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ESTIMATING THE IMPACT OF BREXIT ON THE UNITED KINGDOM'S IMPORT DEMAND OF BOVINE MEAT

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On 23rd of June 2016 the United Kingdom (UK) held The United Kingdom European Union membership referendum on the question whether the country should remain in the European Union (EU). The result was that the UK decided to exit from the European Union. This event was coined as Brexit.

The primary objective of this Thesis is to estimate the impact of Brexit on the United Kingdom's import demand for bovine meat. In order to estimate the impact an econometric time series model is used to capture the unit price and income elasticities of import demand. The specific model used is Autoregressive Distibuted Lag Error Correction Model (ARDL-ECM). The results of the model are used to analyse possible impacts of different Brexit scenarios. The time series is based on annual data from 1993 until 2018. The data was collected from EUROSTAT, UN COMTRADE and UK government sources.

The results of the model were used to analyse possible impacts of Brexit. The results show that bovine meat imports from the EU are quite inelastic. The results from the thesis can be used to indicate possible magnitude of the changes due to Brexit. In order to capture better estimates for the impact of Brexit the elasticities gained from the Thesis could be utilized in a general- or partial equilibrium models.

Keywords
Import demand, Brexit, Bovine meat, ARDL, ECM

Additional information

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1. INTRODUCTION

"The more divergence there is, the more distant the partnership has to be. Without an extension of the transition period beyond 2020, you cannot expect to agree on every single aspect of our new partnership. Without the freedom of movement of people, you cannot have the free movement of capital, goods and services. Without a level playing field on environment, labour, taxation and state aid, you cannot have highest-quality access to the world's largest single market." - Ursula von der Leyen

On 23rd of June 2016 the United Kingdom (UK) held The United Kingdom European Union membership referendum on the question whether the country should remain in the European Union (EU). The result was that the UK decided to exit from the European Union. This event has been abbreviated commonly as Brexit. On 31st of January 2020 the UK officially withdrew from the EU after lengthy negotiations. The aim of the transitory period was for the UK and the EU to negotiate their future relationship. As per words from Ursula von der Leyen, the president of the European Commission since 1st of December 2019, the Brexit negotiations with the EU faced many difficult questions. Yet after intense negotiations a free trade agreement (FTA) between the EU and the UK was reached on 24th of December 2020.

If the negotiations would not have led to a deal between the participants, the UK would have been set to leave the EU without a deal. In that case the jurisprudence of the WTO (World Trade Organization) would have taken place in the trade between the areas. The scenario would have set the EU on equal footing with the Rest of the World (RoW) as a trade partner of the UK. This no-deal Brexit was also coined as a hard-Brexit. As noted by Ursula von der Leyen, there was many other issues in addition to trade in the Brexit negotiations. In this thesis the focus is on direct and indirect effects of the Brexit on trade.

From the perspective of Finland, indirect effects of Brexit are far more important than the direct effects of possible tariff increases. This claim is supported by a working paper from Lawless and Morgenroth (2016) who estimated that there would have been only a 5 % decrease in trade between the UK and Finland from Hard Brexit, the lowest direct effect of all the EU countries in their study. Thus it is of great interest to consider the magnitude of the excess supply that might be caused by the Brexit.

In order to consider the magnitude from the perspective of agriculture a single commodity was chosen. This was due to different tariff regimes between agricultural commodities that would have made more aggregate analysis quite difficult. The other reason was to narrow the research question for the Thesis. Hence Bovine meat was decided as the commodity whose import demand was modelled. Bovine meat has various properties to justify its choice. The first property of bovine meat that makes it an interesting good to consider is that it is imported to the UK from both the EU and the Rest-of-the-World - a property that many agricultural goods lack. Second, bovine meat trade is significant for both the EU and the UK. Third, it is a heavily protected good by the EU. Though the third property is also problematic for the econometric estimation as will be shown. These properties are discussed more in depth in chapter 2 of the thesis.

1.1. **Research question and objective**

The objective of this thesis is to assess the impact of the Brexit to the United Kingdom's import demand of bovine meat. The results will hopefully shed light to the research questions, which are, to what extent are bovine meat imports elastic to the price and hence what impact would a tariff increase due to Brexit have had?

The analysis was decided to be done solely with a single-equation import demand econometric model for the imports from the EU and from an aggregate of all the exporting countries. From the model elasticity of import demand to price, income and production can be derived. The elasticities are then used to estimate the impact on import demand of bovine meat of different tariff increases due to Brexit. In the econometrical approach the thesis follows closely the study conducted by Pattichis (1999) with the use of Autoregressive Distributed Lag Model (ARDL), Unrestricted Error Correction Models (UECM) and bound test for cointegration.

1.2. **Data**

The data for the model comes from United Kingdom's government sources, United Nations Comtrade Database and UN's FAOSTAT Database. For the UKs GDP and CPI source has been Office for National Statistics. The modelling has been conducted with RStudio with the use of ARDL and tsDyn libraries among many. For the product estimation the Harmonized System codes are used. The import quantity and unit price are calculated by aggregating the two different Harmonized System four-digit categories for the bovine meat. HS0201 that stands for Bovine Meat, fresh or chilled and HS0202 that stands for Bovine Meat, Frozen. In this study the codes are used as abbreviation for the categories they represent.

1.3. **Structure of the Thesis**

This thesis proceeds as follows. In the next chapter the bovine meat market in the UK is introduced. In chapter 3 the literature review is outlined. The chapter presents prior studies for import demand estimations as well as the models and economic theory behind it. In chapter 4 the economic and econometric theory behind the model is introduced. In the chapter 5 the data used is presented and tested econometrically. Chapter 6 shows the results from the econometric application of the model for both the World and the EU levels. In the chapter the results are also interpreted and analysed from the perspective of the Brexit. In the last chapter 7 the conclusion of the study is drawn.

2. BOVINE MEAT AND THE BREXIT

Chapter 2 addresses EU-UK relations and the specific situation of bovine meat in the UK. In the chapter production levels, trade and the impact of Bovine Spongiform Encephalopathy are considered.

2.1. The Brexit

Holmes, Rollo and Winters (2016) outlined three possible scenarios for the relations between the UK and the EU. First, the authors note that the UK could leave the EU and join the European Economic Area (EEA) instead. Yet it was deemed unlikely. Secondly, the EU and the UK could negotiate a trade agreement, which also has its share of problems. Lastly comes the "hard Brexit" where the UK would have left the EU without a deal, thus entering the WTO based trade rules. On 24th of December 2020 the EU and the UK reached an free trade agreement (FTA) where it was decided that there would be no tariffs between the EU and the UK in bovine meat. In addition to considering the effects of the free trade agreement, in this Thesis the possibility of what might have happened due to the hard Brexit is also considered.

2.2. The Bovine Meat

The United Kingdom is globally a significant importer and consumer of meat products, thus the Brexit scenario without deal might have significant impact on the UK. According to a study conducted by Poppy, Baverstock and Baverstock-Poppy (2019) the UK's meat imports were 5.3 % of the total international meat trade. The researchers note that the amount is quite large when considering that UK's population is only 0.87 % of the worlds. In 2015 86.2 % of bovine meat imports were from the EU. As figure 2 shows the bovine meat imports from the EU have grown quite consistently since 1996. The share of imports from outside of the EU is quite large for bovine meat when compared to other meat products. In 2015 95.5 % of poultry and 99.8 % of pork was imported from the EU according to Poppy et al. (2019).

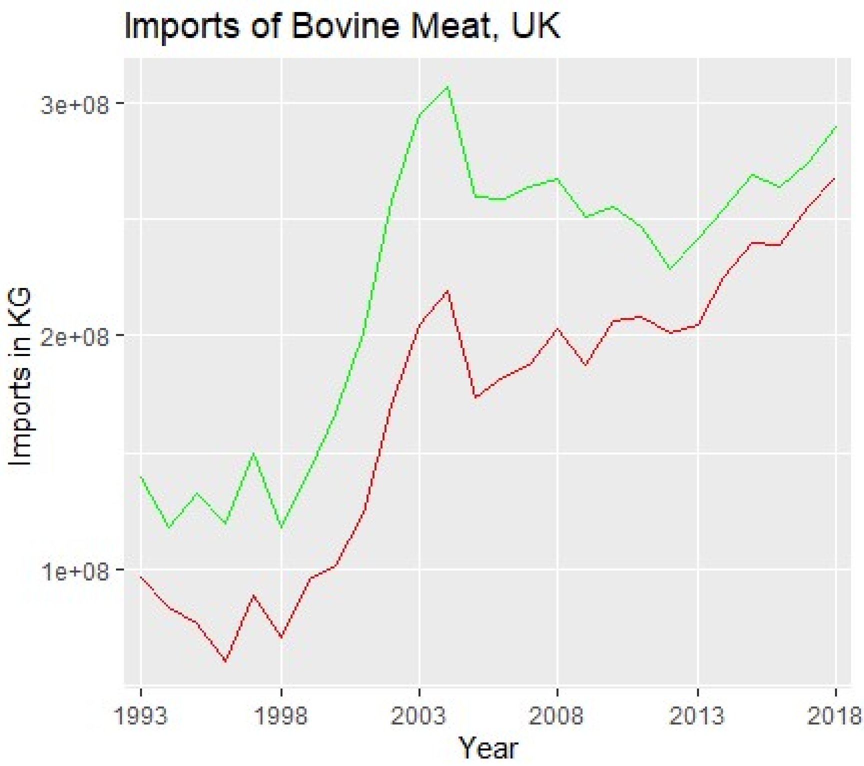


Figure 1. Imports of Bovine Meat to the UK. (UN Comtrade Database)

In Figure 1 the upper line is all the imports and the lower line is the imports from the EU. The factors causing the increase in imports ever since the 1996 are various. The United Kingdom had been member of the European Communities (EC) since 1972 (the European Union after the Maastricht Treaty in 1993). One of the explaining factors could be the changes that happened in the European Communities during the 90's. As can be seen from the graph, the growth in imports has been mainly driven by the EU area.

Even though the UK enjoyed tariff-free trade with the EU since joining the EC in 1972, the technical barriers to trade saw large reduction as late as 1992. In addition in 1990 United Kingdom joined the European Exchange Rate Mechanism (ERM), which meant that the British pound sterling was pegged to a basket of the eight other European currencies. Yet the main factor behind the rise in imports in the 1990's is arguably the BSE.

2.1. Bovine Spongiform Encephalopathy

Bovine Spongiform Encephalopathy (BSE), commonly known as "mad cow" disease had a significant effect on the bovine market in the UK from 1980's to the first decade of the new millenia, with the legacy still lasting. As can be seen from the Figure 2 the production quantities of bovine meat crashed in the mid 90's and have not recovered to the 80's levels ever since. In addition to the domestic production the effects are still lasting in trade. For instance Japan lifted its ban of British beef imports in 2019 after 23 years since the ban began. Notably the export ban had also been in force to the USA until March 2020. In 30th of September the first shipment of the UK beef departed to the USA according to the British government. The EU had ended the ban already in 1999, though France continued the ban for another three years.

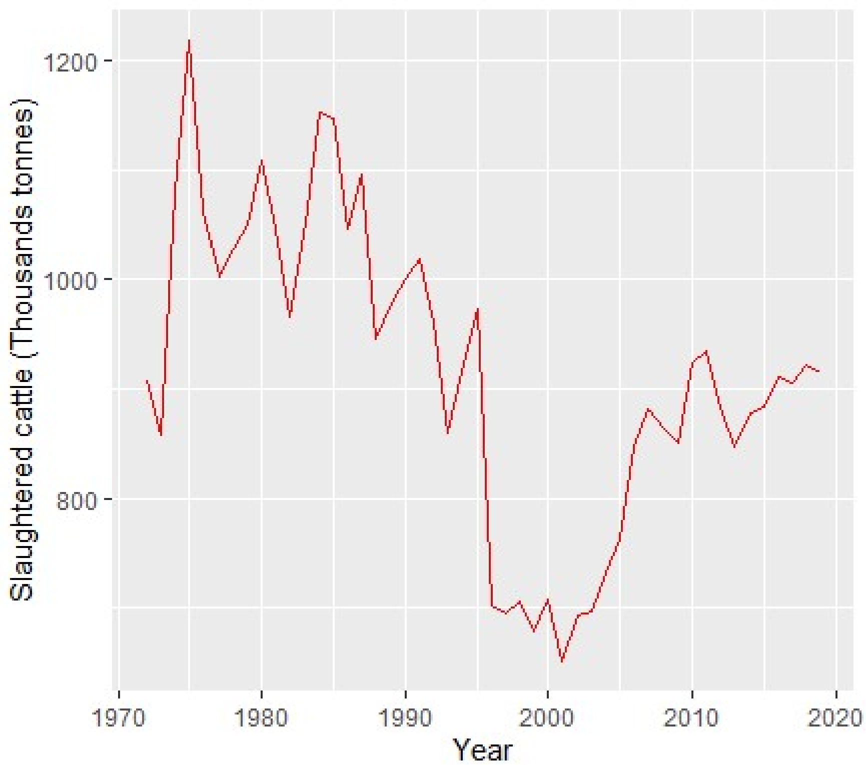


Figure 2. Cattle Production in the UK (Eurostat)

The crisis took a leap on 20th of March 1996 when the UK government made an announcement on a possible link between BSE and new variant of Creutzfeldt-Jakob disease (CJD), which was deemed dangerous for humans. This led to a complete export ban of the bovine meat from the UK, with some countries continuing it for decades as mentioned before. In addition to the exports the consumption in the UK fell. In 1998 the UK's House of Commons received a report on the state of beef market in the UK with the following statement:

"The UK beef industry is in the midst of a crisis, triggered by the Government announcement on 20 March 1996 on the possible link between BSE and new variant CJD, which is now approaching its third year. In 1996, following the complete loss of the export market and the sharp fall in consumer confidence in the product, beef consumption in the UK fell by 18 per cent to 739,000 tonnes. By 1997 production had fallen back sharply to 692,000 tonnes, primarily because of the exclusion from the food chain of meat from over 30 month old cattle, although the high number of calves entering the Calf Processing Aid Scheme was also further depressing production."[1]

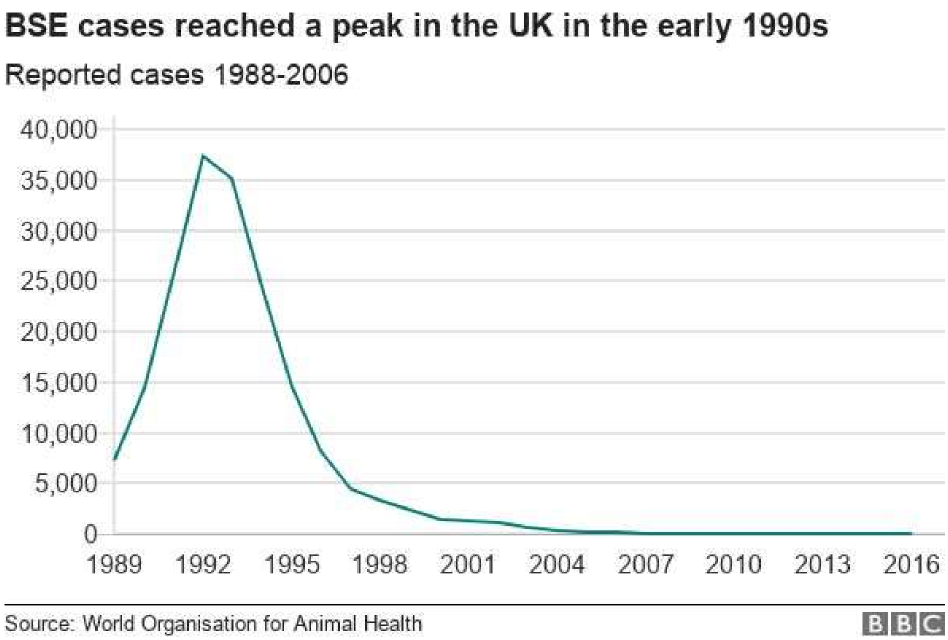


Figure 3. Number of BSE cases in the UK (World Organisation for Animal Health)

Figure 3 shows that when the crisis began the BSE cases were already decreasing at a fast pace. For the time series analysis on the elasticities of income and price to import demand, the BSE creates a problem. Certainly there is other non-quantifiable factors

[1] https://publications.parliament.uk/pa/cm199798/cmselect/cmagric/474iii/ag0302.htm

at play other than the income or the price of imports due to the BSE. Yet to an extent it should be considered with the econometric specification where domestic prices and production levels are taken into account. In addition it also creates an interesting situation as the United Kingdom was perhaps forced to import its bovine meat.

2.2. The situation as of 2018

According to the UN Comtrade database the United Kingdom imported 195 367 tons of Fresh or Chilled Bovine meat (HS0201) in 2018. The exports of the UK bovine meat classified as HS0201 were 83 3360 tons. In HS0202 for bovine meat, frozen, category the imports were 94 597 tons and the exports were 27 119 tons. Thus for HS0201 the imports were 234 % more than exports. For HS0202 the statistic is 352 %.

According to the statistics from the United Kingdom's Department for Environment, Food & Rural Affairs, the consumption for beef and veal in the UK in 2017 was 1 204 000 tons. The statistic for 2018 was not available. Based on these numbers the United Kingdom imports approximately 24 % of its consumption. The number is similar to the one published by the United Kingdoms National Beef Association, which stated that the UK is 75 % self-sufficient in Beef. National Beef Association is a British organization that represents the domestic cattle industry. The biggest exporter to the United Kingdom is Ireland with a ~ 70 % market share of of the total bovine meat imports (HS0201 and HS0202 combined) in 2018 based on the calculations from the UN Comtrade database. The import shares are shown below in Figure 4.

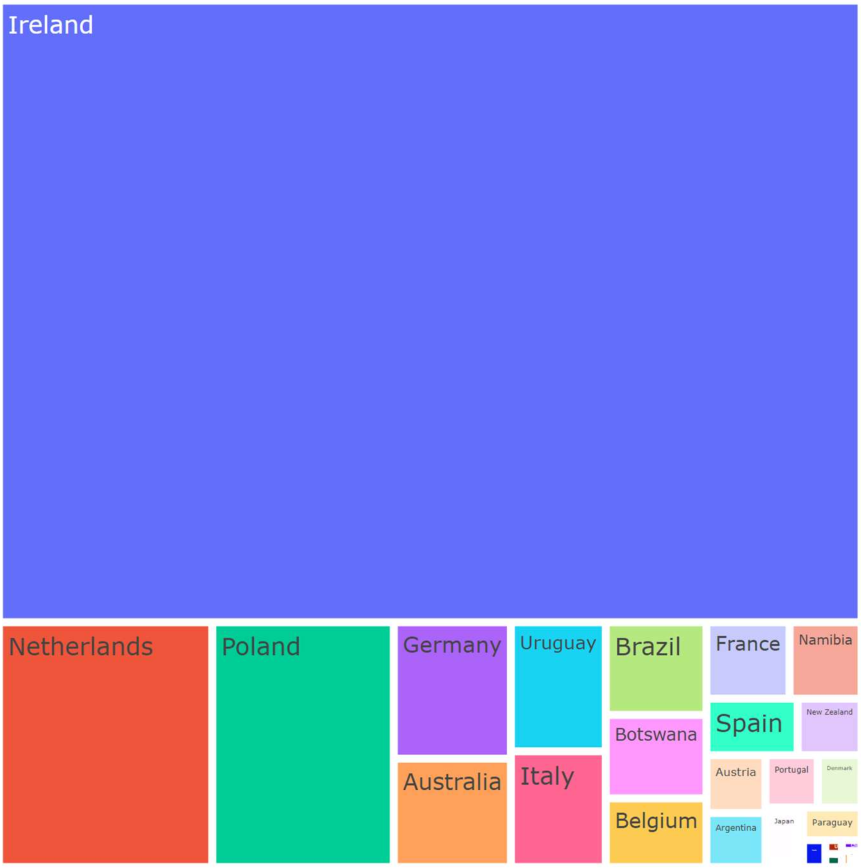


Figure 4. Imports of Bovine Meat to the UK in 2018. (UN Comtrade Database)

2.3. Bovine meat trade outside of the EU

In addition to the restrictions caused by the BSE for the exports by the UK, the exports from outside of the EU to the UK have seen their fair share of protectionism. As the figure 5 below shows agricultural goods suffer from various tariffs and non-tariff measures. For tariffs there are two distinct values based on the World Trade Organization General Agreement on Trade and Tariffs (GATT 1994) framework. The first level of tariffs is inside a tariff rate quota (TRQ), which means that a certain amount of a good can be imported at a lower tariff inside the quota. Based on GATT 1994 tariff rate quota is required to be non-discriminatory and administered in a transparent way (Movchan, Kosse & Giucci 2015). The second level is MFN tariffs, which stands for most-favourable nation. According to GATT 1994, MFN requires that all the countries which are part of the WTO are regarded equally. Thus, the MFN tariffs is applied to all the imports that are not part of trade agreements.

The tariffs inside TRQs for beef vary between nations and regulations. Based on a working document EU's DG Agri the TRQ tariffs varied from 0 tariff to Ukrainian beef imports (HS0201 and HS0202) with a limit of 12 000 tons to 20 % for high quality beef from the USA, Uruguay, Argentina, Brazil and other main importers from outside of the EU area. Against this backdrop the MFN tariff for high quality beef was 12,8 % + 303,40 EUR / 100kg for Mercosur countries. With an approximated unit price based on the UN Comtrade data for Argentine the tariff would have been ~ 50 % of the import value in 2018. Yet for Brazil it would have been more than 100 %.

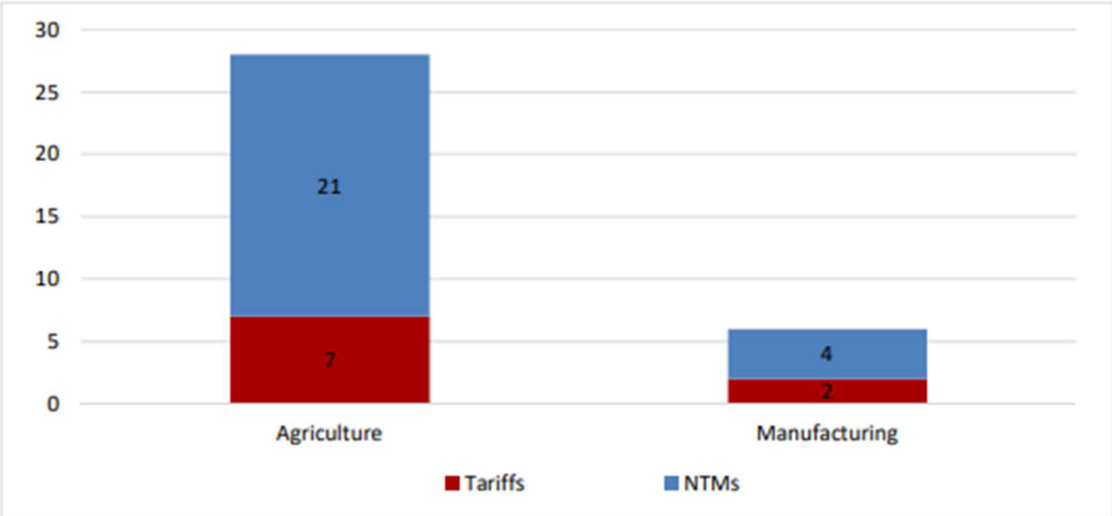


Figure 5. Comparison of trade costs related to NTMs and tariffs (UNCTAD & World Bank (2018))

2.3.1. Non-Tariff Measures

In addition to tariffs, the non-tariff measures (NTM) are significant for the agricultural and bovine meat trade as can be seen from figure 5. According to UNCTAD (2013) NTMs are three times more important for trade costs than tariffs. In addition, Fugazza et al. (2017) and Fotagne et al. (2015) have stated that they affect disproportionally small firms.

The list of non-tariff measures is long and it can be divided to technical and non-technical measures, as is done in the Figure 6 by UNCTAD shown below:

Imports	Technical measures	A	Sanitary and phytosanitary measures
		B	Technical barriers to trade
		C	Pre-shipment inspection and other formalities
	Non-technical measures	D	Contingent trade-protective measures
		E	Non-automatic import licensing, quotas, prohibitions and quantity-control measures and other restrictions not including sanitary and phytosanitary measures or measures relating to technical barriers to trade
		F	Price-control measures, including additional taxes and charges
		G	Finance measures
		H	Measures affecting competition
		I	Trade-related investment measures
		J	Distribution restrictions
		K	Restrictions on post-sales services
		L	Subsidies and other forms of support
		M	Government procurement restrictions
		N	Intellectual property
		O	Rules of origin
Exports		P	Export-related measures

Figure 6. International classification of Non-tariff Measures. (UNCTAD 2019)

According to UNCTAD TRAINS database, the European Union has 32 Non-Tariff Measures in force in the case of bovine meat. 24 of the measures are sanitary and phytosanitary, 4 are technical barriers to trade, 3 are quantity control measures and 1 not classified. According to UNCTAD (2020) European Union has four broad models with third countries in the case of NTMs:

"First, with countries with which the European Union has no FTA, WTO rules apply. Trade regulations have to follow certain principles such as those specified in the WTO

TBT and SPS Agreements. They provide for, for example, the requirement of scientific evidence, use of international standards and that regulations must not be more trade protective than necessary. However, in reality, regulations are often very different causing significant costs to traders (ESCAP and UNCTAD, 2019).

Second, the European Union has more than 40 free trade agreements notified to the WTO. Free trade agreements often include provisions to strengthen regulatory cooperation. The free trade agreement with Canada, for example, includes a chapter on technical barriers to trade that encourages cooperation in technical regulations. CETA includes a protocol that establishes the mutual recognition of European and Canadian Accreditation Bodies and Conformity Assessment Bodies by accepting the results of each other's conformity assessment certificates in areas such as electrical goods. The United Kingdom Prime Minister has mentioned this FTA as a possibility for the future European Union – United Kingdom relation.3

Third, Iceland, Liechtenstein and Norway are part of the European Union Single Market (European Economic Area, EEA), sharing all technical regulations. It is an option very close to being a European Union member but requires committing to its four freedoms: free movement of goods, services, capital and labor (Sampson, 2017). The European Union – Switzerland bilateral relationship is somewhat similar though it does not imply sharing all technical regulations.

Fourth, the European Union has a customs union with a few countries, for example with Turkey on industrial goods. This implies common external tariffs and foresees that Turkey aligns itself with the European Union Acquis Communautaire in essential internal market areas. However, the WTO rules on customs unions do not require eliminating restrictive regulations of commerce under GATT Articles XI and XX, which provide for exceptions to the elimination of quantitative restrictions and discrimination between countries where it is necessary, for example, for the application of standards or regulations for classification or grading; or to protect human, animal or plant life or health."

In the case of no deal with Brexit, the first of the four possible scenarios would have applied. In the case of the FTA the second one applies.

3. LITERATURE REVIEW

The literature review presents the prior research in import demand estimation and the various methods that have been utilized. In the last part of the chapter the specific research on bovine meat is presented. The table 1 at the end of the chapter shows the estimated results for import demand elasticities of bovine meat imports from the previous studies.

3.1. Empirical studies on Import Demand

One way to divide research on import demand estimation is between aggregate and disaggregate models. The aggregate imports of a country have been studied by Ahmed and Dutta (1999), Tang (2003) and Murray and Ginman (1976) among many others. In the aggregate studies import demand of a country is estimated on an aggregate level of all the imports to a country. On the other hand many studies focus on disaggregate imports. In disaggregate import demand estimation the focus is on a single commodity, a basket of commodities or at an industry level. Such studies have been conducted for example by Niemi (2003), Seale, Zhang and Traboulsi (2013), Sarris (1979) and Tshikala and Fonsah (2012), and Fukumoto (2012). The disaggregate studies of agricultural goods are the focus of the literature review as the thesis is based on an import demand estimation of a single agricultural good.

The other choice of an econometric study in import demand estimation is to decide the economic model that will be used. In many cases Almost Ideal Demand System (Tshikala & Fonsah, 2012, Yang & Koo, 1994) or Rotterdam Model (Seale, Zhang & Traboulsi, 2013) have been utilized. Rotterdam Model was developed by Barten (1964) and Theil (1965) where as Almost Ideal Demand System (AIDS) was developed later on by Deaton and Muellbauer (1980). Both models are multi-equation models where a number of import demand equations are combined in order to calculate substitution effects between different goods or products from different countries. Hence the benefit of the models is the possible calculation of substitution effects.

In addition to Rotterdam Model and AIDS, other studies have been conducted with a single-equation models instead of AIDS or Rotterdam Model. In some of these cases ARDL model with cointegration techniques has been utilized by Akinboade, Ziramba & Kumo. (2008), Pattichis (1999) and Rehman (2007). Akinboade et al. (2008) utilized the model for estimating import demand of gasoline, Rehman (2007) used it for aggregate imports where as Pattichis (1999) used the model for a basket of agricultural goods.

3.2. Import demand estimation of agricultural goods

In the specific case of import demand estimation for agricultural goods with econometric methods the studies utilize more often AIDS or Rotterdam models than single-equations models. Yet most of the studies use an econometric approach with error correction models when specifying single import demand equations, for example Niemi (2003), Seale et al. (2013), Sarris (1979) and Tshikala and Fonsah (2012) and Pattichis (1999) have utilized single import demand models. From these studies the approach of using import volumes, error correction model and relative prices has been absorbed.

Niemi (2003) studied import demand of seven different agricultural goods (cassava, cocoa, coconut oil, palm oil, pepper, rubber and tea) from ASEAN countries to the EU. The trade was analysed with a set of error correction models on import and export as well as demand and supply levels. For import demand the elasticity of demand to price and income changes was measured in the short and in the long term with the use of Error Correction Model. The long-run price elasticity of import demand in the EU was negative and significant for all the goods except for tea. In the case of tea no significant results were estimated. The coconut oil had the smallest coefficient at -0.77 and pepper the largest at -0.05. In the case of long run income elasticity the greatest coefficient was 1.91 for Cassava and the smallest 0.004 for rubber.

Seale, Zhang and Traboulsi (2013) estimated the import demand and supply response of the USA for fresh tomatoes, cantaloupes, onions, oranges and spinach. The estimations for elasticities were conducted econometrically with the use of Error Correction Models, Ordinary-Least Squares and first-differencing. For each good

Rotterdam Model with three largest exporters and Rest-of-the-World was utilized. The results showed that the price elasticity of import demand for each good and each area was negative except for cantaloupe imports from Rest-of-the-World, the price elasticity for cantaloupes for RoW import demand was 0.053. In the case of the others the elasticities were quite small as all the elasticities were greater than -0.10.

Tshikala and Fonsah (2012) investigated the import of fresh and frozen melons to the USA using quarterly data of import volumes and prices and utilizing the AIDS model. Again the error correction model was used for the econometric estimation. Seale, Sparks, and Buxton (1992) have estimated import demands of fresh apples from four different markets, UK, Canada, Hong Kong and Singapore to the USA.

In all of the studies previously mentioned the economic theory stems from the Armington Model (1969). Especially the Armington Assumption that the imports from different countries are distinct goods is adopted. The Armington model will be detailed in the chapter 4 of the thesis.

Yet the study that is closest to this thesis is the study conducted by Pattichis (1999) on price and income elasticities of disaggregated import demand. In the study Pattichis uses an autoregressive distributed lag model (ARDL) for measuring the elasticities of import demand for maize, milk powder, butter and rice. In addition the object is similar to the thesis, as the authors objective was to *"derive long-run price and income elasticities of import demand that can be used to analyse the impact of various policies"*. The policy effect that is analyzed by Pattichis (1999) is joining the EU whereas in this Thesis the opposite is considered. The function that was used for analyzing the import demand in the study by Pattichis (1999) was based on conventional demand theory where the demand is a function of money income and the relative price of the imported commodity.

3.3. Import demand estimation of bovine meat

In the case of import demand estimation for bovine meat the most notable studies are by Brester (1996), Miljikovic, Marsh & Brester (2002), Seleka & Henneberry (1993), Mutondo & Henneberry (2007) and Kawashima & Puspito Sari (2010). Brester (1996) analysed the aggregate import demand and domestic demand of bovine meat to the US with the use of Rotterdam Model. Brester (1996) did not report results for aggregate bovine meat imports. Instead Brester disaggregated imports between ground beef and table-cut beef. Thus the results from Brester are not quite comparable with this study. Yet perhaps the most comparable result from Brester (1996) is the estimation of the own price elasticity of demand of bovine meat (both domestic and imported), which was -0.70.

Miljikovic, Marsh & Brester (2002) estimated Japanese import demand for the US beef and pork with a modified Hooper and Kohlhagen's trade model. The econometric estimation of the study was done with Ordinary Least Squares (OLS) with variables in levels. The study found that in the import equation for beef import price and income were significant. The elasticity of import demand on income was 0.25 and the elasticity of import demand on price of imports was -0.25. A notable econometric specification in the study was that competitive prices from Australia were included as a variable in the regression model. A similar approach that is utilized in the thesis in the case of EU import demand as the competitive prices from Rest-of-the-World will be included.

In addition to the study by Miljikovic, Marsh & Brester (2002), Kawashima & Puspito Sari (2010) estimated Japanese import demand of bovine meat more recently with the use of Armington demand model to distinguish beef products by the country of origin. The focus of the study was to analyse country-of-origin bias in Japan. In the econometric study market-shares were used as a dependent variable instead of import volumes. Seleka & Henneberry (1993) researched the import demand of beef for Hong Kong. Seleka & Henneberry (1993) used a basic Marshallian demand model for the econometric research where perfect substitutability was assumed.

In 2007 Muton & Henneberry (2007) estimated US import demand price elasticities for beef for domestic bovine meat and imported bovine meat from Canada, Australia, New Zealand and Rest-of-the-World (RoW). The results of the import demand estimations in the case of beef imports that are relevant for the thesis are presented in the table 1. The relevant results from studies are below:

Table 1. Import Demand Estimates of Bovine Meat

Study	Country	Dependent variable	Variable	Value
Miljikovic, Marsh & Brester (2002)	*Japan*	Import of US beef to Japan	Own-Price elasticity of imports	-0.25
Miljikovic, Marsh & Brester (2002)	*Japan*	Import of US beef to Japan	Income elasticity of imports	0.25
Seleka & Henneberry (1993)	*Hong Kong*	Imports of beef to Hong Kong	Own-price elasticity of imports	-0.45
Muton & Henneberry (2007)	*USA*	RoW Import demand for beef	Own-price elasticity of RoW imports	-1.285

When comparing the price elasticities that have been estimated for bovine meat and for the other agricultural goods it is interesting to note that the results indicate that bovine meat has been more elastic than the agricultural goods estimated by Seale et al (2013) and that the bovine meat would rank in the more elastic portion in the study by Niemi (2003). The results from Seale et al. (2013) and Brester (1996) might support this claim as both are considering the USA markets.

The problem with comparing studies by Seale et al. (2013) and Brester (1996) is that the time periods of the studies are different and Brester (1996) estimated demand of bovine meat from both domestic and foreign markets. Hence the problem with comparing different studies is that the markets and time periods are likely different. In the case of Niemi (2003) the agricultural goods considered are such that there is likely no domestic production in the EU. Where as in the case of bovine meat and the UK domestic production has a large share of the market.

In the next sections the economic theory behind the model is presented. In the theory section the model specified is based on the import demand literature as presented above. It should be noted that the model is not completely equal to previous studies on import demand of beef. Instead it bears the most resemblance to the study by Pattichis (1999) and other studies where ARDL cointegration techniques have been utilised. One of the reasons for the use of the approach is that the study utilized single-equation models instead of multi-equation models such as Rotterdam model and AIDS. This is partly due to the nature of European and British bovine markets.

4. THEORETICAL FRAMEWORK

In theoretical framework chapter the economic theory behind the import demand estimation is presented. The economic theory presented will be later used in the methodology section to specify the econometric model.

4.1. The Economic Theory

"Few areas in all of economics, and probably none within international economics itself, have been subject to as much empirical investigation over the past thirty-five years as the behaviour of foreign trade flows." – Goldstein (2017)

According to Goldstein (2017), the formation of trade model from the perspective of economics begins with the decision whether the disaggregate model is considering imperfect or perfect substitutes in comparison to the domestic production. With imperfect substitutes it is meant that the products from different locations are not homogenous, hence domestic beef and foreign produced beef are not perfect substitutes for each other. In the perfect substitutes' scenario, the commodities are homogenous. According to Goldstein (2017), from the imperfect substitution assumption it can be derived that the price elasticities of demand and supply are finite. To illustrate this Goldstein (2017) formulated the aggregate import demand of imperfect substitutes for an importing country as follows:

$$M_i^d = f\ (Y_i, P_d, P_i), f_1, f_3 > 0, f_2 < 0 \quad (1)$$

Where the quantity of imports demanded by country i is M_i^d, the nominal income of the country i is Y_i, domestic currency prices paid by the importers are Pi and the price of domestically produced goods in the importing region are Pd. F stands for function and f_1, f_2, f_3 are the expected results of the functions of the variables, respectively. In the case of perfect substitutes import demand estimation $P_d = P_i$. This is because in the case of perfect substitutes there is only one world price that is defined by world supply and world demand according to Goldstein (2017).

In the formulation (9) by Goldstein (2017) the function is used as a part of the general equilibrium system where supply and demand for domestic market and rest of the world are formulated. The full proof that the quantity of imports demanded is assumed to be a function of the import price, domestic income level and domestic prices can be seen from the work by Goldstein (2017). In the model it is also assumed that the import demand has a negative price elasticity of import demand. On the other hand domestic prices and income have a positive elasticity to import demand.

In the model all of the right side variables are assumed to be exogenous. Thus the quantity of imports is not assumed to have a significant effect to income, price of the imports and domestic prices. According to Goldstein (2017) it is often also assumed that supply for the imports is infinite. Hence it is possible to estimate import demand with a single equation (without the full supply and demand equation system) and view P_d and P_i as exogenous variables. The authors argue that this assumption is more defensible for the country's import demand than exports. According to Goldstein (2017) it is also often assumed that there does not exist money illusion. I.e. consumer doubling of income and prices leads to same amount of quantity demanded. The assumption is also used in the model.

4.2. The Disaggregate Model

In this thesis the Armington (1969) model (the disaggregate model) is not used, yet it is presented in order to prove the usefulness of relative prices as a variable and Armington assumptions. The disaggregate model for the import demand according to Goldstein (2017) can be a two-step process. The first step is to estimate the consumers preference for the good as a whole. The second step is to estimate the demand from different sources. For the step approach to be valid in the case of a single commodity, the Armington assumptions are necessary. In the Armington assumption it is assumed that all the products are distinguished by the place of production. Thus all the products are assumed to be imperfect substitutes and bovine meat from Ireland is different from Bovine meat from Argentine. Without the assumption the import demand estimation would be of different model where excess demand is covered with imports and the imports are seen as perfect substitutes for the domestic production. The last assumption needed for the step two of disaggregate model is that "*the elasticities of substitution* *between all pairs of products in the same goods family are identical and constant in any market"* according to Goldstein (2017). From these assumptions the second step of the disaggregate model can be derived:

$$M_{1ij}^{d}/M_{1i}^{d} = b_{ij}^{\varphi ij}\,(P_{1ij}/P_{\,1j})^{-\varphi ij} \tag{2}$$

In the equation 2, M_{1ij}^{d} stands for the quantity of imports demanded of product 1 from region i, where as M_{1i}^{d} is for imports of product 1 from all the sources. $b_{ij}^{\varphi ij}$ is the base period quantity share of the country j. P_{1ij} is the price of product *1* from the country *i* to the importing country *j.* $P_{\,1j}$ is the weighted average of prices of good 1 in the domestic market (both imported and domestic). φij stands for the elasticity of substitution of the product.

As can be seen in equation 10, the import share from a single area is a function of import demand for the whole of the good and the relative price of the good to its substitutes. From the equations 9 and 10 the modelling approach of the study absorbs that the import volume from an area is a function of income and the relative price of the imports. An assumption that is common per economic theory. Yet instead of the two-step approach of the Armington model, a single-equation is used as done by Pattichis (1999) and Miljikovic, Marsh & Brester (2002). In addition if the import demand is source differentiated the competing prices of imports are included. Also in both of the models for the EU and the World the domestic production of bovine meat is included as a variable, notated as S.

$$M_i = Y_i + \frac{P_{ij}}{P_{\,i}} + S_i \tag{3}$$

$$M_i = Y_i + \frac{P_{ij}}{P_{\,i}} + \frac{P_{RoW}}{P_{\,i}} + S_i \tag{4}$$

The single-equation approach for aggregate imports of bovine meat (3) and for single area (4) is used in the empirical study. According to research by Chang & Bettington (2001) single equation approach is consistent with the multi-equation models such as Rotterdam, AIDS and Armington. The model is used especially because Pattichis

(1999) used single equation approach in unison with ARDL cointegrating model. In addition the single-equation approach makes it easier to estimate the elasticities of the EU imports when the rest-of-the-world estimates are not reliable due to protectionist nature of European Union's bovine market.

To conclude, the main variables of income and relative price that are used in the econometric model stem from the economic theory. In addition to that certain assumptions are made for the model based on economic theory. First, it is assumed that the bovine meat as a product has imperfect substitutability based on place of production. Second it is assumed that supply for the bovine meat is infinite from the perspective of the importing country. Third, it is assumed that there exists no money illusion. With these assumptions, the econometric model will be defined in the next chapter.

5. METHODOLOGY

Methodological discussion has been divided into two parts. In the first part econometric theory is presented and concepts such as unit roots, nonstationarity and cointegration are covered. In the second part the econometric models that will be used for the estimation are defined.

5.1. The Econometric Theory

"Applying appropriate methodology for the time series data is most crucial part of the time series analysis as wrong specification of the model or using the wrong method provides biased and unreliable estimates." - Shrestha, M. B., & Bhatta, G. R. (2018)

In this part of the thesis the methodology for the econometric model is presented. Especially the concepts of stationarity, cointegration and error correction model (ECM) are defined. The concept of autoregressive distributed lag model will be further defined in the chapter 4.3. where the models used are presented. The econometric models and related tests are based on Nelson and Plosser (1982), Engle and Granger (1987), Dickey and Fuller (1981), Hendry and Anderson (1977), Shrestha & Bhatta (2018) and Pesaran et al. (2001) in addition to many others.

5.1.1. Stationarity

In order to begin defining the methodological framework the concept of stationarity and non-stationarity should be defined. A concept of unit roots is the base for understanding stationarity. The unit root was studied by Nelson and Plosser (1982). The unit root means for a time series that the series has no tendency to return back to its long-term deterministic path. If a time series has a unit root then it is viewed as nonstationary. If there exists no unit root the time series is viewed as stationary and there is a tendency for the variable to return back to its mean. In addition the variance is regarded as finite for stationary time series. The number of unit roots corresponds to the order of integration of the variable. I.e. if there exists two unit roots the time series has the order of integration two which is notated as I(2). For order of integration with one unit root the notation is I(1).

According to Shrestha & Bhatta (2018) the econometric analysis should begin with univariate testing of the variables for their stationarity. In the study univariate augmented Dickey-Fuller tests are used as developed by Dickey and Fuller (1981). In addition Autocorrelation Functions are visually analysed.

5.1.2 Cointegration

The nonstationary time series can be transformed to become stationary (Shrestha & Bhatta, 2018). This can be achieved for instance by taking the first difference of the variables. If the series has a long-run trend, it can be made stationary by including a time trend variable in the model or extracting the trend with filtering techniques. Yet Shrestha & Bhatta (2018) note that such transformations can lead to a loss of information. Instead of transforming the variables it is possible in some cases to get rid of the nonstationarity with error correction model. Yet this requires that there exists a cointegrating relationship between the variables.

Engle and Granger (1987) specified that whereas the variables could have first-order of integration I(1) their coefficients could have a stationary relationship at the equilibrium. The benefit of cointegration approach is that it can be used for the Error Correction Model without losing valuable long-term information by differencing the variables. According to Granger (1986), in cointegration the residuals of the model are stationary even if the variables are not. The idea of cointegration can be modelled as follows when there is *n* amount of I(1) variables that have a stationary linear combination:

Long-term equilibrium relationship:

$$\beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \cdots + \beta_n x_{nt} = 0 \quad (5)$$

Cointegrating vector:

$$\beta = (\beta_0, \beta_1, \beta_2, \beta_n) \quad (6)$$

Equilibrium error:

$$e_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \cdots + \beta_n x_{nt} \tag{7}$$

In the case of cointegrating relationship it is meant that the equilibrium error of the model e_t is stationary. In addition the system is in it equilibrium when e_t is equal to 0. Perhaps the most famous is the Engle and Granger (1987) test for cointegration named after them. Granger (1986) described cointegration along these lines:

"At the least sophisticated level of the economic theory lies the belief that certain pairs of economic variables should not diverge from each other by too great an extent, at least in the long run. Thus, such variables may drift apart in the short run or according to seasonal factors, but if they continue to be too far apart in the long run, then economic forces, such as the market mechanism or government intervention, will begin to bring them together again."

Johansen test is another approach to cointegration testing, developed by Johansen (1988, 1991). The benefit of the Johansen test is that it can be used to test for multiple cointegrating relationships. Yet the basic test modelled by Johansen is not suitable for small samples according to Johansen (2002). The third model for testing cointegration has been suggested by Pesaran et al. (2001). According to Pesaran et al. (2001) the ARDL bounds test for cointegration requires smaller sample for significant results than Johansen test. The other differences to Johansen are that the model only requires single equation and that different lag lengths for variables can be chosen. In order to study the multivariate models an approach with cointegration is preferred instead of differencing the variables separately or conducting other transformations. Yet this requires that the cointegrating relationship exists.

5.1.3 Error Correction Model

Traditionally the next step after the cointegrating relationship has been found would be defining the error correction model. With error correction it is meant that the model adjusts to the long-run equilibrium of the system. According to Enders (2014) "*in an*

ECM the short-term dynamics of the variables are influenced by the deviation from equilibrium". The error correction model that is utilized in the econometric modelling was first developed by Sargan (1964). The approach was developed by Engle and Granger (1987) who specified 2-step approach for the Error Correction Model. Johansen (1991) developed another approach to the ECM called Vector Error Correction Model (VECM). The Engle-Granger method requires that the order of integration be of the same level for all the variables. Thus it requires certain amount of pretesting that makes it vulnerable to error according to Pesaran et al. (2001).

The third model comes again from Pesaran et al. (2001) who continued to develop ECM further by using autoregressive distributed lag model (ARDL) for specifying the ECM. According to Pesaran et al. (2001) leads to "a further degree of uncertainty into the analysis of levels relationships". Instead Pesaran et al. (2001) suggest an approach for testing cointegration irrespective of the order of integration of the variables. This test is called bounds test for cointegration or ARDL bounds test for cointegration. Instead of requiring previous knowledge of the order of integration for I(0) and I(1) variables, Pesaran et al (2001) require that the variables do not have an order of integration of I(2) or greater. The authors suggest that an autoregressive distributed lag (ARDL) modelling approach is used. The approach is based on their study which tested five different conditional Error Correction Models and found out that:

"*if a sufficiently high order is selected for the lag lengths of the included variables, the hypothesis that there exists no relationship in levels between these variables is rejected, irrespective of whether they are purely I(0), purely I(1) or mutually cointegrated"*

Thus the first step with Pesaran et al (2001) approach is also to conduct univariate tests in order to fulfil the requirement of <I(2) variables. The second step is to create an Ordinary Least Squares model. Then the OLS is used in order to test for a suitable lag length with Akaike Information Criterion. With the specified Error Correction Model the tests for cointegration can be done. Lastly the models results can be interpreted if there is significant cointegration between the variables. Next the formulation of a generic Engle-Granger error correction model (ECM) is shown:

$$y_t = a_1 + a_2 x_{1t} + a_3 x_{2t} + a_4 y_{t-1} + \varepsilon_t \tag{8}$$

In the equation y_t is the dependent variable, ε_t is the error term and $x_{nt}$are the exogenous variables and a_n are the coefficients. For the model the long-run equilibrium relationship would be:

$$y_t = a_1 + a_2 x_{1t} + a_3 x_{2t} + a_4 y_{t-1} \tag{9}$$

And the short-run relationship would be where y_{t-1} is taken from both sides with some algebraic transformations:

$$\Delta y_t = a_1 + a_2 \Delta x_{1t} + a_3 \Delta x_{2t} - \lambda(y_{t-1} - \alpha - \beta_0 x_{1t-1} - \beta_1 x_{2t-1}) + \varepsilon_t \tag{10}$$

If there is linear cointegrating combination for the nonstationary variables of the same order the cointegrating term $(y_{t-1} - \alpha - \beta_0 x_{1t-1} - \beta_1 x_{2t-1})$ is stationary. In the case where cointegration does not exist the Error Correction Model cannot be used. The equation inside the brackets will be notated as $\hat{\varepsilon}_t$:

$$\hat{\varepsilon}_t = y_{t-1} - \alpha - \beta_0 x_{1t-1} - \beta_1 x_{2t-1} \tag{11}$$

Where $\hat{\varepsilon}_t$ is the variable that connects the y and $x_1$and x_2 in the long run. As equation (9) is the long-run equation for the error correction model, we can append it with the short-run part of the model where the cointegration variable is included. Thus we can derive the ECM model as follows:

$$\Delta y_t = a_0 + \alpha_1 \Delta x_t + \pi \hat{\varepsilon}_{t-1} + v_t \tag{12}$$

Now the equation includes both long-run and short-run information. In the model b_1 is the short-run effect and π is the adjustment effect. This error correction model can also be presented in ordinary least squares form.

5.1.4 ARDL Bounds test

In the case of the ARDL bounds test approach the model differs slightly from the equation 12:

$$\Delta y_t = a_0 + \alpha_1 \Delta x_t + \beta_0 y_{1t-1} + \beta_1 x_{1t-1} + \beta_2 x_{2t-1} + e_t \qquad (13)$$

In the equation 13 instead of using the Engle-Granger method where there is a constraint (equation 11) the ARDL bounds test approach uses unrestricted Error Correction Model. With unrestricted ECM it is meant that all the long run variables are specified and thus there is no restriction about the presence of any variables, as there would be with the residual based approach of Engle-Granger method. In the equation 13 the variables $\beta_0 y_{1t-1}$, $\beta_1 x_{1t-1}$ *and* $\beta_2 x_{2t-1}$ come from the equation 11. A basic F-statistic test is used to test the hypothesis:

$$H_0: \beta_0 = \beta_1 = \beta_2 = 0 \qquad (14)$$

If the H_0 can be rejected a long-run relationship between the variables exist and thus they are cointegrated. Hence in the case of ARDL Bounds Test the error correction model is specified before the cointegration tests. The results of the tests for the data will be shown in chapter 6 of the thesis.

5.2 The Econometric Model

The econometric modelling approach is done with an ARDL model where variables can have different lag lengths. The lags for the ARDL model have been chosen with Akaike Information Criterion following the guideline by Shrestha & Bhatta (2018). The values of the information criterion per model are presented later on with the data. An example of the ARDL model for all the imports to the UK with a lag length of 2 for the production quantity S and a lag length of 1 for the rest of the variables without error correction transformation is the following:

$$lnM_t = \alpha_0 + \alpha_1 lnY_t + \alpha_2 lnY_{t-1} + \alpha_3 ln\frac{P_{ij}}{P_{i_t}} + \alpha_4 ln\frac{P_{ij}}{P_{i_{t-1}}} + \alpha_5 lnM_{t-1} + \alpha_6 lnS_t + \alpha_7 lnS_{t-1} + \alpha_7 lnS_{t-2} + \varepsilon \quad (15)$$

In the model *M* stands for import volume in kilograms to the UK. *Y* for domestic economic activity which is measured with UK chained GDP. P_{ij} is the average annual unit value of bovine meat from the exporting country *j* at a nominal value. P_i is the price index of the bovine meat in the domestic market. Thus $\frac{P_{ij}}{P_i}$ is the relative price of imports. The expected signs per economic theory are negative for α_3, α_4, α_6, α_7 and positive for α_1, α_2. For the income and prices the signs are the same which were shown in the economic model (1). The domestic production *S* is assumed to have a negative impact to import volumes. The next step is to transform the equation (15) to an error correction form, according to theory from the previous section The model is shown below, driven by *Y, S* and $\frac{P_{ij}}{P_i}$. :

$$\Delta \ln M_t = \alpha_0 + \alpha_1 \Delta \ln Y_t + \beta_2 \ln Y_{t-1} + \alpha_3 \Delta \ln\frac{P_{ij}}{P_{i_t}} + \beta_4 \ln\frac{P_{ij}}{P_{i_{t-1}}} + \beta_5 \ln M_{t-1} + \alpha_6 \Delta \ln S_t + \alpha_7 \ln S_{t-1} + \alpha_8 \ln S_{t-2} + v_t \quad (16)$$

In the equation β is the notation for long-run coefficients and α is for the short-term. Short term coefficient α_1 and the long-term β_2 coefficients are expected to be positive where as the price effects α_3 and β_4 are expected to be negative. The fifth term β_5 is the feedback coefficient of the error correction term of the equation. The coefficients for production are expected to be negative. The feedback coefficient indicates the magnitude of the dependent variable that is corrected from disequilibrium when going from one period to another and it is expected to be between 0 and -1. In this context the period is annual.

The equation (16) is used for the aggregate imports and is notated as ARDL(1, 1, 1, 2) from now on. The notation for the ARDL is following ARDL(L_1 …. L_i) where L_1 is the lag length of the first variable and L_i is the lag length of *i:*th variable. Hence in ARDL (1,1,1,2) the notation of 2 is used for the lag length of production S. In the case of import demand estimation for the EU the equation (16) is modified to include a variable for the price level of the other markets. Thus the second step equation becomes:

$$\Delta \ln M_t = \alpha_0 + \alpha_1 \Delta \ln Y_t + \beta_0 \ln Y_{t-1} + \alpha_2 \Delta \ln \frac{P_{ij}}{P_i}_t + \beta_1 \ln \frac{P_{ij}}{P_i}_{t-1} + \beta_2 \ln M_{t-1} +$$

$$\alpha_3 \Delta \ln \frac{P_{RoW}}{P_i}_t + \beta_3 \ln \frac{P_{RoW}}{P_i}_{t-1} + \alpha_4 \Delta \ln S_t + \beta_4 \ln S_{t-1} + \beta_5 \ln S_{t-2} + v_t \qquad (17)$$

In the equation (17) i stands for the area in question (EU) and RoW for the rest of the world. The ARDL model for the EU is notated as ARDL(1, 1, 1, 1, 2). The lag lengths of the models were selected with Akaike Information Criterion (AIC). The tests will be shown in chapter 6.

As can be seen from the equations (16) and (17), the constant is included in the regressions. Pesaran et al (2001) presents five different cases for the long-run relationship (cointegrating equation) and the bounds-test for cointegration and restricted ECMs.

Case 1: No intercept and no trend.
Case 2: Restricted intercept and no trend.
Case 3: Unrestricted intercept and no trend.
Case 4: Unrestricted intercept and restricted trend.
Case 5: Unrestricted intercept and unrestricted trend.

In the case of the thesis the Case 3 approach is adopted for the cointegration tests and the modelling. In the next section the data is presented as well as the tests conducted.

6. DATA

6.1. Data

As indicated earlier, based on trade theory the dependent variable is usually a quantity of the imported good. Thus, the dependent variable can be quite easily derived from the real world data. In the model the dependent variable *M* is the net weight of imports of bovine meat in kg where harmonized system codes HS0201 (Bovine Meat, Fresh or Chilled) and HS0202 (Bovine Meat, Frozen) have been aggregated. On the right hand side of the equation (1) the variable Y_i stands for income of the country i as mentioned before. The income is estimated with the chained GDP of United Kingdom. The expected value is that the import demand is a positive function of income. The other value from the model is P_{ij} which stands for the price of imports to the country *i* from country/countries *j*. It is estimated with the trade data where the net weight of imports in kg has been divided by the value of the imports.

In order to derive the relative value to the domestic prices the unit price has been divided with price index of beef P_i in the UK. The expected coefficient for the relative import price impact is negative. Thus it is expected that the relative price increase leads to a decrease in imports. The relative price variable follows from the models outlined in (1) and (2). Production in the country *i* has been measured with the amount of slaughtered animals (headcount). The variable is notated as S. Data for the study comes from United Nations Comtrade database[2], eurostat[3] and the UK government sources[4]. Variables used for the study are the following in Table 2 below:

[2] https://comtrade.un.org/
[3] https://ec.europa.eu/eurostat/web/agriculture/data/database
[4] https://www.ons.gov.uk/economy/

Table 2. Data and Variables

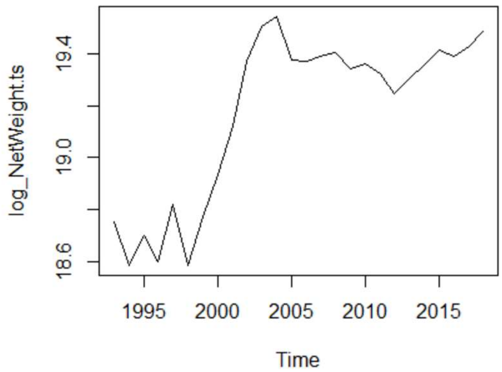
Variable	Abbreviation	Unit	Source
Net Weight of Imported Bovine Meat in KG. (Aggregated HS0201 and HS0202)	M	KG	UN Comtrade
Trade Value of imported Bovine Meat.	–	$	UN Comtrade
Price Index of Beef in the UK	P_i		UK Government
Gross Domestic Product at Chained Value	Y		UK Government
Slaughters of cattle in the UK in KG. Used as a proxy for production.	S	KG	eurostat
Relative Unit Price of Imports. Calculated by dividing trade value with the net weight of imports. Then dividing with the price level of domestic goods.	$\frac{P_{ij}}{P_i}$	$	Calculated
Log of Net Weight of Imports	lnM		Calculated
Log of Relative Unit Price of Imports	$ln\frac{P_{ij}}{P_i}$		Calculated
Log of GDP Chained Value	lnY		Calculated
Log of Slaughters	lnS		Calculated

The time period of the study is 1993-2018 with an annual data frequency. Imports are estimated at the World and the EU levels. In the case of the model for the imports from the EU the price of imported goods from the Rest-of-the-World is included as the variable.

The imports of bovine meat are tested with aggregated bovine meat data. Harmonized Commodity Description and Coding Systems is used in the aggregation of Bovine meat. The tests are conducted with aggregated HS0201, Bovine Meat Fresh or Chilled and HS0202 Bovine Meat Frozen in order to include all bovine meat trade. The aim of the model is to achieve results at the World and the EU level in order to estimate possible effects of Brexit. The estimation was also conducted for Rest-of-the-World import demand, but no results were reached.

6.2. Univariate tests for the data

According to Shrestha & Bhatta (2018) the testing of the data should begin from graphical analysis of the time series. After the graphical analysis, the time series properties are to be verified via testing. For the testing and the model all of the variables are transformed to log-linear form in order to gain better interpretability of the results. The transformed variables are shown in table 2.



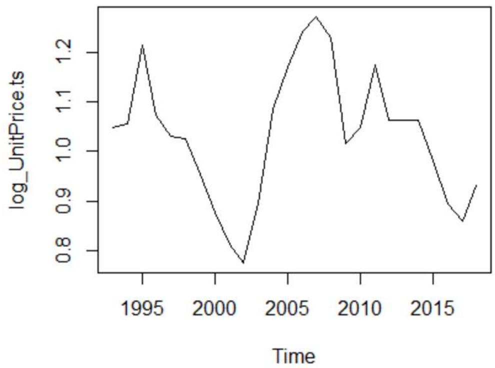


Figure 7. Bovine Meat Imports and Unit Prices of combined HS0202 and HS0201 to the UK.

As can be seen from the graphs in figure 7, the aggregate imports of bovine meat as a net weight in kilograms (left) in log-linear form has a clear trend. The relative price of imports in logarithmic form (right) seems to have a downward trend which is not so clear. The next step is to verify these claims. For all the variables Augmented Dickey Fuller approach is used where constant has been included. For first differences of the variables the constant is removed from the ADF test. The next table shows the univariate tests for all the areas and all the variables.

Table 3. Unit Root tests of the variables

Area	Value	Augmented Dickey Fuller T-statistic*	diff(ADF)*	Order of Integration
World	lnM	1.55 (>0.10)	-2.05 (<0.05)	I(1)
	$ln\frac{P_{ij}}{P_i}$	-0.377 (>0.10)	-3.04 (<0.01)	I(1)
EU	lnM	1.66 (>0.10)	-2.38 (<0.05)	I(1)
	$ln\frac{P_{ij}}{P_i}$	-0.21 (>0.10)	-3.174 (<0.01)	I(1)
UK	lnY	2.23 (>0.10)	-1.41 (>0.10)	I(2)
	lnS	0.16 (>0.10)	-4.00 (<0.01)	I(1)

```
* Critical values for test statistics:        1pct  5pct 10pct
                                             -2.62 -1.95 -1.61
```

In addition to ADF tests shown in Table 3, the log-linear form variables and their first differences are graphically inspected with the use of Autocorrelation Function plot.. In figure 8 below there is an example of the ACF plots for the first differences of the net weight of aggregate imports of bovine meat to the UK (right) and the price of the imports (left):

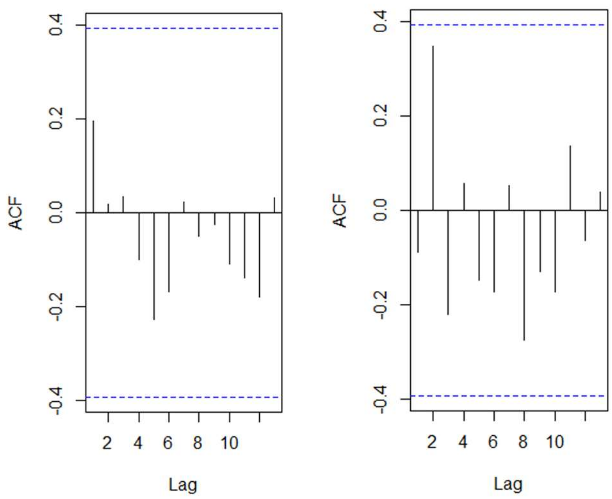


Figure 8. Autocorrelation Function plots (Left: Net weight of Imports from the world. Right: Unit price of the imports)

6.2.1. Unit Root test of the GDP variable

The problem in the unit root tests is that for the chained GDP in logarithmic form, lnY, the results show that the variable would have an order of integration of 2 whereas based on economic theory GDP should not be I(2). In addition the plot in figure 9 shows that the differenced lnY variable is quite stationary yet the financial crisis outlier might be the reason why the test does not result to I(1) level. Because of the plot variable, relatively close t-statistic (-1.41) to 10 % (-1.61) level and the basic economic theory it is assumed that the GDP has an order of integration (1) instead of I(2). Thus the variable is used as an independent variable in the models.

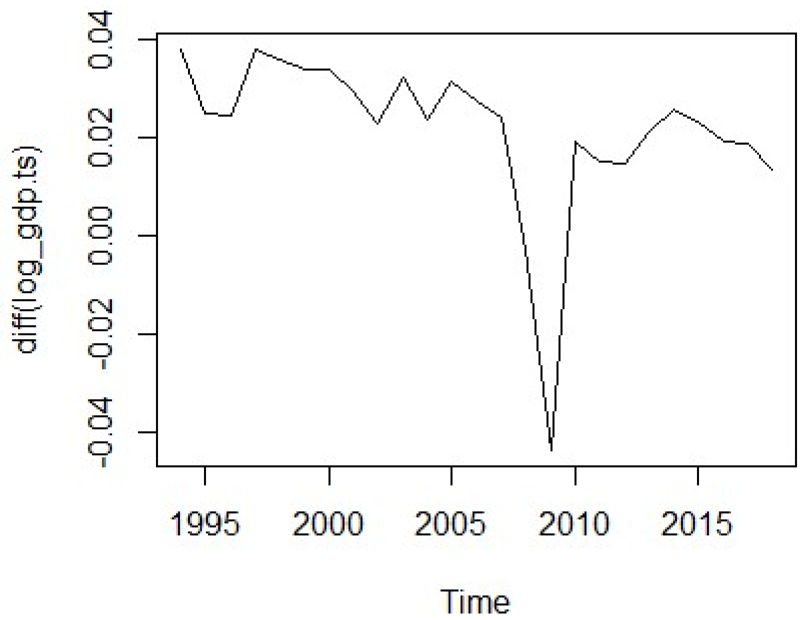


Figure 9. Graph of the logarithmic form of chained GDP in the first differences

6.3. Cointegration tests

According to Shrestha & Bhatta (2018), after testing for the unit roots the tests for cointegration are conducted with the log-linear form variables in order to capture the long-run relationships between the variables. The specific test for cointegration is Autoregressive Distributed Lag (ARDL) bound test for f-statistic (Wald) according to Pesaran et al (2001). The basic idea of the test is to test whether the value β from the equation (2) is significantly different from zero. According to Philips (2018) a few assumptions must be met before cointegration test can be trusted. First of all the dependent variable must have an order of integration I(1). This requirement is met for both the EU and the World models. Secondly it should be checked that there is no autocorrelation left in the residuals. For the models autocorrelation function of the residuals was plotted that suggested that there was no serial correlation left. The plots will be shown in chapter 7.

The Wald-test of F-statistic can be computed from the equations (14) and (15), the unrestricted ECM ARDL models. Only the variables in levels can be tested for cointegration with the dependent variable. In addition the equations are restricted thus that:

$$H0 : \beta_0 = \beta_1 = 0 \quad (16)$$

Where the null hypothesis is that the coefficient of the lagged dependent variable (β_0) and the coefficients of the vector of independent variables in levels (β_1) have no cointegrating relationship. In the bounds F-test for cointegration the critical value is calculated for both stationary I(0) and order of integration I(1) levels. If the value is greater than I(1) level, cointegration can be accepted. If the value is less than I(0) value, it can be accepted that there is no cointegration. In the case that value is between the two, the result is inconclusive. The interpretation of the Bound Test Statistics according to Philips (2018) is shown in figure 10.

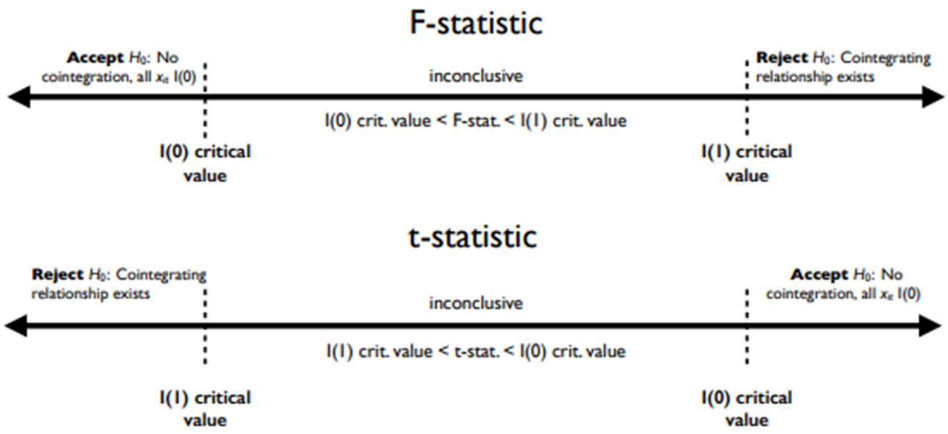


Figure 10. F- and t-statistic interpretation (Philips 2018)

The test values have been calculated according to research by Narayan (2005) with critical values for the specific small sample size (T=24). The results are shown in the table below:

Table 4. Values of F-statistic test for the EU and the World models.

Area	Model	Bound F-Test (Wald) for no Cointegration t-value	P-value
World	ARDL (1,1,1,2)	-3.55	0.088*
EU	ARDL(1, 1, 1, 1, 2)	-3.71	0.091*

**Critical Value bounds of the F statistic: intercept and no trend (T=24):*

10 % level		5 % level		1 % level	
I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
-2.59	-3.49	-2.98	-3.92	-3.73	-4.88

In Table 4 the models used are the equation (14) for the world and equation (15) for the EU. Both the EU and the World show cointegration between import quantities and the vector of the other variables in levels at the 10 % level. Cointegration was also tested for Rest-of-the-World with different ARDL lengths and variables. Yet no cointegration was found. Likely this is due to the protectionist barriers for imports of beef. Especially Tariff-Rate-Quotas might affect the amount of imports thus that price nor income are not likely to show relation with the amount of imports. The next step of the thesis is to show the results of the ARDL-ECM estimation with the EU and the World models.

7. RESULTS

7.1. The World

The first ARDL model was run on aggregate level with all the imports of Bovine Meat to the UK. In order to define suitable lag length Akaike Information Criterion was utilized. The model was run with log of BSE cases per year included as a variable and without. The results were that the inclusion of the BSE variable decreased adjusted R-squared of the ECM (ARDL 1,1,1,1,2) model to a 0.61 level from the 0.66 level of the model that did not include the variable (ARDL 1,1,1,2). Thus, the Akaike Criterion was tested for a set of models without a variable for BSE. The lag length for each variable was set to be between 1 and 2 in order to keep the interpretability of the model and due to the short length of time series. For the variables that have an order of integration of 1 it is necessary to have a lag length that is greater than 0. The results of the AIC value for different aggregate imports of bovine meat are the following:

Table 5. AIC tests for the World models

lnS	lnM (dependent)	$ln\frac{P_{ij}}{P_i}$	lnY	AIC
2	1	1	1	-48.533
2	2	1	0	-47.674
1	1	1	1	-41.601
1	1	1	0	-41.086
1	2	1	0	-38.755
1	2	1	1	-37.889
1	1	2	1	-36.953

The lag length for the model was decided to be ARDL (1,1,1,2) based on the AIC. The results for the error correction model are the following:

Table 6. ECM-ARDL (1,1,1,2) for the dependent variable lnM

Area	Coefficients	Value	P-Value	Adj. R-squared
World				0.657
	(Intercept)	-1.447	0.445	
	Long-term variables			
	$LlnM$	-0.483	0.003	
	$Lln\frac{P_{ij}}{P_i}$	-0.339	0.030	
	$LlnY$	0.783	0.016	
	$LlnS$	-0.448	0.026	
	$\Delta LlnS$	0.811	0.001	
	Short-term variables			
	$\Delta ln\frac{P_{ij}}{P_i}$	0.315	0.163	
	ΔlnY	-1.00	0.442	
	ΔlnS	-0.437	0.063	

In the table 6, L stands for the first lag of the variable and Δ for the first differences. Thus ΔL in the case of slaughters stands for the second differences. The autocorrelation function of the residuals of the model in figure 11 shows that there is no serial correlation:

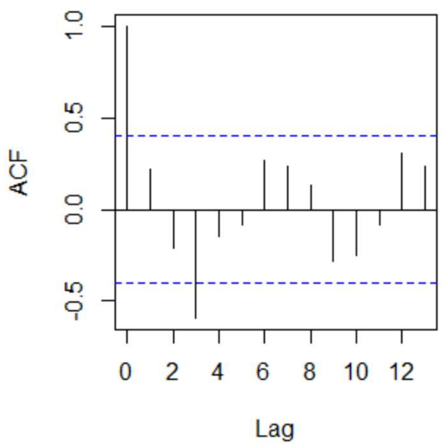


Figure 11. ACF of the residuals of the World model

The results show that all the long-run variables are significant at 1 % or 5 % levels whereas out of the short-run variables only the production quantity S is significant.

The coefficients of significant variables are as expected a priori in equation 1 of the economic theory. The adjusted R-squared is at 0.66 level.

Due to the transformation of variables to logarithms the coefficients can be straightforwardly interpreted as elasticities. Thus the results indicate that the long run relative price elasticity of import demand is quite inelastic at -0.34. The estimated import demand of bovine meat to the UK is quite similar to the study by Miljikovic, Marsh & Brester (2002). They estimated import demand of bovine meat to Japan from the USA to have a coefficient of -0.25 in double logs. The estimation was also based on aggregate imports of bovine meat. The difference is that Miljikovic, Marsh & Brester (2002) did not estimate the import demand model for the whole world.

The long run income elasticity of import demand at 0.78 level is higher than in the study conducted by Miljikovic, Marsh & Brester (2002) whose study estimated income elasticity of import demand to be 0.25. Yet the income elasticity of import demand is quite similar to the income elasticity of aggregate demand for beef estimated by Brester (1996). In the study the income elasticity of aggregate demand for beef was estimated at 0.70.

7.2. The EU

The AIC test for the EU is the following:

Table 7. AIC tests for the EU models

lnS	$lnM(dependent)$	$ln\frac{P_{ij}}{P_i}$	$ln\frac{P_{RoWj}}{P_i}$	lnY	AIC
2	1	1	1	1	-44.217
2	2	2	1	1	-42.255
2	1	2	2	1	-41.627
2	1	2	1	2	-40.730
2	2	2	2	1	-40.671
1	2	2	1	1	-40.305
2	2	2	1	2	-40.082
1	2	1	1	1	-39.720

Thus the ARDL(2,1,1,1,1) model was chosen. The results for the Error Correction Model with the EU are in the Table 8:

Table 8. ECM-ARDL (2,1,1,1, 1) for the dependent variable lnM

Area	Coefficients	Value	P-Value	Adj.R-squared
EU	*(Intercept)*	-9.412	0.131	0.746
	Long-term variables			
	$LlnM$	-0.635	0.003	
	$Lln\frac{P_{ij}}{P_i}$	-0.412	0.030	
	$LlnY$	1.549	0.017	
	$Lln\frac{P_{iRoW}}{P_i}$	-0.201	0.369	
	$LlnS$	-0.062	0.862	
	$\Delta LlnS$	0.673	0.022	
	Short-term variables			
	$\Delta ln\frac{P_{ij}}{P_i}$	0.145	0.537	
	ΔlnY	-1.021	0.499	
	$\Delta ln\frac{P_{iRoW}}{P_i}$	0.406	0.080	
	ΔlnS	-0.562	0.097	

And the ACF plots of the residuals of the model is shown below in Figure 12:

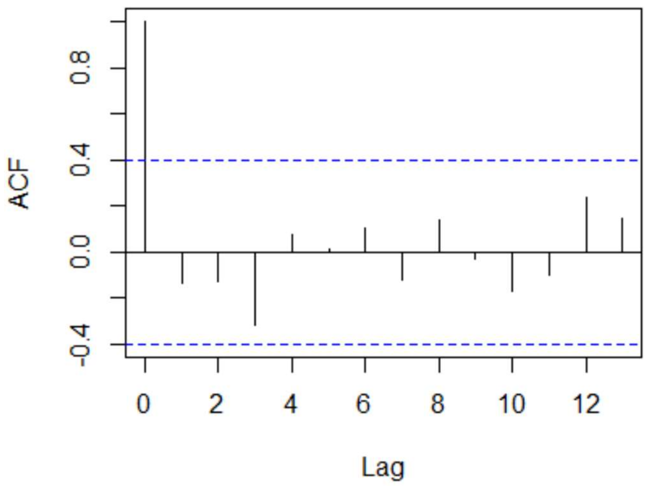


Figure 12. ACF Plots of the Residuals of the EU model

The expected signs, based on economic theory, of the coefficients for significant variables are met by the results. The adjusted R-squared value is quite high at 0.75 level. The long run price elasticity of import demand $Lln\frac{P_{ij}}{P_i}$ at -0.412 indicates that import demand from the EU is more elastic than the World import demand of bovine meat to the UK. However not by a large margin. The difference in results might be due to problems in estimating the Rest-of-the-World imports. Yet it might also be that the first model estimates elasticity of all the imports and thus substituting them is a question of substitution between imports and domestic production. On the other hand the second model is a question of substitution between imports from the EU and imports from elsewhere in addition to domestic production.

The long run income elasticity of demand for the model is 1.55 which implies that it is quite elastic. Especially so, when compared to the study by Miljikovic, Marsh & Brester (2002) whose study estimated income elasticity of import demand to 0.25 as noted before. Yet the difference might be explained again by the use of a different model. It is also interesting that income elasticity is larger by a wide margin between the world long run income elasticity of import demand and the EU's.

In the EU model competitive prices are included. In the long-run the model shows that the prices are not significant. Yet in the short-run the competitive prices are significant and the elasticity of import demand to prices from RoW is 0.406. This shows that the import demand is quite inelastic to competitive prices. Economically the coefficient is as per economic theory. It makes sense that if the price in competitive markets increases, more is imported from the EU.

7.3. Rest-of-the-World

For the countries outside of the European Union no cointegration was found between import volumes and the variables. The main reason for this could be the Tariff Rate Quotas (TRQs). For the European Union, the factors affecting imports are more likely to be in the market forces while imports from rest-of-the-world suffers from heavy regulation. Partly the reason why single-equation models were used in the study is that results from the estimation of the rest-of-the-world import demand might not have been trustworthy. This is also a problem with the inclusion of the Rest-of-the-World relative prices variable in the EU equation. Yet the best estimate is likely reached with the inclusion of the variable.

7.4. What the results mean for the Brexit

The study was done with single-equation models instead of a multi-equation model such as Rotterdam or AIDS. One of the reasons for this specification was the reasons mentioned for difficulty of estimating trade from outside of the EU. Yet in the case of the EU it is shown that the prices from Rest-of-the-World affect the import volumes from the EU. Though this might not be purely due to the market forces. In the case of the Brexit the rest-of-the-world trade will be different from the time series used as there will be a change in how competitive the EU and the Rest-of-the-World markets will be that is not related to the price of the products but instead in regulatory change. Thus instead of change in the tariff levels the change in non-tariff measures will have a significant impact on the competition.

With the above facts in mind, an indicative estimation of the different scenarios of Brexit that might have happened has been mase. In the case of the tariffs, the hard Brexit is considered as a scenario where the UK would have tariff levels that the EU might have set against it. The tariff level by the EU is its tariff level for countries whom the EU has no deal with. Yet instead of using the methodology provided by the EU an aggregate approximation of the tariff in ad valorem equivalent form is used. The aggregate value is used due to the complexity of the import tariffs that are used by the EU. For instance tariff for high quality beef imports from Argentina is 12.80 % + 176.80 €/ 100 kg. Instead of such a values the WTO's IDB database provides ad-valorem equivalent (AVE) form of tariffs. Ad-valorem equivalent means that the tariffs are not in percentages are converted to percentage form. For HS0201 and HS0202 bovine meat the average AVE of the tariffs is 94.56 %, based on the WTO's IDB database.

In the case of Non-Trade Measures (NTM) an AVE of 71 % has been estimated for cattle meat by Sanjuán, Resano & Philippidis (2017) in the context of EU-USA bilateral trade. Obviously, the tariff equivalent impact of NTMs would be different for different countries, yet for the simulation purposes the number is used as the estimation for the NTMs that might have come into place for the EU-UK relationship with no deal Brexit. Calculating the AVE value of the FTA that came into force between the

EU and the UK on 1.1.2021 is outside of the scope of the thesis yet is likely less than the value of NTMs between the EU and the USA.

The analysis is done with the ARDL-ECM EU model as defined in the previous chapter and with an assumption of *ceteris paribus*. Thus the income and production levels are assumed to stay the same when the relative price changes. In this study it is not simulated whether the income, production or Rest of the World prices would have changed due to different Brexit scenarios, instead the focus is solely on the price effect.

In the case of a one standard deviation increase in the relative price of imports from the EU the volume would decrease ~ 7 %. One standard deviation change is approximately 17 % increase for the European prices, and thus a good indicator of the change that would have happened if the bovine meat tariffs were inside the tariff-rate quota levels. If the most-favored-nation (MFN) levels of the EU were to be in force against the EU (without NTM's included) the import price of 4,97 $ in 2018 would move to 9,69 $. The MFN level tariffs are interesting to consider as those would have been the tariff level that the EU would have had on the British exports to the EU after the Brexit if there had been no deal. The increase would have been ~ 6 standard deviations from the time series used for estimation. Based on the model the decrease in imports from the EU would have fallen ~39%. The scenario would have been even worse with the NTMs. As the study by Sanjuán, Resano & Philippidis (2017) shows, the impact of NTM's can be almost the same for bovine meat as the tariffs. In Table 9 below the different scenarios will be shown. The estimated changes are indicative as constant elasticity is assumed. In order for a better estimates the elasticities from the study should be used in a partial- or general equilibrium model. The ad valorem estimate of non-trade measures (NTM) of the Brexit is considered to be the same as in the EU-USA.

Table 9. Price effect of different scenarios on imports of bovine meat

Scenario	*Change in the price of imports*	*Change in the import volume*
Tariff increase by one standard deviation	17 %	-7 %
NTMs	71 %	-29 %
EU level tariffs	94 %	-39 %
EU level tariffs + NTM's	165 %	-68 %

Hence the results show that the import of bovine meat is quite inelastic, yet in the case of the Brexit, the impact to tariffs and NTMs could have been such that the fall in import demand would have been drastic even though the import demand is inelastic. As the result from the EU import demand estimation shows, if the relative price of imports from the Rest-of-the-World increases, more is demanded from the EU. It is likely that the effect is opposite, yet the extent is not possible to be estimated based on the past time series. Even though the EU and the UK reached a deal where there is no tariffs between the participants there will be NTM's that will increase the cost of trade between the areas. The NTM's will certainly have an effect on the price of the imports of bovine meat. In addition a threat to the competitiveness of the European bovine meat in the UK is that due to the Brexit the UK is free to decrease its tariffs and NTM's for the Rest-of-the-World and hence the imports from the EU will suffer more competition than before.

8. CONCLUSIONS AND THE WAY FORWARD

The research question of the Thesis were to what extent are United Kingdom's bovine meat imports elastic to price and how a possible tariff increase due to Brexit would affect the imports. The estimates reached by the study suggest that United Kingdom's bovine meat imports are quite inelastic at both World and the EU levels. Yet the question of how Brexit would have impacted and will impact the import volume from the EU is more troublesome to answer.

In the past two decades the EU has dominated United Kingdom's imports. In order to answer the second question thoroughly the possibilities of importing bovine meat from outside of the EU would need to be known. Yet due to the regulation of the EU the rest-of-the-world has not been able to compete with the EU in the past. Thus it was not possible to model the extent of substitution from the EU imports to RoW imports due to tariff increase in the EU imports.

The estimated elasticities from the econometric research suggests that especially hard Brexit would have led to a significant decrease in the import volumes from the EU. Even in the case of Brexit with a deal between the EU and the UK the imports will decrease due to non-tariff measures and increased competition. Yet the decrease in imports depends on the coming trade relations of the UK and Rest-of-the-World as well as the costs of non-tariff measures due to Brexit. The decrease in imports would mean that especially Ireland would need to find other destinations for its bovine meat exports. This could mean excess supply in the EU where Ireland can continue exporting bovine meat without restrictions. Thus, the Brexit is likely to have a price decreasing effect for the EU markets as there will be an excess supply of bovine meat. Yet a less significant than what it would have been due to hard Brexit.

In addition to the price elasticity of the import demand, the income elasticity was found to be significant in all the cases studied. It is likely that there would be a decrease in the imports of bovine meat to the UK due to Brexit and the possible decrease caused by it in the GDP. Yet it is difficult to forecast the fall in GDP due to different Brexit scenarios, and thus the modelling of the scenario was omitted from the scope of this thesis.

A single other event that might have caused distortions in the time series is the BSE, “mad cow” disease, that certainly affected the import demand in the 90’s. In order to avoid this omitted variable bias, the BSE variable was tested in the model but found out to be non-significant and decreasing the goodness of fit of the model for the time period in question. Yet the BSE is taken into account to an extent with the inclusion of production data in the UK that shows a clear slump at the time of worst the BSE crisis. In addition, the relative prices take into account BSE with the price level index of the UK.

In the study many assumptions were made and thus decreasing the assumptions needed would make the results more trustworthy. Considering production quantities in the other countries, and thus having a supply demand equation instead of an assumed infinite supply, might affect the results. In addition, constant elasticity of substitution was assumed whereas in the real world it is likely not the case. However with this study the elasticities of the import demand of bovine meat from the EU to the UK were defined. The elasticities estimated in the study could be used in the construction of a general or partial equilibrium models that would be able to consider impact of Brexit more thoroughly. With a partial equilibrium model perhaps more accurate estimates of different Brexit scenarios would be reached.

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