at the 0.10 level. Frozen beef products have the highest expenditure elasticities meaning that those products are expenditure elastic. Frozen beef from the ROW is the most expenditure elastic (2.192). In other words, ROW frozen beef is the most sensitive to changes in total beef expenditures where a one percent increase in total expenditures results in a 2.192 percent increase in imports of frozen beef from ROW. U.S. frozen beef is the second most sensitive with an expenditure elasticity of 1.731. New Zealand chilled beef has the smallest expenditure elasticity (0.163).

The next column shows each country's own price elasticity. This elasticity indicates how much quantity demanded would change (in percentage terms) if there was a one percent increase in price. Five products have own price elasticities that are significant. Those products are Australian chilled beef, New Zealand chilled beef, New Zealand frozen beef, U.S. frozen beef, and ROW frozen beef. In addition, all significant own price elasticities are negative. In terms of magnitude, New Zealand frozen beef has the highest own price elasticity (-0.803). This means that if New Zealand frozen beef's price was to increase by one percent, then the quantity imported would decrease by 0.803 percent. Australian chilled beef has the smallest own price elasticity (-0.379). All compensated own price elasticities are less than one indicating that Japanese beef imports are inelastic regardless of source in the short run.

Similar to the price coefficients, positive and negative cross-price elasticities represent substitute and complementary relationships, respectively. Australian chilled beef is a substitute good for New Zealand chilled beef and U.S. chilled beef. New Zealand chilled beef is a substitute good for Australian chilled beef and a complementary good for ROW chilled beef. U.S. chilled beef is a substitute good for Australian chilled. U.S. frozen beef is a substitute good for ROW frozen beef. ROW chilled beef is a substitute good for ROW frozen beef and a complementary good for New Zealand chilled beef and U.S. frozen beef. ROW frozen is a substitute for U.S. frozen and ROW chilled beef. The largest substitute relationship is between the price of US frozen beef and the quantity of ROW frozen beef (0.916). The largest complementary relationship is between the price of US frozen beef and the quantity of ROW chilled beef (-0.551).

Table 10 shows the compensated long run demand elasticities for Japanese beef imports. In the long run, elasticities values should become larger in magnitude. All expenditure elasticities became larger in the long run. U.S. frozen beef had the largest increase. U.S. frozen beef went from having an expenditure elasticity of 1.731 in the short run to 2.592 in the long run. ROW frozen beef still has the largest expenditure elasticity and New Zealand chilled beef has the smallest.

The own price elasticities for Australian chilled, New Zealand chilled, New Zealand frozen, U.S. frozen, and ROW frozen beef increased in absolute value in the long run. Something to note is that New Zealand frozen beef now has an own price elasticity greater than one (-1.090). This means that in the long run, the demand for this product is elastic, which is the opposite of what was found in the short run. The other significant elasticities also increased in magnitude but remained less than one in absolute value. This means that in the long run these products are still inelastic. The cross-price elasticities changed the most in the long run. All significant cross price elasticities increased in the long run. For example, the effect between US frozen beef price and ROW chilled beef quantity increased from -0.551 in the short run to -3.272 in the long run.

In addition to examining compensated elasticities, it is also important to study the uncompensated elasticities. Table 11 shows the uncompensated short run demand elasticities for Japanese beef imports. The uncompensated elasticities encompass both the substitution and income effect of a price change. The magnitude of uncompensated elasticities tends to be larger than the compensated elasticities because of the added income effect. All own price elasticities are significant in the short run apart from ROW chilled beef. In addition, all own price elasticity values increase in absolute value when compared to the corresponding compensated elasticities.

For example, U.S. frozen beef's uncompensated own price elasticity is -0.768, compared to the compensated own-price elasticity of -0.564.

When looking at the cross-price elasticities, none of the relationships switched signs. This indicates that the compensated cross-price relationships are the same as the uncompensated cross-price relationships. However, there are new complementary relationships. For example, Australian frozen beef now has a complementary relationship with Australian chilled beef, New Zealand chilled beef, U.S. chilled beef, ROW chilled beef, and ROW frozen beef.

The long run uncompensated elasticities are shown in Table 12 and follow a similar pattern as the uncompensated short run elasticities. Again, the long run elasticity estimates are larger than the short run elasticity estimated. For example, New Zealand frozen beef's own price elasticity increased in absolute value from -0.806 in the short run to -1.148 in the long run. In addition, the effect of U.S. frozen beef price on ROW chilled beef quantity increased significantly in the long run; the cross-price effect between these two goods when from -0.610 in the short run to -3.627 in the long run.

Aggregated Model Results

Next, we will look at the results for the aggregated model. The aggregated model only considered country of origin, not product form. The demand estimates for Japanese beef imports are shown in Table 13. All expenditure coefficients are statistically significant at the 0.01 level of significance. Australian beef has the highest expenditure coefficient (0.521) followed by the U.S. (0.340). The own-price coefficients are along the diagonal. All own-price terms are negative as expected and statically significant at the 0.01 level where the U.S. (-0.275) and Australia (-0.269) have the largest own price coefficients. All significant cross-price coefficients in this model are positive. Positive coefficients indicate that the two goods are substitutes. Australian beef has a substitute relationship with New Zealand beef and U.S. beef. U.S. beef also has a substitutes relationship with New Zealand beef as well as ROW beef. Table 14 shows the lag coefficients for the aggregated model. All own lag terms are positive, as expected. This indicates habit formation for all four products.

Table 15 shows the compensated short-run demand elasticities for the aggregated model. All four expenditure elasticities are significant at the 0.01 level of significance. All expenditure elasticities, except Australia, have values greater than 1. This indicates that these products are expenditure elastic. Beef from ROW has the greatest expenditure elasticity (1.780). Australian beef (0.930) has the lowest expenditure elasticity.

All own price elasticities in this model are negative and significant at the 0.01 level. New Zealand beef has the largest own price elasticity (-1.428). These results differ from what was found in the disaggregated model (Table 9) because, in the short run, beef was inelastic regardless of source.

One complementary relationship was found. This is the relationship between New Zealand beef and ROW beef. All other significant cross price effects show a substitute relationship between the two products. Australian beef has a substitute relationship with New Zealand beef and U.S. beef. U.S. beef also has substitute relationships with New Zealand beef and ROW beef.

Table 16 shows the long run compensated elasticities for the aggregated model. Like before, the long run elasticities tend to larger than the short run elasticities. For example, the expenditure elasticity for ROW beef increase from 1.780 in the short run to 3.312 in the long run. In addition, all own price elasticity values increased in magnitude. For example, the compensated own price elasticity for U.S. beef was -0.810 in the short run but -1.107 in the long run. As for the cross-price elasticities, there were no major changes aside from the absolute value increases.

Table 17 shows the uncompensated short run demand elasticities for the aggregated model. Again, the uncompensated elasticities tend to be larger than the compensated elasticities because the full effect of a price change is shown. All own price elasticities are negative as expected and significant at the 0.01 level of significance. In addition, all own price elasticity values are larger in magnitude when compared to the compensated elasticities. Table 18 shows the uncompensated long run demand elasticities for the aggregated model. Following previous patterns, both the own price and cross price elasticity values for each product increased in absolute value. In addition, there were no new cross-price relationships.

Comparison of Disaggregate and Aggregate Results

The following six figures compare the aggregated model elasticities and the disaggregated model elasticities. The goal of this comparison is to see if the aggregated estimates differ significantly from the disaggregated estimates. Figure 8 shows the expenditure elasticities in the short run. The aggregated expenditure elasticity for all countries is between the disaggregated expenditure elasticities suggesting that ignoring product attributes will simply results in an average value of the more defined products. We can tell if the aggregated model elasticities statistically differ from the disaggregated model elasticities from the error bars. If the error bars overlap, then the values are not statistically different differ from one another. For example, the aggregated expenditure elasticity for Australian beef does not overlap with either of the defined products. This indicates that these three elasticities are statistically different. Also, the expenditure elasticity for Australian frozen beef is significantly greater than the expenditure elasticities for the aggregated model and chilled beef. According to the data, in 2021, about 57 percent of Australian beef exports to Japan were chilled boneless beef. Since this is the case, the aggregate model for Australia is mostly estimating changes concerning chilled beef.

Figure 9 compares the long-run expenditure elasticities. To be expected, the long run elasticities are larger than the short run elasticities. One of the biggest changes compared to Figure 8 is for U.S. beef products. In the short run, none of the error bars overlap. Now, the error bar for U.S. beef aggregated overlaps the error bar for U.S. Chilled beef. This indicated that these two elasticity values are not statistically different in the long run.

Figure 10 compares the compensated own-price elasticity for each country-product pair against its corresponding aggregated model. For each country, the aggregated own price elasticity is larger in magnitude than the two defined products. This means that the aggregated product's demand is more elastic. For example, New Zealand's aggregated own price elasticity is much larger than the elasticities for chilled and frozen beef. The aggregated elasticity resembles the elasticity for frozen beef more than the elasticity for chilled beef. In addition, the aggregated elasticity does not differ from the frozen beef elasticity due to the error bars overlapping. The aggregated elasticity does differ statistically from the chilled beef elasticity. Beef from the U.S. also follows the same pattern. The aggregated elasticity for U.S. beef is closer in value to the elasticity for U.S. frozen. However, the aggregated elasticity does not differ from the two defined products own price elasticities.

Figure 11 compares the long-run compensated own-price elasticity for the aggregated model against the disaggregated model for each country. The own price elasticities for each country increased in the long run, as expected. For example, the aggregated and defined elasticities for U.S. beef increased in the long run. The aggregated elasticity is still closer in value to the frozen beef elasticity. The error bars for chilled and frozen beef overlap the error bar for the aggregated model. This means that the aggregated model still does not differ from the defined products in the long run.

Now moving on to the uncompensated own-price elasticities. Again, the uncompensated elasticity encompasses both the substitution and income effect, therefore we expect these elasticities to be larger than the compensated ones. Figure 12 compares the short-run uncompensated own-price elasticities for the aggregated model and the disaggregated model. The results for the uncompensated elasticities show that the aggregated products are more elastic than the defined products. This is true for all countries. The aggregated elasticity for Australian beef increased the most when comparing it back to the compensated results. It went from being less than -0.50 to being about -1.00. In addition, the aggregated elasticity for Australian beef is closer in value to the elasticity for chilled beef. Also, the aggregated elasticity results statistically differ from both defined products.

Figure 13 shows the last set of elasticity comparisons. This figure is comparing the uncompensated own-price elasticities for the aggregated and disaggregated models in the long run. As seen in other results, the long run elasticities for all countries are larger in magnitude than the short run elasticities.

CHAPTER 7: SUMMARY AND IMPLICATIONS

The Japanese beef industry is an important destination market for U.S. beef producers. Despite the BSE outbreak in 2003, the trade relationship between the U.S. and Japan has remained strong for decades. Country of origin and product attributes are two important factors when determining the demand for imported beef. Both factors have been used to study the demand for beef in Japan, however, the majority of those studies considered country-of-origin and product attributes separately. Very few studies have considered how country-of-origin and product attributes combined affect Japanese demand for imported beef. This study builds upon what has already been done to provide a more detailed analysis of how U.S. beef products compete in the Japanese beef import market relative to other countries based on price and product characteristics.

Two models were estimated for this analysis: a disaggregated model and an aggregated model. The disaggregated model examined products by source and product attribute. The exporting countries used were Australia, the U.S., New Zealand, and the ROW. The beef products used in the analysis were chilled and frozen boneless beef. The aggregated model only separated products by source. Using the results, we compared the two models to see if country-of-origin and product attributes combined affected Japanese demand for imported beef.

Preforming aggregated and disaggregated analysis provided helpful information for policymakers. Something to considered was whether or not the different models over or underestimates the effects of expenditure and price changes. This was shown by comparing the magnitude of the aggregated model's own-price elasticities to the defined product's own-price elasticities (i.e., Australian chilled beef). When the magnitude of the aggregated model's own-price elasticity was smaller than the two defined products' own-price elasticities, then there was a possibility that the aggregated model was underestimating demand changes. When the magnitude of the aggregated model's own-price elasticity was larger than the defined product's own-price elasticities, then there was a possibility that the aggregated model is overestimating demand changes. After analyzing the results, several key takeaways were found.

The effects of prices on Australian beef might be overestimated if the aggregated model is used. Looking back at the model comparison for both the short-run compensated and uncompensated own-price elasticities (Figures 10 and 12), you can see that the magnitude of the elasticity for Australian beef aggregated is larger than the elasticities for both defined products. In addition, the aggregated model might not be needed since 56 percent of Australian beef exports to Japan are chilled beef products. Because of this large percentage, the aggregated model might be overcompensating, which would lead to overestimation.

When comparing both compensated and uncompensated own-price elasticities for New Zealand, the magnitude of the aggregated elasticity was much larger than the defined products. Again, this could imply that the aggregated model is overestimating effects. Frozen beef accounts for about 63 percent of New Zealand's exports to Japan. With this product making up most New Zealand beef products, there is a possibility that frozen is heavily influencing the Aggregated own-price elasticity. In the short run, both chilled and frozen beef have own-price elasticities that are inelastic. The own-price elasticity for all New Zealand beef was elastic in the short run. If the true response to a change in price comes from the results of the disaggregated model, then this means a price change would produce a smaller reaction than initially expected.

U.S. beef might also be overestimated if the aggregate model was used in policymaking. When looking at the compensated elasticities, U.S. chilled beef, frozen beef, and U.S. beef aggregated all had own-price elasticities that were inelastic. However, the own-price elasticity for all U.S. beef was larger than the two defined products. The aggregated uncompensated own-price elasticity was also larger than the two defined products. However, it has a value that was elastic in the short run. No matter the type of elasticities used, the aggregated model still runs the risk of overestimating the response to pricing policy. Chilled beef could be influencing the aggregated results because it makes up 71 percent of U.S. beef exports to Japan.

Lastly, the effect of prices on the ROW beef could be overestimated if the aggregated model was used. When looking at both the compensated and uncompensated elasticities, ROW chilled beef had an insignificant own-price elasticity. If the ROW aggregated model were used, then the own-price elasticity would be accounting for both chilled and frozen beef. Chilled beef should not be included in the results since it was insignificant in the disaggregated model. Also, the frozen beef product could be influencing the aggregated results because it makes up 64 percent of ROW's beef exports to Japan. Furthermore, the aggregated model's results have a higher own-price elasticity. An elasticity higher value would lead to a larger response in quantity demanded to a price change.

Overall, this study found that both country of origin and product attributes are important to Japanese beef demand. Note that elasticity estimates are very different when aggregating across product attributes.

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APPENDIX

Table 1. Japanese Beef Imports by Product Attribute: Five-Year Average: 2017-2021

HS Code	Product Description	Average (billion $)	Share
020130	Meat; of bovine animals, boneless cuts, fresh or chilled	2.049	47%
020230	Meat; of bovine animals, boneless cuts, frozen	1.363	31%
020610	Offal, edible; of bovine animals, fresh or chilled	0.618	14%
020621	Offal, edible; of bovine animals, tongues, frozen	0.221	5%
020629	Offal, edible; of bovine animals, (other than tongues and livers), frozen	0.071	2%
160250	Meat preparations; of bovine animals, meat or meat offal, prepared or preserved (excluding livers and homogenized preparations)	0.044	1%
020120	Meat; of bovine animals, cuts with bone-in (excluding carcasses and half-carcasses), fresh or chilled	0.014	0%
020622	Offal, edible; of bovine animals, livers, frozen	0.002	0%
020110	Meat; of bovine animals, carcasses and half-carcasses, fresh or chilled	0.000	0%
021020	Meat; salted, in brine, dried or smoked, of bovine animals	0.000	0%
020210	Meat; of bovine animals, carcasses and half-carcasses, frozen	0.000	0%

Source: UN Comtrade Database

Table 2. United States' Beef Exports by Product Attribute: Five-Year Average: 2017-2021

HS Code	Product	Average Value (billion$)	Share
020130	Meat; of bovine animals, boneless cuts, fresh or chilled	3.52	43%
020230	Meat; of bovine animals, boneless cuts, frozen	2.71	33%
020220	Meat; of bovine animals, cuts with bone-in (excluding carcasses and half-carcasses), frozen	0.75	9%
020629	Offal, edible; of bovine animals, (other than tongues and livers), frozen	0.31	4%
020610	Offal, edible; of bovine animals, fresh or chilled	0.28	3%
020120	Meat; of bovine animals, cuts with bone-in (excluding carcasses and half-carcasses), fresh or chilled	0.22	3%
160250	Meat preparations; of bovine animals, meat or meat offal, prepared or preserved (excluding livers and homogenized preparations)	0.22	3%
020621	Offal, edible; of bovine animals, tongues, frozen	0.10	1%
020622	Offal, edible; of bovine animals, livers, frozen	0.09	1%
020110	Meat; of bovine animals, carcasses and half-carcasses, fresh or chilled	0.01	0%
020210	Meat; of bovine animals, carcasses and half-carcasses, frozen	0.00	0%
021020	Meat; salted, in brine, dried or smoked, of bovine animals	0.00	0%

Source: USDA Foreign Agricultural Service's Global Agricultural Trade System

Table 3. Summary Statistics for Disaggregated Model

	Price ($US/ kg)		Value (Million $)		Quantity (Million kg)		Expenditure Share (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AU								
Chilled	6.97	0.86	74.30	10.80	10.80	2.07	0.33	0.08
Frozen	3.84	0.54	54.90	13.80	14.50	3.58	0.24	0.05
NZ								
Chilled	8.08	1.08	4.26	0.92	0.53	0.10	0.02	0.00
Frozen	4.77	0.90	6.61	3.20	1.46	0.77	0.03	0.01
US								
Chilled	7.24	0.68	54.30	26.30	7.37	3.33	0.22	0.08
Frozen	4.20	0.56	28.60	14.90	6.89	3.62	0.12	0.05
ROW								
Chilled	6.99	0.63	4.43	3.67	0.63	0.51	0.02	0.01
Frozen	4.09	0.52	9.57	6.62	2.32	1.44	0.04	0.02

Note: AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 4. Summary Statistics for Aggregated Model

	Price ($US/ KG)		Value (Million $)		Quantity (Million kg)		Expenditure Share (%)	
Country	Mean	SD	Mean	SD	Mean	SD	Mean	SD
AU	5.18	0.65	129.00	20.80	25.30	5.00	0.56	0.11
NZ	5.79	1.15	10.90	3.49	1.99	0.81	0.05	0.02
US	5.80	0.56	82.90	37.50	14.30	6.36	0.33	0.10
ROW	4.70	0.50	14.00	9.85	2.95	1.88	0.06	0.03

Note: AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 5. Disaggregated Model Log-Likelihood Values

Model	Log-likelihood Value	LR Statistic	Restrictions	p-value
Unrestricted	3204.03			
Homogeneity	3198.05	11.97	7	0.10
Symmetry	3165.96	64.17	21	0.00

Table 6. Aggregated Model Log-Likelihood Values

Model	Log-likelihood Value	LR Statistic	Restrictions	p-value
Unconstrained	1154.18			
Homogeneity	1150.42	7.52	3	0.06
Symmetry	1147.28	6.27	3	0.10

Table 7. Demand Estimates for Japanese Boneless Beef Imports (Disaggregated)

	Expenditure Share (θ_{ij})	Price Coefficient							
		AU Chilled	AU Frozen	NZ Chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen
AU Chilled	0.161 (0.022)***	-0.123 (0.031)***	-0.011 (0.026)	0.013 (0.004)***	0.006 (0.009)	0.083 (0.028)***	0.023 (0.019)	0.001 (0.005)	0.008 (0.013)
AU Frozen	0.367 (0.023)***		0.021 (0.037)	-0.005 (0.003)	0.006 (0.010)	-0.020 (0.030)	0.032 (0.021)	-0.008 (0.005)	-0.013 (0.014)
NZ Chilled	0.003 (0.002)***			-0.009 (0.005)*	0.000 (0.002)	0.007 (0.004)	0.001 (0.003)	-0.005 (0.002)**	-0.001 (0.002)
NZ Frozen	0.043 (0.006)***				-0.023 (0.007)***	0.015 (0.012)	0.003 (0.007)	-0.005 (0.003)	-0.002 (0.007)
US Chilled	0.133 (0.021)***					-0.070 (0.046)	-0.016 (0.022)	0.010 (0.007)	-0.010 (0.017)
US Frozen	0.204 (0.025)***						-0.066 (0.023)***	-0.009 (0.004)**	0.034 (0.012)***
ROW Chilled	0.008 (0.003)***							0.005 (0.004)	0.011 (0.004)***
ROW Frozen	0.081 (0.010)***								-0.027 (0.013)**
Equation R^2		0.41	0.67	0.28	0.52	0.59	0.38	0.62	0.52

Notes: Standard errors are in parenthesis. Homogeneity and symmetry are imposed.
***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 8. Dynamic Adjustments Estimates (Disaggregated)

	Lag Coefficient								
	AU Chilled	AU Frozen	NZ Chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen	Constant
AU	0.028	0.042	0.009	-0.008	-0.061	0.008	-0.006	-0.002	-0.005
Chilled	(0.021)	(0.012)***	(0.019)	(0.006)	(0.014)***	(0.008)	(0.009)	(0.006)	(0.004)
AU	-0.017	0.004	-0.002	-0.009	-0.010	-0.017	0.007	-0.018	-0.010
Frozen	(0.023)	(0.013)	(0.020)	(0.006)	(0.015)	(0.008)**	(0.010)	(0.006)***	(0.004)**
NZ	-0.003	-0.001	0.003	0.000	0.002	-0.001	0.002	0.001	-0.001
Chilled	(0.002)	(0.001)	(0.002)**	(0.001)	(0.001)	(0.001)	(0.001)*	(0.000)***	(0.000)*
NZ	-0.011	-0.009	-0.002	0.008	0.006	-0.006	0.004	0.001	-0.003
Frozen	(0.006)*	(0.003)***	(0.005)	(0.002)***	(0.004)	(0.002)***	(0.003)	(0.002)	(0.001)***
US	0.007	-0.007	0.016	0.006	0.114	-0.006	-0.020	0.007	0.007
Chilled	(0.021)	(0.012)	(0.019)	(0.006)	(0.014)***	(0.007)	(0.009)**	(0.006)	(0.004)*
US	0.020	-0.007	-0.028	0.000	-0.040	0.039	-0.014	-0.004	0.009
Frozen	(0.024)	(0.014)	(0.021)	(0.007)	(0.016)**	(0.009)***	(0.010)	(0.006)	(0.004)**
ROW	-0.009	-0.003	-0.001	-0.001	-0.003	-0.004	0.014	0.005	0.001
Chilled	(0.003)***	(0.002)*	(0.003)	(0.001)	(0.002)	(0.001)***	(0.001)***	(0.001)***	(0.001)*
ROW	-0.015	-0.019	0.004	0.004	-0.008	-0.014	0.014	0.010	0.002
Frozen	(0.009)	(0.005)***	(0.009)	(0.003)	(0.006)	(0.003)***	(0.004)***	(0.003)***	(0.002)

Notes: Standard errors are in parenthesis. Homogeneity and symmetry are imposed.
***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 9. Compensated Short-Run Demand Elasticities for Japanese Beef Imports (Disaggregated)

			Compensated							
	Expenditure	Own Price	AU Chilled	AU Frozen	NZ chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen
AU Chilled	0.493	-0.379		-0.035	0.040	0.019	0.256	0.069	0.004	0.025
	(0.068)***	(0.094)***		(0.078)	(0.013)***	(0.028)	(0.087)***	(0.06)	(0.016)	(0.040)
AU Frozen	1.557	0.088	-0.048		-0.023	0.025	-0.086	0.136	-0.036	-0.057
	(0.099)***	(0.156)	(0.108)		(0.014)	(0.042)	(0.129)	(0.088)	(0.022)	(0.059)
NZ chilled	0.163	-0.475	0.707	-0.290		-0.021	0.380	0.038	-0.268	-0.073
	(0.096)*	(0.268)*	(0.224)***	(0.177)		(0.111)	(0.234)	(0.140)	(0.124)**	(0.135)
NZ Frozen	1.502	-0.803	0.222	0.208	-0.014		0.532	0.090	-0.177	-0.058
	(0.217)***	(0.242)***	(0.318)	(0.348)	(0.072)		(0.423)	(0.258)	(0.112)	(0.228)
US Chilled	0.603	-0.317	0.378	-0.092	0.032	0.069		-0.074	0.047	-0.043
	(0.097)***	(0.211)	(0.129)***	(0.138)	(0.020)	(0.055)		(0.101)	(0.032)	(0.077)
US Frozen	1.731	-0.564	0.191	0.272	0.006	0.022	-0.138		-0.078	0.288
	(0.209)***	(0.198)***	(0.165)	(0.176)	(0.022)	(0.062)	(0.189)		(0.036)	(0.102)***
ROW Chilled	0.506	0.294	0.086	-0.508	-0.296	-0.303	0.623	-0.551		0.655
	(0.184)***	(0.237)	(0.313)	(0.319)	(0.137)**	(0.192)	(0.422)	(0.255)**		(0.236)***
ROW Frozen	2.192	-0.731	0.220	-0.363	-0.035	-0.045	-0.256	0.916	0.294	
	(0.263)***	(0.338)**	(0.353)	(0.374)	(0.066)	(0.176)	(0.456)	(0.325)***	(0.106)***	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 10. Compensated Long-Run Demand Elasticities for Japanese Beef Imports (Disaggregated)

			Compensated							
	Expenditure	Own price	AU Chilled	AU Frozen	NZ Chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen
AU Chilled	0.540	-0.415		-0.038	0.044	0.021	0.280	0.076	0.005	0.027
	(0.081)***	(0.102)***		(0.086)	(0.014)***	(0.031)	(0.095)***	(0.065)	(0.017)	(0.044)
AU Frozen	1.587	0.090	-0.049		-0.023	0.026	-0.088	0.139	-0.037	-0.058
	(0.145)***	(0.159)	(0.110)		(0.014)	(0.043)	(0.132)	(0.091)	(0.023)	(0.060)
NZ chilled	0.196	-0.572	0.850	-0.349		-0.026	0.457	0.046	-0.322	-0.088
	(0.115)*	(0.330)*	(0.275)***	(0.209)*		(0.134)	(0.284)	(0.168)	(0.151)**	(0.162)
NZ Frozen	2.038	-1.090	0.301	0.282	-0.019		0.722	0.122	-0.240	-0.079
	(0.357)***	(0.300)***	(0.432)	(0.471)	(0.097)		(0.565)	(0.351)	(0.152)	(0.310)
US Chilled	1.245	-0.653	0.780	-0.190	0.066	0.142		-0.152	0.097	-0.089
	(0.220)***	(0.451)	(0.287)***	(0.288)	(0.041)	(0.116)		(0.205)	(0.067)	(0.158)
US Frozen	2.595	-0.845	0.286	0.408	0.009	0.033	-0.206		-0.116	0.432
	(0.433)***	(0.304)***	(0.249)	(0.265)	(0.033)	(0.094)	(0.284)		(0.055)**	(0.162)***
ROW Chilled	3.008	1.749	0.512	-3.021	-1.76	-1.803	3.701	-3.272		3.894
	(1.856)	(1.796)	(1.917)	(2.752)	(1.165)	(1.423)	(3.035)	(1.863)*		(2.017)*
ROW Frozen	2.963	-0.988	0.298	-0.491	-0.048	-0.061	-0.346	1.238	0.397	
	(0.452)***	(0.467)**	(0.481)	(0.515)	(0.089)	(0.238)	(0.612)	(0.446)***	(0.147)***	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 11. Uncompensated Short-Run Demand Elasticities for Japanese Beef Imports (Disaggregated)

		Uncompensated							
	Own Price	AU Chilled	AU Frozen	NZ chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen
AU Chilled	-0.540		-0.151	0.031	0.005	0.147	0.011	-0.004	0.007
	(0.093)***		(0.082)*	(0.013)**	(0.028)	(0.090)	(0.060)	(0.016)	(0.040)
AU Frozen	-0.279	-0.555		-0.051	-0.019	-0.429	-0.047	-0.062	-0.115
	(0.161)*	(0.109)***		(0.014)***	(0.042)	(0.131)***	(0.089)	(0.023)***	(0.059)*
NZ chilled	-0.478	0.654	-0.329		-0.026	0.344	0.019	-0.270	-0.079
	(0.268)*	(0.223)***	(0.183)*		(0.111)	(0.237)	(0.140)	(0.124)**	(0.135)
NZ Frozen	-0.806	-0.267	-0.146	-0.041		0.201	-0.088	-0.201	-0.114
	(0.242)***	(0.316)	(0.360)	(0.072)		(0.430)	(0.257)	(0.112)*	(0.228)
US Chilled	-0.449	0.181	-0.234	0.021	0.052		-0.145	0.037	-0.066
	(0.214)**	(0.129)	(0.142)*	(0.020)	(0.055)		(0.101)	(0.032)	(0.077)
US Frozen	-0.768	-0.373	-0.135	-0.026	-0.028	-0.519		-0.106	0.224
	(0.199)***	(0.174)**	(0.186)	(0.022)	(0.063)	(0.196)***		(0.036)***	(0.103)**
ROW Chilled	0.286	-0.079	-0.628	-0.306	-0.318	0.511	-0.610		0.526
	(0.237)	(0.310)	(0.329)*	(0.137)**	(0.191)*	(0.427)	(0.254)**		(0.196)***
ROW Frozen	-0.767	-0.493	-0.879	-0.075	-0.107	-0.739	0.658	0.236	
	(0.338)**	(0.352)	(0.386)**	(0.066)	(0.175)	(0.463)	(0.325)**	(0.098)**	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 12. Uncompensated Long-Run Demand Elasticities for Japanese Beef Imports (Disaggregated)

		Uncompensated							
	Own Price	AU Chilled	AU Frozen	NZ chilled	NZ Frozen	US Chilled	US Frozen	ROW Chilled	ROW Frozen
AU Chilled	-0.591		-0.165	0.034	0.006	0.161	0.012	-0.004	0.007
	(0.103)***		(0.089)*	(0.014)**	(0.031)	(0.098)*	(0.066)	(0.018)	(0.044)
AU Frozen	-0.284	-0.565		-0.052	-0.020	-0.437	-0.048	-0.063	-0.117
	(0.165)*	(0.118)***		(0.015)***	(0.043)	(0.137)***	(0.090)	(0.023)***	(0.061)*
NZ chilled	-0.575	0.787	-0.395		-0.031	0.414	0.023	-0.325	-0.095
	(0.330)*	(0.274)***	(0.215)*		(0.133)	(0.287)	(0.168)	(0.151)**	(0.162)
NZ Frozen	-1.148	-0.362	-0.198	-0.056		0.273	-0.119	-0.273	-0.155
	(0.299)***	(0.431)	(0.491)	(0.097)		(0.579)	(0.349)	(0.152)*	(0.311)
US Chilled	-0.928	0.375	-0.483	0.043	0.107		-0.299	0.076	-0.135
	(0.464)**	(0.274)	(0.302)	(0.041)	(0.115)		(0.203)	(0.067)	(0.159)
US Frozen	-1.151	-0.559	-0.203	-0.039	-0.042	-0.778		-0.159	0.336
	(0.315)***	(0.269)**	(0.282)	(0.034)	(0.094)	(0.308)**		(0.057)***	(0.159)**
ROW Chilled	1.699	-0.467	-3.730	-1.816	-1.889	3.039	-3.627		3.782
	(1.780)	(1.818)	(3.065)	(1.185)	(1.445)	(2.888)	(1.977)*		(1.977)*
ROW Frozen	-1.098	-0.667	-1.188	-0.101	-0.145	-0.999	0.889	0.348	
	(0.470)**	(0.474)	(0.553)	(0.089)	(0.237)	(0.620)	(0.441)***	(0.146)**	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World.

Table 13. Demand Estimates for Japanese Boneless Beef Imports (Aggregated)

		Price Coefficient			
	Expenditure Share (θ_i)	AU	NZ	US	ROW
AU	0.521	-0.269	0.055	0.205	0.009
	(0.025)***	(0.038)***	(0.010)***	(0.035)***	(0.014)
NZ	0.050		-0.071	0.026	-0.010
	(0.005)***		(0.009)***	(0.009)***	(0.007)
US	0.340			-0.275	0.044
	(0.024)***			(0.038)***	(0.016)***
ROW	0.089				-0.042
	(0.009)***				(0.013)***
Equation R^2		0.77	0.65	0.66	0.56

Notes: Standard errors are in parenthesis. Homogeneity and symmetry are imposed.
***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 14. Dynamic Adjustments Estimates (Aggregated)

	Lag Coefficient				
	AU	NZ	US	ROW	Constant
AU	0.051	-0.018	-0.046	-0.014	-0.017
	(0.023)***	(0.012)	(0.018)***	(0.01)	(0.005)***
NZ	-0.016	0.006	-0.004	0.002	-0.002
	(0.005)***	(0.003)*	(0.004)	(0.002)	(0.001)*
US	-0.003	0.003	0.091	-0.011	0.012
	(0.023)	(0.012)	(0.017)***	(0.009)	(0.004)***
ROW	-0.033	0.009	-0.041	0.023	0.007
	(0.009)***	(0.005)*	(0.007)***	(0.004)***	(0.002)***

Notes: Standard errors are in parenthesis. Homogeneity and symmetry are imposed.
***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 15. Compensated Short-Run Demand Elasticities for Japanese Beef Imports (Aggregated)

			Compensated			
	Expenditure	Own Price	AU	NZ	US	ROW
AU	0.930	-0.480		0.098	0.367	0.015
	(0.044)***	(0.068)***		(0.018)***	(0.062)***	(0.025)
NZ	1.004	-1.428	1.100		0.529	-0.201
	(0.104)***	(0.173)***	(0.202)***		(0.183)***	(0.135)
US	1.000	-0.810	0.604	0.078		0.129
	(0.071)***	(0.113)***	(0.103)***	(0.027)***		(0.047)***
ROW	1.780	-0.848	0.173	-0.201	0.876	
	(0.187)***	(0.269)***	(0.286)	(0.135)***	(0.318)	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 16. Compensated Long-Run Demand Elasticities for Japanese Beef Imports (Aggregated)

			Compensated			
	Expenditure	Own Price	AU	NZ	US	ROW
AU	1.023	-0.528		0.108	0.403	0.017
	(0.070)***	(0.076)***		(0.020)***	(0.070)***	(0.028)
NZ	1.134	-1.614	1.243		0.598	-0.227
	(0.144)***	(0.161)***	(0.218)***		(0.201)***	(0.152)
US	1.367	-1.107	0.825	0.106		0.176
	(0.126)***	(0.158)***	(0.140)***	(0.037)***		(0.065)***
ROW	3.312	-1.578	0.322	-0.374	1.630	
	(0.577)***	(0.549)***	(0.533)	(0.256)	(0.634)***	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 17. Uncompensated Short-Run Demand Elasticities for Japanese Beef Imports (Aggregated)

		Uncompensated			
	Own Price	AU	NZ	US	ROW
AU	-1.001		0.052	0.050	-0.031
	(0.070)***		(0.018)***	(0.066)***	(0.026)
NZ	-1.478	0.538		0.187	-0.251
	(0.172)***	(0.211)**		(0.192)	(0.135)*
US	-1.150	0.043	0.028		0.079
	(0.118)***	(0.107)	(0.027)		(0.047)*
ROW	-0.937	-0.824	-0.290	0.271	
	(0.269)***	(0.300)***	(0.135)**	(0.332)**	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

Table 18. Uncompensated Long-Run Demand Elasticities for Japanese Beef Imports (Aggregated)

		Uncompensated			
	Own Price	AU	NZ	US	ROW
AU	-1.101		0.057	0.055	-0.034
	(0.089)***		(0.020)***	(0.072)	(0.028)
NZ	-1.670	0.608		0.212	-0.284
	(0.161)***	(0.230)***		(0.214)	(0.152)*
US	-1.572	0.059	0.038		0.108
	(0.174)***	(0.145)	(0.037)		(0.065)*
ROW	-0.1.743	-1.533	0.156	1.465	
	(0.558)***	(0.597)***	(0.531)	(0.628)**	

Note: ***, **, *Significance level = 0.01, 0.05, and 0.10 respectively.
AU is Australia, NZ is New Zealand, US is United States, and ROW is Rest of World

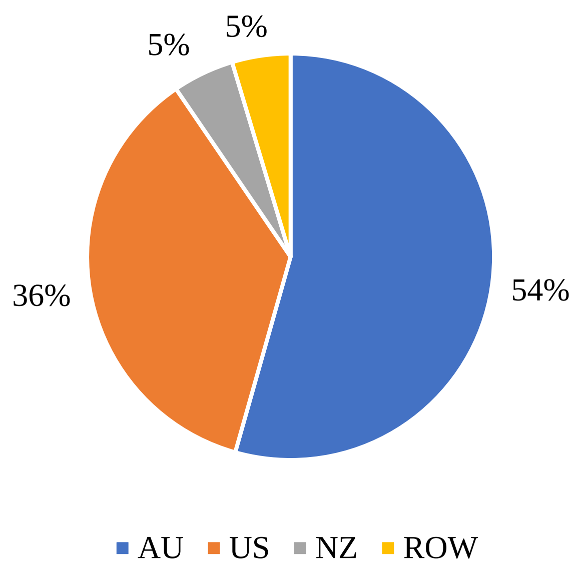

Figure 1. The Proportion of Japan's Beef Imports by Country (Value): 2012-2016

Source: Trade Data Monitor

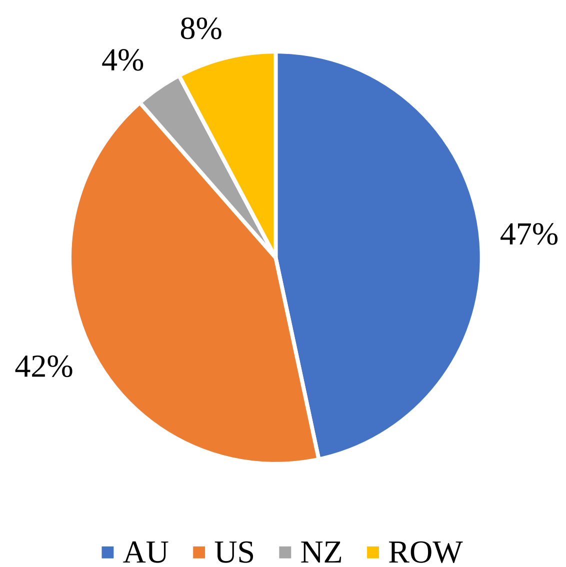

Figure 2. The Proportion of Japan's Beef Imports by Country (Value): 2017-2021

Source: Trade Data Monitor

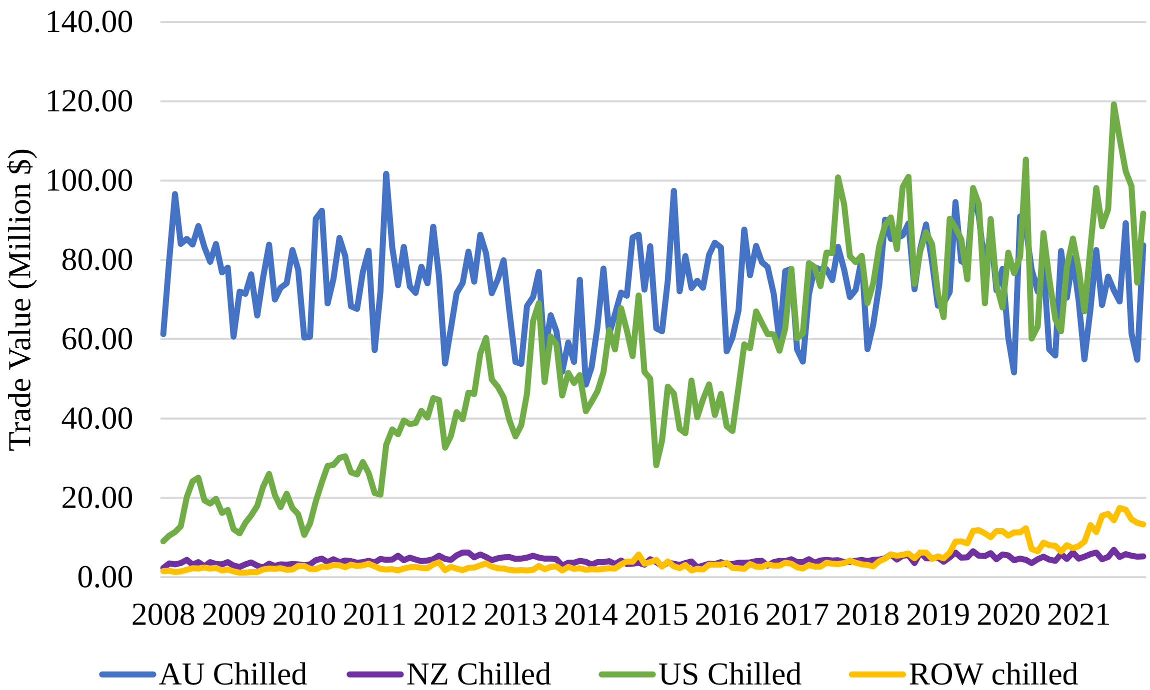

Figure 3. Japan's Chilled Boneless Beef Imports: 2008-2021

Source: Trade Data Monitor

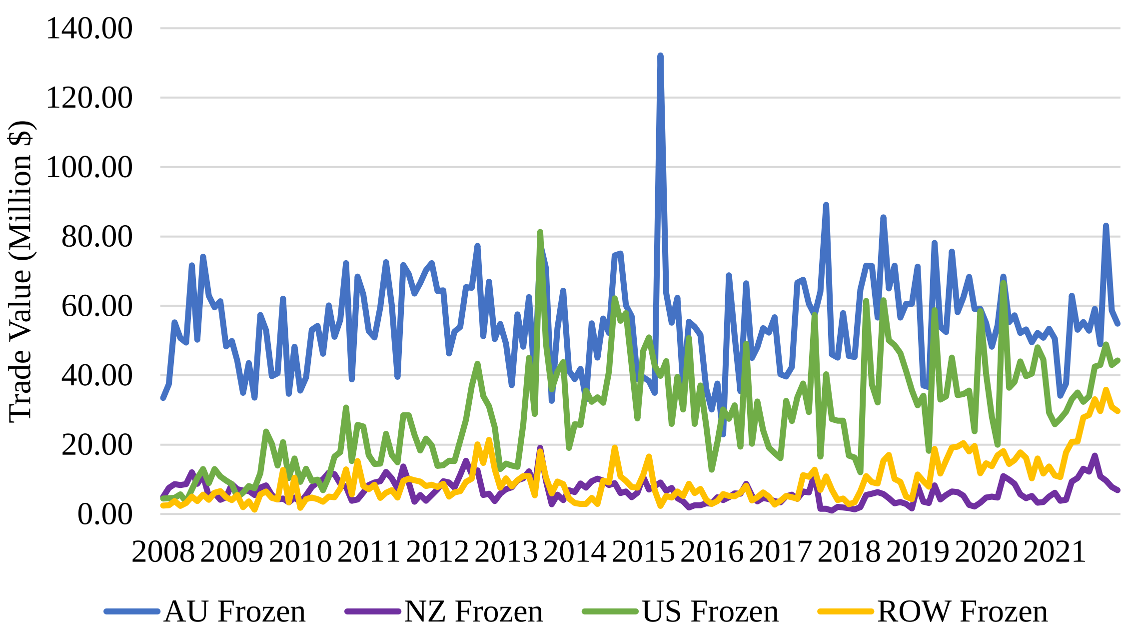

Figure 4. Japan's Frozen Boneless Beef Imports: 2008-2021

Source: Trade Data Monitor

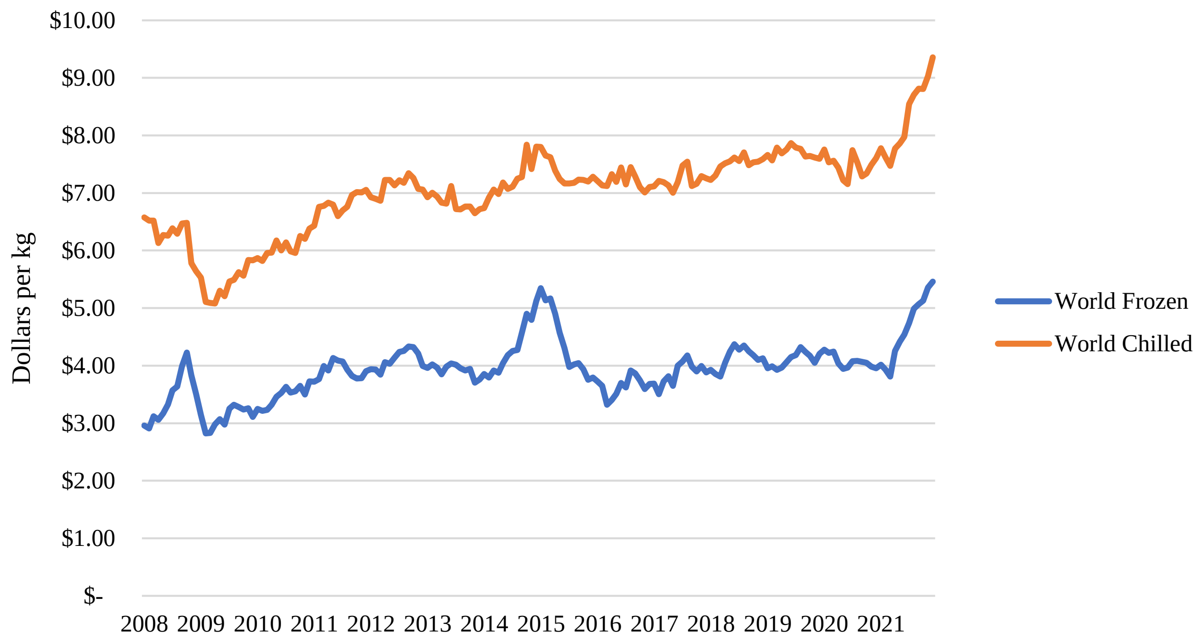

Figure 5. Average Beef Import Prices in Japan by Product Characteristic: 2008-2021

Source: Trade Data Monitor

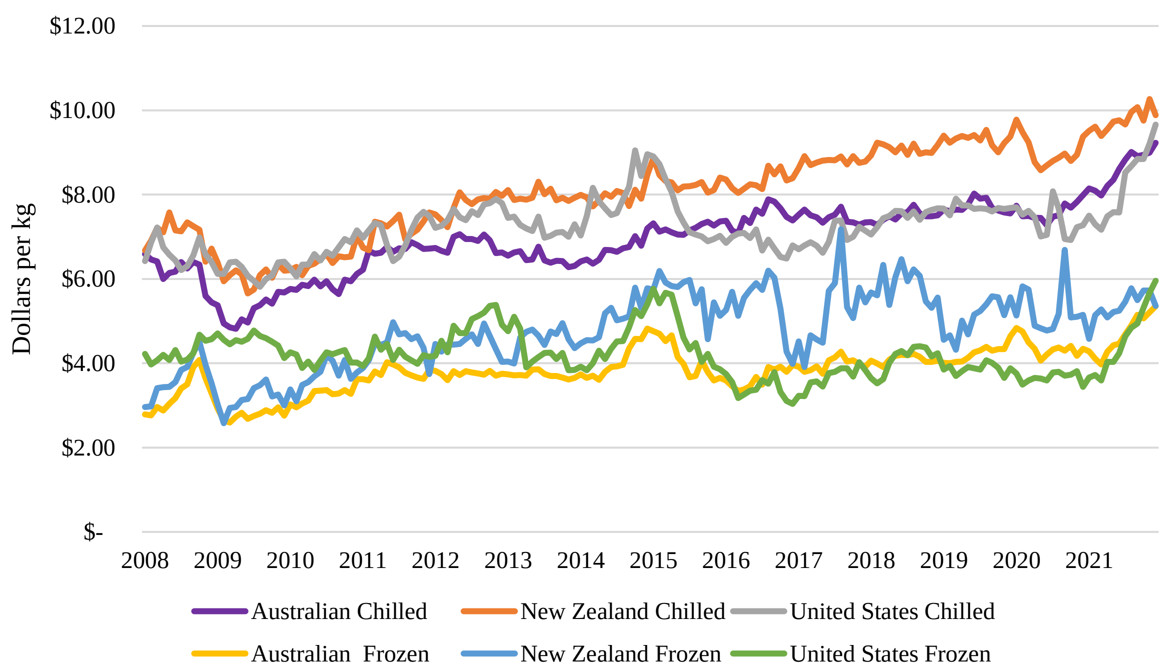

Figure 6. Boneless Beef Import Prices in Japan by Country and Product Characteristic: 2008-2021

Source: Trade Data Monitor

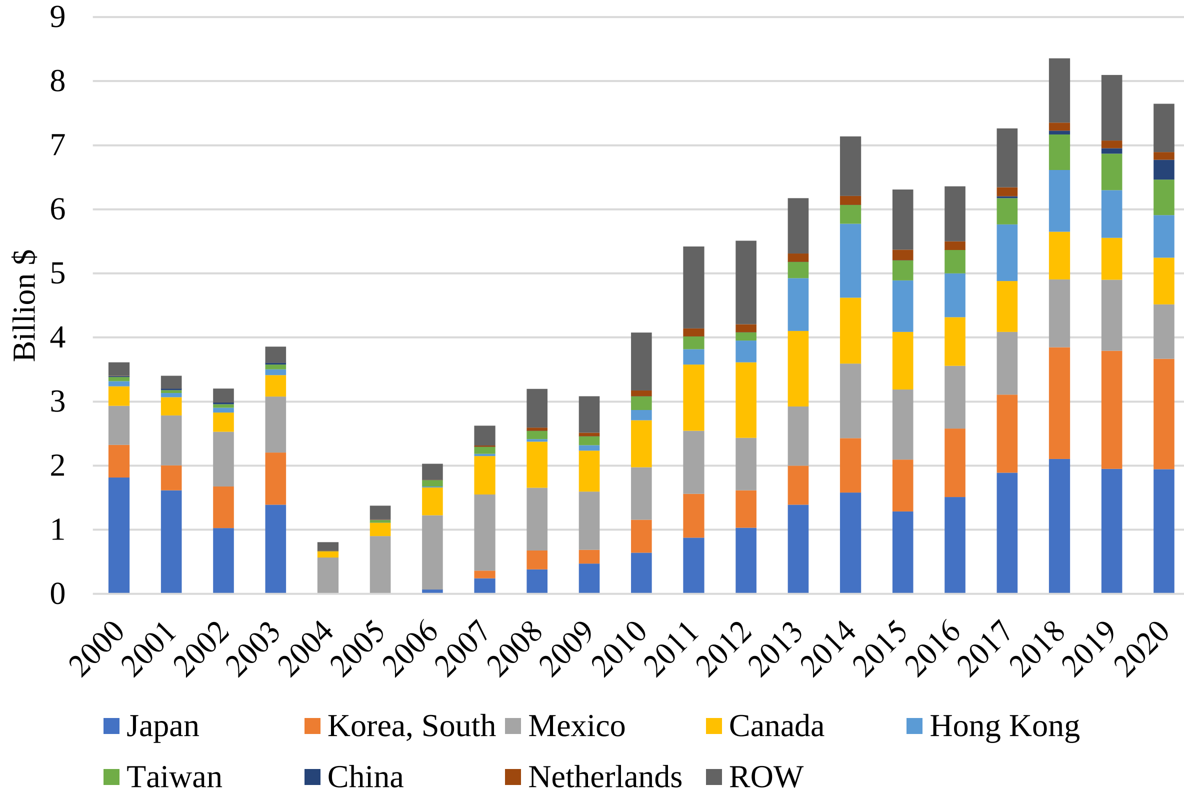

Figure 7. US Beef Export Value by Country: 2000-2020

Source: USDA Foreign Agricultural Service's Global Agricultural Trade System

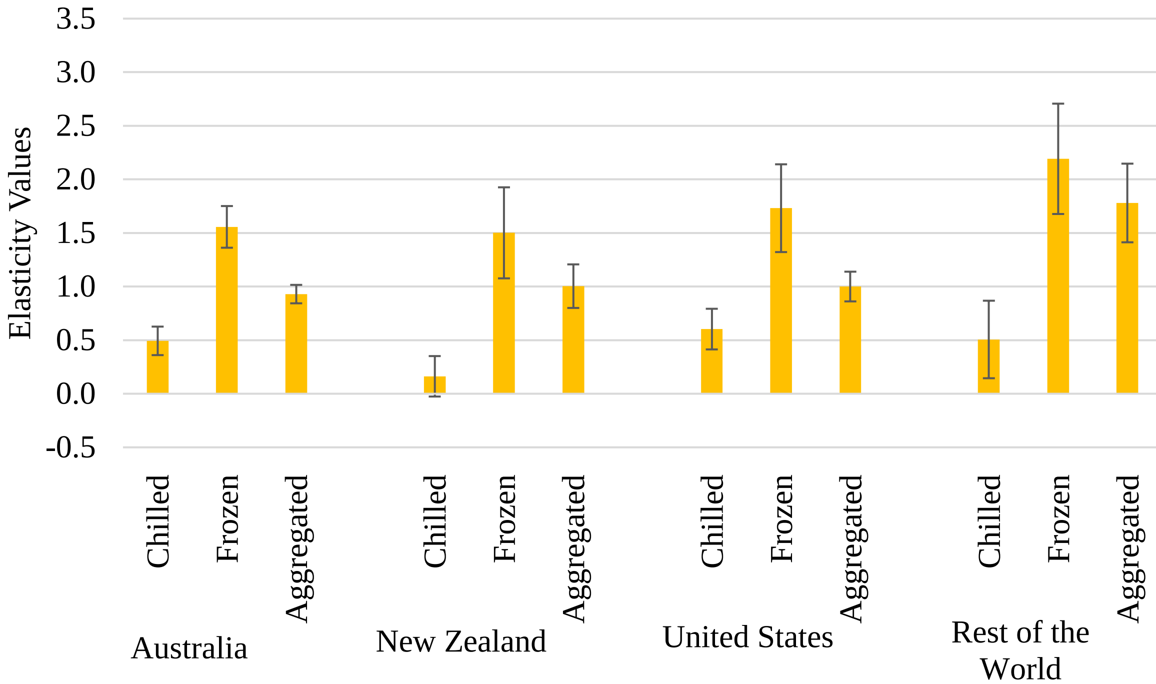

Figure 8. Comparison of Short Run Expenditure Elasticities

Note: Error bars represents the 0.95 confidence interval

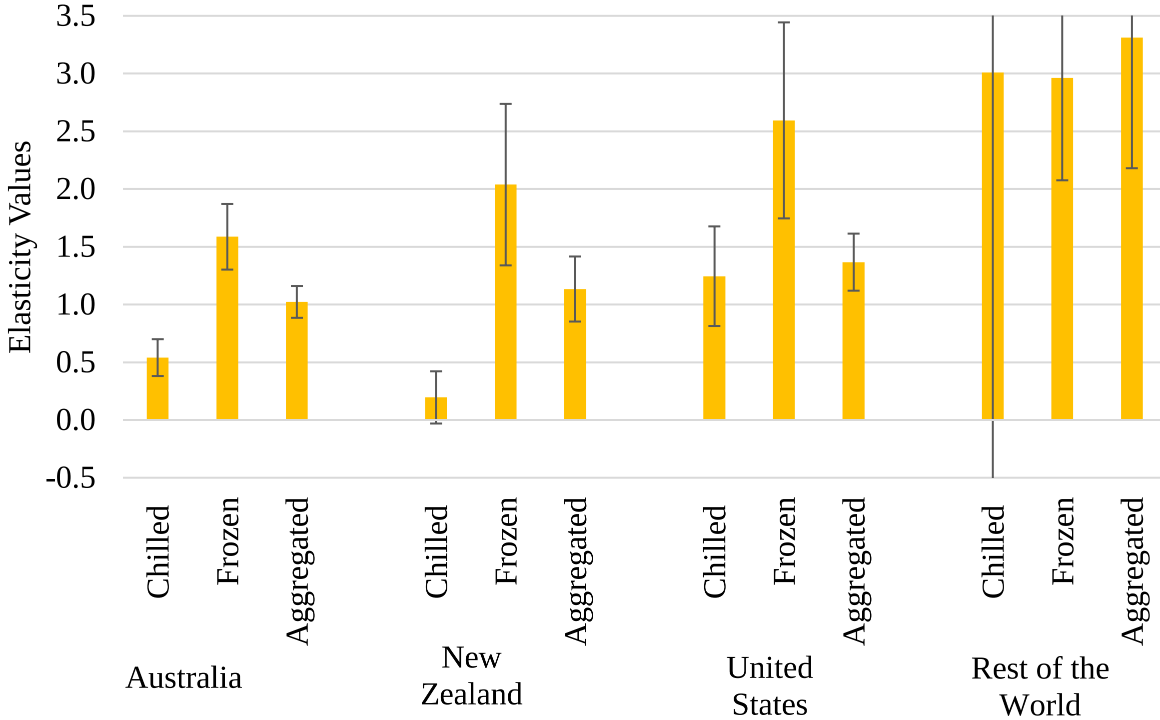

Figure 9. Comparison of Long Run Expenditure Elasticities

Note: Error bars represents the 0.95 confidence interval

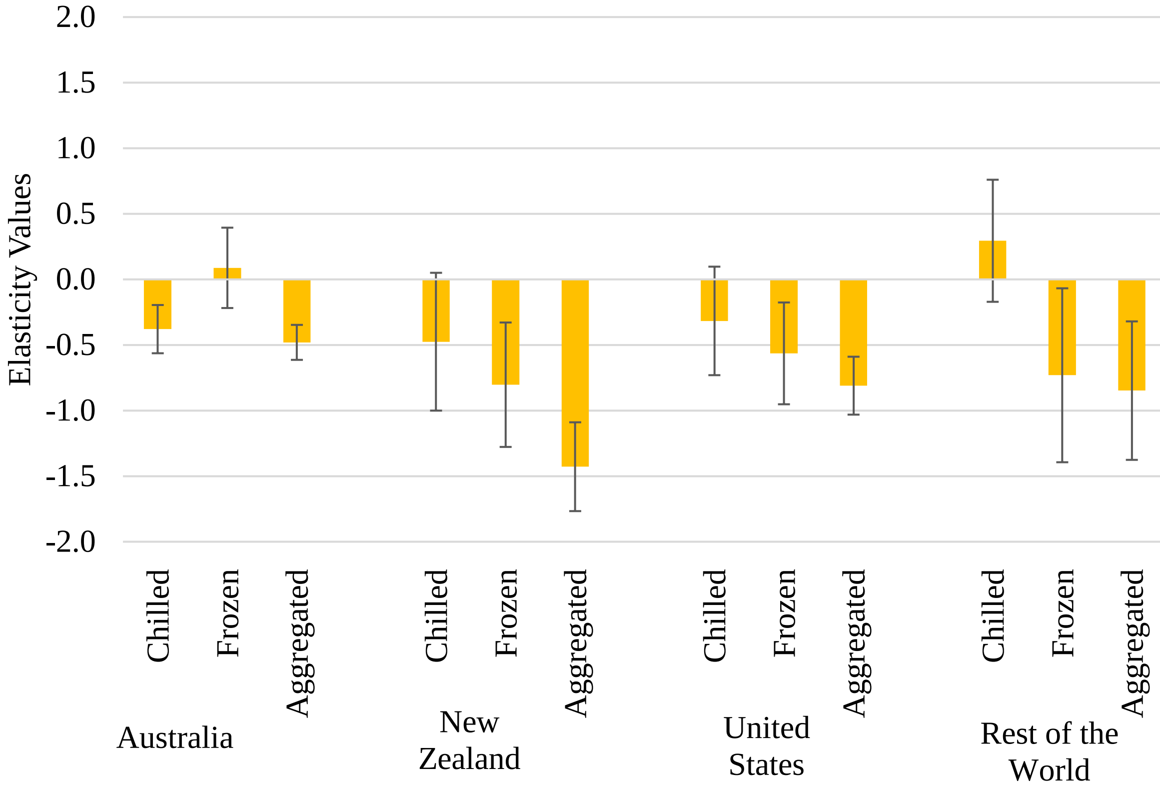

Figure 10. Comparison of Compensated Short Run Own Price Elasticities

Note: Error bars represents the 0.95 confidence interval

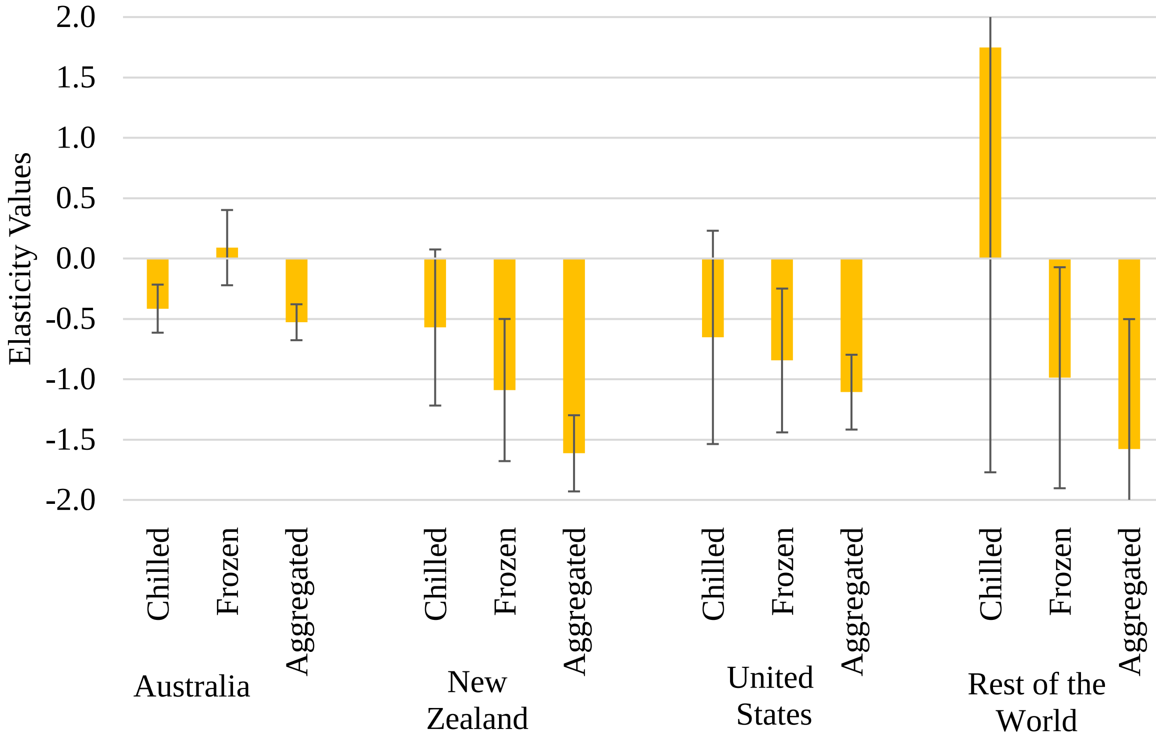

Figure 11. Comparison of Compensated Long Run Own Price Elasticities

Note: Error bars represents the 0.95 confidence interval

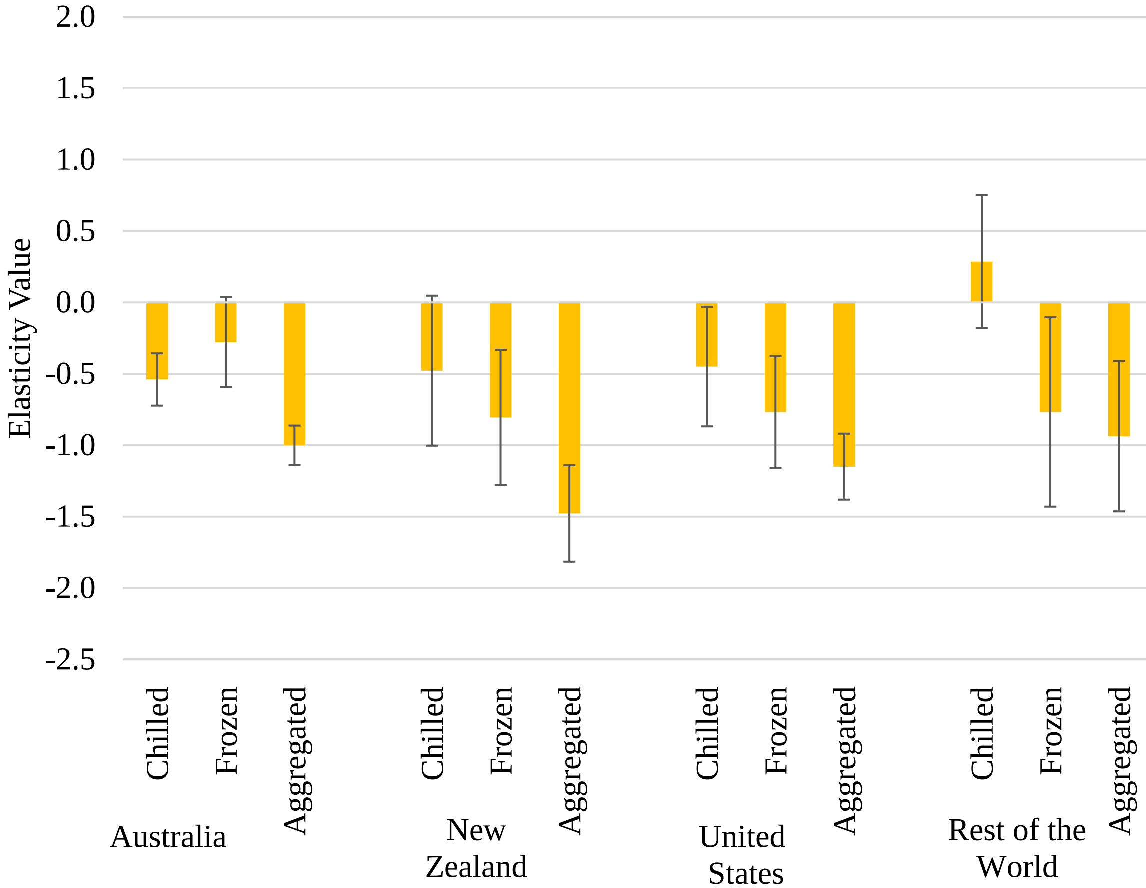

Figure 12. Comparison of Uncompensated Short Run Own Price Elasticities

Note: Error bars represents the 0.95 confidence interval

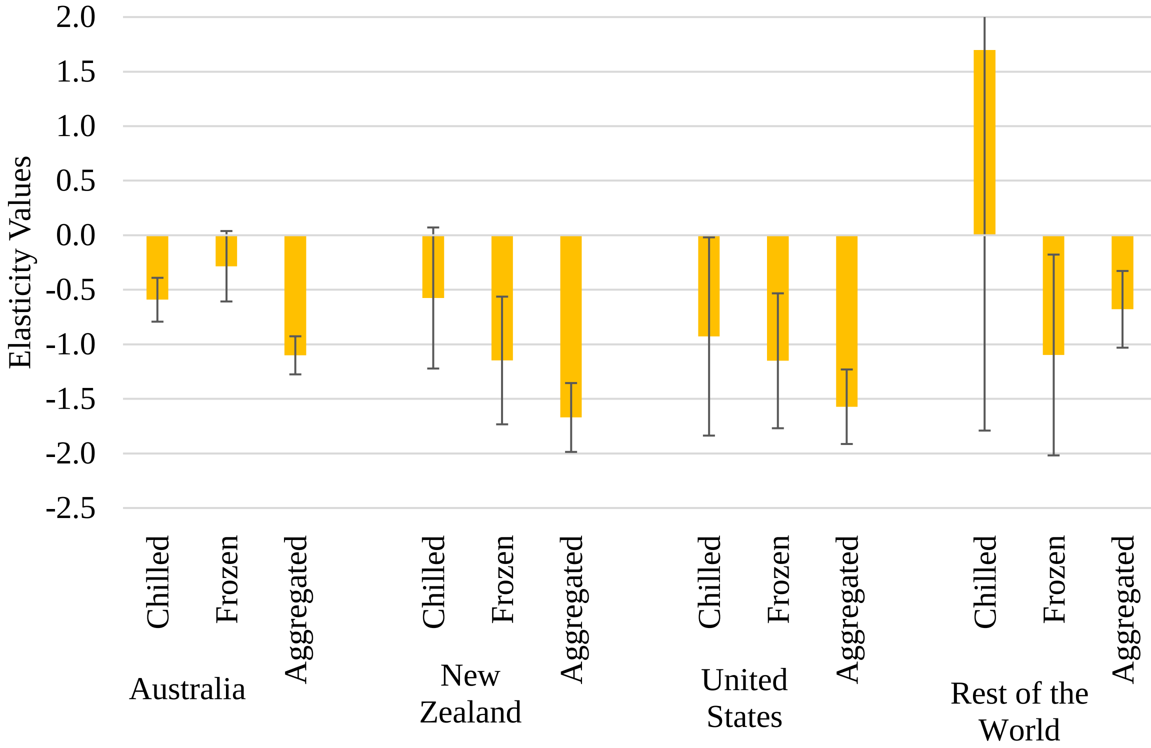

Figure 13. Comparison of Uncompensated Long Run Own Price Elasticities

Note: Error bars represents the 0.95 confidence interval

VITA

Christina Greer is a master's candidate at the University of Tennessee, Knoxville. She is originally from Lebanon, TN and attended Lebanon High School where she graduated in 2017. After high school, she attended the University of Tennessee, Knoxville and received a Bachelor of Science degree in Food and Agricultural Business from the Agricultural and Resource Economics department. After being motivated by her advisors and other professors, she decided to pursue graduate school at her alma mater. In May 2022, she will receive her Master of Science degree in agricultural economics. Her research interest includes international trade and international beef demand. She is extremely grateful for all the love and support her family and friends have given her over the last five years. She would also like to thank her advisors and professors for being amazing mentors during her time at the University of Tennessee.