THESIS

QUALITY AND PRICE IMPACTS ON U.S. DEMAND FOR LAMB IMPORTS

Submitted by

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ABSTRACT

QUALITY AND PRICE IMPACTS ON U.S. DEMAND FOR LAMB IMPORTS

The U.S. lamb industry has changed in the last decade, potentially impacting the structure of the import industry, which has become necessary to meet domestic demand. Domestic production has continued to decline, consumer demographics have shifted to reflect a growing ethnic consumer population, and promotional efforts have been met with varying degrees of success. This work updates previous research to evaluate how changes in the industry may affect import demand using a differential production model approach, and extends the literature to evaluate the role of boneless/bone-in product differentiation in importer demand using an absolute price version of the Rotterdam model. Results indicate that the structure of the lamb import market has remained relatively consistent across the past three decades, even with the inclusion of an additional fifteen years of data. Importers appear to have become less responsive to changes in prices, with demand for all imports becoming more inelastic. Product differentiation is found to play an important role in import demand, with boneless and bone-in products showing evidence of separability. Source-specific association with different product qualities appear to be emerging, with preference for frozen lamb from New Zealand and chilled lamb from Australia, with frozen Australian lamb demonstrating shrinking influence within the market. Overall, as imports become essential to meet U.S. domestic demand for lamb, the boneless and bone-in imported lamb markets both display low variability in an increasingly inelastic lamb import market that has become more insensitive to price changes over time.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Lamb is distinguished as a product subject to unique and dynamic forces, both for United States lamb producers and consumers. U.S. lamb production has decreased continually for the past seven decades. This decline has been attributed to many factors including changes in domestic policies such as the National Wool Act and the Incentive Payment program, increasing competition from other meats, fibers, and imports, as well as labor market challenges in the sheep industry. This has been met with a simultaneous rise in imports to meet domestic demand (Williams et al., 2008). Domestic demand for lamb has exhibited a more moderate declining trend, still owing to many of the same factors such as competing meats and the negative experiences of soldiers in World War II with sheep meat. Lamb imports to the U.S. originate primarily in Australia and New Zealand, and have grown steadily over the past three decades (Figure 1). Lamb production in Australia and New Zealand is pasture-based, rather than grain-fed, as is the conventional American method of production, which contributes to Australia and New Zealand having a comparative advantage in lamb production. This has led to increasing imports to meet domestic demand as American lamb producers shift production away from sheep and toward more profitable enterprises such as beef cattle. Indeed, domestic production has shrunk at such a rate, with coinciding growth of imports, that lamb import quantities are now nearly equivalent to domestic production and, if the trend of the past three decades continues, lamb imports will become the primary source of lamb for domestic consumption (Figure 2). As imports have become increasingly important to meeting U.S. domestic demand, this work seeks to better understand the nature of the imported lamb market over the past three decades and its influences, including prices of domestic and imported lamb, as well as lamb quality.

Muhammad, Jones and Hahn (2007) estimated conditional and unconditional elasticities of demand for imported lamb from 1989 to 2003; however, we provide an update and extension to understand how lamb import demand has changed over time. The elasticity estimates from the previous study shed light on the behavior of importers in the face of declining domestic production. With a changing consumer demographic and a continued decline in domestic production, though not as high as the rate of decline observed in the 1990s, there is cause to reevaluate the current nature of the lamb industry and current import patterns (USDA, 2016). This work updates the work of Muhammad et al. (2007) by estimating conditional and unconditional elasticities using a differential production model with current data to investigate whether or not importer behavior has changed over the past decade. Results suggest that, despite the aforementioned changes in the domestic lamb industry, the structure of lamb imports has remained consistent over the past three decades, with importers becoming less sensitive to price changes and further removed from the influence of the domestic lamb market. This work then extends the literature by evaluating the role of further disaggregated product quality on lamb imports, determined by boneless/bone-in product differentiation, using an absolute price version of the Rotterdam model (AP Rotterdam). Results indicate boneless and bone-in imported lamb are separable products and further support the inelasticity of imported lamb markets.

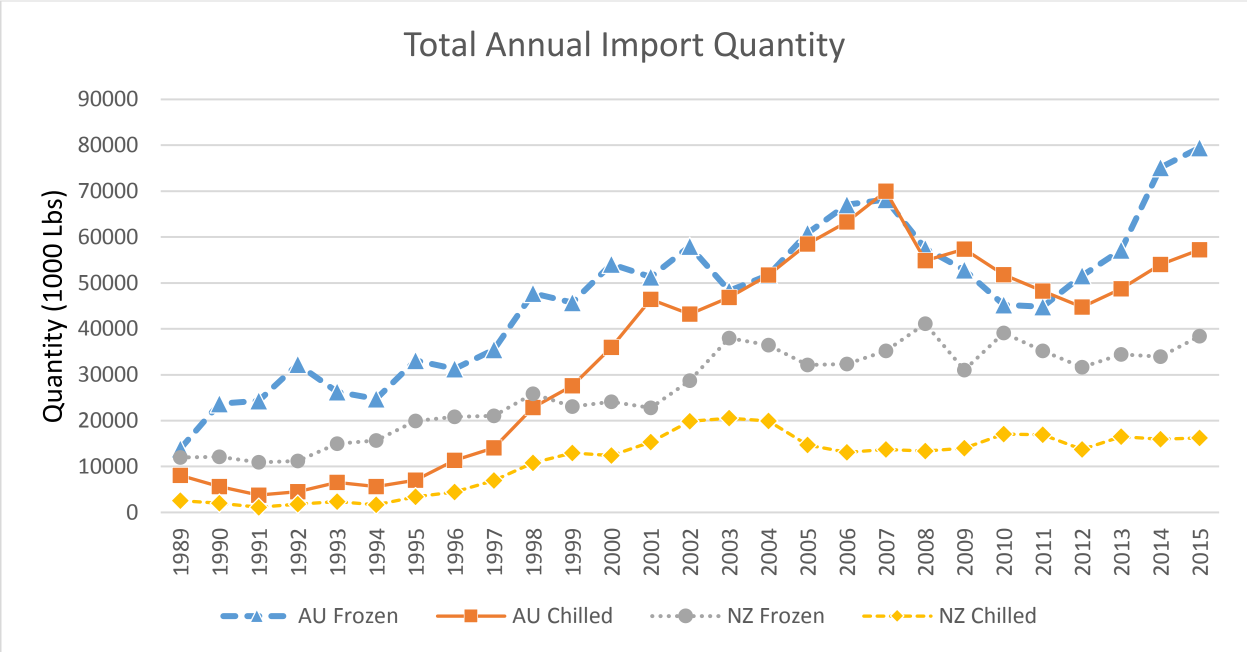

Figure 1. Total Annual Import Quantity by Source and Product (Chilled or Frozen)
Source: U.S. Census Bureau Trade Data, 2016 and authors' calculations

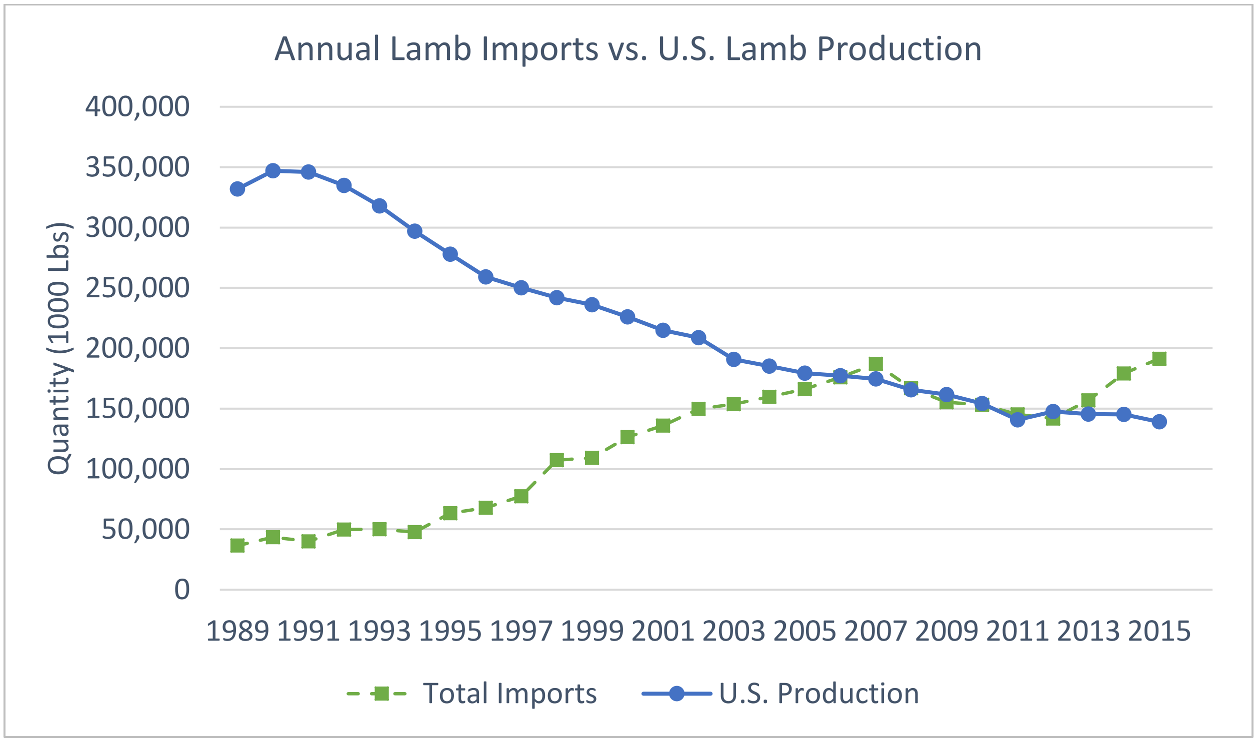

Figure 2. Total Annual Import Quantity and Total Annual U.S. Domestic Production
Source: U.S. Census Bureau Trade Data, 2016; USDA Red Meats Yearbook and authors' calculations

1.2 Background and Motivation

The portrait of the American lamb consumer has changed over the past few decades, owing in part to influences such as an increased ethnic consumer demographic and unsuccessful industry promotion efforts. Shiflett et al. (2010) determined that ethnic consumers, defined as those consumers not fitting the traditional white American consumer profile (Hispanics, Muslims, Eastern Europeans, etc.) consumed 58% of all lamb in the country, both domestic and imported, in 2010. While ethnic consumers appear to display a relative degree of loyalty to domestic lamb products, domestic production is not available to meet demand in all locations, forcing many ethnic consumers to turn to imported products to meet their consumptions needs (Shiflett, et al., 2010). The combined growth of the ethnic population and decline of domestic lamb production may further increase U.S. dependence on imports to meet domestic demand. The reduction in lamb consumption by the traditional American consumer demographic may have been influenced by the Great Recession’s impact on consumption patterns. Darko and Eales (2013) determined that the recession had a significant impact on both real food expenditure and meat demand, particularly due to decreases in away-from-home food consumption. As Shiflett et al. (2007) found that lamb was increasingly being consumed in away-from-home settings, the recession had the potential to have an even greater effect on the lamb industry than on those of other meats that were, and are, commonly prepared at home.

Despite a changing consumer landscape, promotion has been a major point of focus for the industry in attempting to maintain or garner more consumer interest. Capps et al. (2010) determined that promotional efforts from the American Lamb Board had been enormously successful and beneficial to producers; however, Shiflett et al. (2007) highlighted the lack of visible evidence of these effects in the industry. The growth of the ethnic demographic may have given the appearance of successful promotional efforts, by replacing the loss of traditional consumers. Promotional efforts on the part of exporters may have also influenced domestic demand, with Clemens and Babcock (2004) finding that country of origin labelling (COOL) requirements helped create a brand for New Zealand, associating New Zealand lamb with high quality and influencing global consumer perceptions in favor of New Zealand imports. However, the same report determined that the branding hadn't been quite as successful in the U.S. as in other countries, prompting New Zealand and Australia to join a coalition with the U.S. to jointly promote lamb, demonstrating exporter interest in maintaining consumer demand for lamb in the U.S. market.

The domestic production of lamb has also been subject to a variety of influences, some the same as those which have influenced consumers. The growth of the ethnic demographic has driven growth in the non-traditional supply chain of lamb, drawing lamb away from traditional slaughter facilities and subsequently skewing domestic production data such that the actual decline in the domestic industry, while still on trend, may be overstated (Shiflett et al., 2010). Independent promotional efforts by exporters may also have been of indirect benefit to domestic producers, with Paarlberg and Lee (2001) finding that the minimization of trade barriers in the lamb industry would help to protect both producers and consumers from the potential oligopoly and oligopsony power of a highly consolidated processing sector. However, domestic policy reform in the 1990s, such as the removal of domestic subsidies, including the Wool Act, removed market distortions that allowed exporters to gain a larger market share (Whipple and Menkhaus, 1990).

Shrinking governmental support for the U.S. domestic industry is not the only cause for decreased sheep production. The increasing value of livestock production resources, like high-quality rangeland, as well as increasing costs of production after long seasons of drought, have driven producers away from the low perceived returns from lamb production, with producers preferring to capitalize on available resources with higher return livestock production. Sheep are also often viewed as a more labor-intensive investment, given the addition of shearing costs and higher predation losses than experienced in cattle production, as well as specialized labor needs for sheepherding (Williams et al., 2008). The subsequent decline in domestic lamb production owing, in part, to these factors has been met with a coinciding increase in imports, depicted in Figure 2. Though total annual lamb disappearance in the U.S. has only slightly decreased from 1980 to 2015, the share of imported lamb has increased from less than 15% of total disappearance in 1980 to over half in 2015.

Despite the complex network of factors exerting their influence on the domestic market, pushing in multiple directions, a few trends stand out amongst the complicated background. There remains a clear demand for lamb among consumers within the United States, regardless of whether that demand comes from the traditional American consumer, influenced by promotion, or the emerging ethnic markets. With that demand still in place, and shrinking domestic production insufficient to meet it, imported lamb continues to be essential to meet the demand of the American lamb consumer.

CHAPTER 2: DIFFERENTIAL PRODUCTION MODEL

2.1 Methodology

Following Muhammad et al. (2007), we employ a differential production model, based on the methodology of Laitinen and Theil (1978), Laitinen (1980), Theil (1980), Davis and Jensen (1994) and Washington and Kilmar (2002a and b). The differential production model consists of a two-step estimation process incorporating an output supply equation and a system of import demand equations. The modeling framework simplifies the import and domestic supply structure, where real distributers generally source from both domestic and foreign sources, to the case of a single, profit-maximizing importing firm which then distributes all imports as its output to the domestic market. The output supply equation represents the firm's production function, with products from different countries as the firm's inputs, along with labor, and a generalized, wholesale 'imported lamb' product as the import firm's output. The system of import demand equations is then estimated to determine the relationships of import shares among the different source country and product pairs within the firm's production mix.

2.1.1 Base Model

The differential form of the output supply equation is used, such that variables are expressed in the form of finite 12-month log changes:

$$(1) \quad \Delta X_t = \varphi \Delta p_t + \sum_{j=1}^{N} \pi_j \Delta w_{jt} + \varepsilon_t$$

Where the dependent variable ΔX_t is a finite Divisia volume import index defined as:

$$(2) \quad \Delta X_t = \sum_{i=1}^{n} \bar{f}_{it} \Delta x_{it}$$

An index of total imports which is the average import share for period t and period t-12,

$$(3) \quad \bar{f}_{it} = (f_{it} + f_{it-12})/2$$

And $\Delta x_{it} = \log(x_{it}/x_{it-12})$. Of the total cost of lamb imports, f_i represents the share of the *i*th import:

$$(4) \quad f_i = (w_i x_i / \sum_i w_i x_i)$$

In which w_i represents the price of imported lamb from source country *i* and the price of labor, and x_i represents the quantity of either chilled or frozen lamb imports from source country *i*;

$$(5) \quad \Delta w_{it} = \log(w_{it}/w_{it-12});$$

$$(6) \quad \Delta p_{it} = \log(p_{it}/p_{it-12}),$$

Where *p* is the domestic wholesale price, which represents the output price. Parameters to be estimated are π and φ; π measures the change in the import index given a percentage change in the prices of imports or labor, φ represents the change in the import index given a percentage change in the wholesale domestic price, and ε is the error term.

The system of import demand equations is similarly estimated using finite 12-month log changes and is specified as:

$$(7) \quad \bar{f}_{it}\Delta x_{it} = \theta_i^* \Delta X_t + \sum_{j=1}^{n} \pi_{ij}^* \Delta w_{jt} + u_{it}$$

Where w_i and x_i represent the price and quantity of imported chilled or frozen lamb from source country *i*, the import index ΔX_t is as defined above, and π_{ij}^* and θ_i^* are parameters to be estimated. θ_i^* represents the marginal import share coefficient for each country/product pair, π_{ij}^* represents the effect of a change in price on imports from each source, and u_{it} is the error term.

According to general trade theory, restrictions are placed on the model to ensure parameters conform to homogeneity and symmetry assumptions[1].

2.1.2 Elasticities

Ultimately, the combination of Equations (1) and (7), achieved by substituting the right-hand side of (1) as the import index term into each import share equation in (7), produces the unconditional derived demand equation, where changes in import demand are subject to a function of changes in prices rather than output.

Conditional elasticities are derived from Equation (7), with own-price and cross-price elasticities being defined as:

$$(8)\quad \eta_{xw}^{c} = \pi_{ij}^{*}/\bar{f}_i$$

And the total import index elasticity defined as:

$$(9)\quad \eta_{xX} = \theta_{ij}^{*}/\bar{f}_i$$

Unconditional elasticities are derived from the unconditional derived demand equations formed by substituting Equation (1) into Equation (7):

$$(10)\quad \bar{f}_{it}\Delta x_{it} = \theta_i^{*}[\varphi\Delta p_t + \sum_{j=1}^{N}\pi_j\Delta w_{jt}] + \sum_{j=1}^{n}\pi_{ij}^{*}\,\Delta w_{jt} + u_{it}$$

Such that the unconditional elasticities with respect to output price, which measure the responsiveness of each class of imports to the domestic wholesale price, are defined as:

$$(11)\quad \eta_{xp} = \eta_{xX}\varphi$$

[1] $\sum_j \pi_{ij}^{*} = 0$ (homogeneity) and $\pi_{ij}^{*} = \pi_{ji}^{*}$ (symmetry)

And the unconditional own- and cross- price elasticities are defined as:

$$(12)\ \eta_{xw} = \eta_{xX}\pi_j + \eta_{xw}^c$$

2.2 Data

Monthly data collected from publicly available U.S. government sources is used for the time period of January 1989 to July 2016. All data is at the national level. Quantities and total values of imported lamb were obtained from the U.S. Census Bureau's Trade Data (2016). Import data was only collected for Australia and New Zealand, as all other sources of imported lamb are negligible. Data is aggregated into four categories, based on source country, either New Zealand or Australia, and product type, either frozen or chilled. Per-unit values of imports were calculated ($/pound) and used as proxies for import prices, all on a cost, insurance and freight (CIF) basis. Average hourly wage data for employees in the wholesale trade sector was obtained from the U.S. Bureau of Labor Statistics (2016) and deflated using the labor CPI for urban wage earners and clerical workers[2]. The domestic wholesale price or output price was obtained from monthly lamb carcass prices reported by the U.S. Department of Agriculture's Economic Research Service (2016).

2.2.1 Summary Statistics

Descriptive statistics are presented in Table 1. On average, the total quantity of chilled lamb imports exceeds that of frozen imports despite higher chilled prices from both sources. The largest supplier of imported lamb to the U.S. is Australia with an average of approximately 5 million pounds of lamb per month. Australian lamb imports are less expensive than those from

[2] The default base period, 1982-1984, from the U.S. Bureau of Labor Statistics.

New Zealand for both chilled and frozen product, though chilled Australian lamb is approximately 20 $USD/cwt less than its New Zealand counterpart while the difference between Australian and New Zealand frozen lamb is more than 110 $USD/cwt, on average. Despite a greater quantity supplied, the value of New Zealand's frozen lamb imports exceeds that of Australia on average, resulting in a greater average market expenditure share of 29% compared to Australian frozen lamb's 19%. The total market expenditure shares of frozen and chilled lamb indicate a relatively even distribution of imports for the 26-year period, with frozen lamb imports occupying 48% of the market on average and chilled lamb comprising an average share of 52%.

Table 1. Summary Statistics: January 1990 - July 2016

	Chilled		**Frozen**	
Statistic	Australia	New Zealand	Australia	New Zealand
	Price ($/cwt)			
Mean	309.79	332.81	188.90	299.03
St. Dev.	118.70	126.52	88.43	125.04
Min	116.56	178.80	66.73	107.51
Max	654.22	762.88	512.53	824.70
	Monthly Quantity (million lbs)			
Mean	3.05	0.97	1.97	1.79
St. Dev.	2.05	0.58	1.18	0.79
Min	0.19	0.05	0.23	0.45
Max	8.57	2.56	6.53	4.82
	Monthly Value (million $)			
Mean	10.73	3.53	4.44	5.65
St. Dev.	8.56	2.67	4.28	3.62
Min	0.30	0.15	0.22	0.57
Max	35.85	14.21	20.32	19.69
	Market Expenditure Share			
Mean	0.38	0.14	0.19	0.29
St. Dev.	0.12	0.04	0.08	0.12
Min	0.12	0.05	0.05	0.07
Max	0.64	0.27	0.46	0.58

Source: U.S. Census Bureau Trade Data, 2016 and authors' calculations.

2.3 Results and Discussion

2.3.1 Empirical Results

The output supply equation and import demand system are estimated separately, using seemingly unrelated regression estimation in Stata (Version 14.1). The output supply equation and derived demand system can be separately estimated as the errors in (1) and (7) are statistically independent (Theil, 1980, Laitinen, 1980, and Muhammad, et al. 2007). Homogeneity and symmetry constraints are imposed to conform to theory, despite their rejection by likelihood ratio tests. Likelihood ratio test results are reported in Table 2.

Table 2. Likelihood Ratio Results for Symmetry and Homogeneity Constraints

Model	Log Likelihood Value	Chi-Square	Prob > Chi-Squre
Unrestricted	2239.6077	-	-
Homogeneity	2233.2093	12.80(3)	0.0051
Symmetry	2230.1394	18.94(3)	0.0003

The number of restrictions are in parenthesis.
Source: Authors' estimations.

The output supply equation estimation results are reported in Table 3. The coefficients for the import sources New Zealand Frozen (NZF) and Chilled (NZC) and Australia Frozen (AUF) and Chilled (AUC) are -0.0401, -0.2634, 0.1235 and -0.2392, respectively. The coefficients for all import sources except NZF are statistically significant, with both NZC and AUC being significant at the 1% level and AUF at the 10% level, similar to MJH. As such, we expect all coefficients on imports to be negative, which is the case, except for a positive coefficient for AUF. The coefficient for output price is positive but not statistically significant with the updated data, again similar to MJH, indicating that the domestic price of lamb still has no statistically significant effect on imports. The coefficient for wages is not statistically significant, as was the case for MJH.

The conditional derived demand parameter estimates for the import demand equation system are reported in Table 4. Results meet expectations and show little variation in the import sourcing, relative to MJH, indicating that the structure of the import industry has remained relatively consistent over the past three decades. All own-price coefficients are negative and significant at the 1% level, indicating that an increase in the price of an import from a specific source/type will decrease import demand for the product. Cross-price coefficients are all positive, indicating that import sources and product types are substitutes. As such, an increase in the price of one class of imports will increase the demand for a different class. All cross-price coefficients are statistically significant at the 1% level, except NZF/NZC and NZC/AUC, which are significant at the 5% level, and NZF/AUF, which is not statistically significant, as was also the case in MJH. The marginal factor share coefficients θ_i^* are all positive, and indicate how an increase in total imports is distributed among the product/source categories. NZF and AUC hold the highest marginal import shares, with an additional dollar of imports resulting in an expected combined increase in imports of $0.70 coming from those two product classes. This finding is of interest as it is in contrast to MJH, which found approximately one third of an increase in total imports each consisting of frozen imports from New Zealand and Australia, and the remaining third distributed amongst chilled imports. The updated results indicate that the marginal import shares of the market have changed to the effect that the marginal market share for frozen, Australian lamb imports has decreased nearly by half, with that share being redistributed amongst the other sources, primarily to New Zealand frozen lamb and Australian chilled lamb, ultimately demonstrating a decline in total frozen import share and a corresponding increase in chilled import share.

Table 3. Output Supply Parameter Estimates for Imported Lamb to U.S.

New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled	Wage	Output Price
-0.0401 (0.0476)	-0.2634*** (0.0667)	0.1235* (0.0684)	-0.2392*** (0.0894)	1.5267 (1.1407)	0.1530 (0.0986)
R^2 = 0.1022					

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

Table 4. Import Demand System Conditional Parameter Estimates for Lamb

Exporting Country/Good	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled	Marginal Share
New Zealand Frozen	-0.0539*** (0.0169)	0.0167** (0.0074)	-0.0027 (0.0135)	0.0400*** (0.0144)	0.3689*** (0.0212)
New Zealand Chilled		-0.1175*** (0.0095)	0.0205*** (0.0099)	0.0757** (0.0106)	0.1049*** (0.0094)
Australia Frozen			-0.1217*** (0.0217)	0.0986*** (0.0181)	0.1725*** (0.0195)
Australia Chilled				-0.2136*** (0.0227)	0.3537*** (0.0190)
R^2 (AUF) = 0.1905		p = 0.0000	**R^2 (NZC) = 0.5095**		p = 0.0000
R^2 (AUC) = 0.5853		p = 0.0000	**R^2 (NZF) = 0.4957**		p = 0.0000

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

2.3.2 Conditional Elasticities

Conditional elasticities are presented in Table 5. The import index elasticities, or Divisia elasticities, indicate the percentage change in each class of import given an increase in total imports. They are 1.2557, 0.7568, 0.9317 and 0.9252 for NZF, NZC, AUF and AUC, respectively, and are all statistically significant at the 1% level. Hence, a 1% increase in the total import index results in a 1.2574% increase in the quantity of NZF imports, and so on.

The conditional own- and cross-price elasticities indicate the responsiveness of each class of imports to a change in price of the same or other product classes. The conditional own-price elasticities are -0.1836, -0.8476, -0.6572 and -0.5587 for NZF, NZC, AUF and AUC, respectively and are all statistically significant at the 1% level. All conditional own-price elasticities have decreased in magnitude, or have become more inelastic, relative to the values reported in MJH, indicating that importers are less sensitive to price changes.

Conditional cross-price elasticities confirm substitute relationships, with all positive and statistically significant elasticity estimates, consistent with the findings from MJH. However, the shift in import share away from frozen Australian to New Zealand frozen and Australian chilled imports is reflected in the conditional elasticities. As a result, relative to MJH, Australian chilled and New Zealand chilled import quantities have become far less sensitive to changes in the price of Australian frozen imports. The relationship between New Zealand and Australian frozen imports remains statistically insignificant. However, the responsiveness of Australian frozen import quantities to changes in price of chilled New Zealand and Australian imports has remained almost identical to the levels of MJH.

Table 5. Conditional Divisia and Price Elasticities

		Conditional Own- and Cross-Price			
Exporting Country/Good	Divisia	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	1.2557*** (0.0721)	-0.1836*** (0.0576)	0.0567** (0.0253)	-0.0093 (0.0461)	0.1362*** (0.0490)
New Zealand Chilled	0.7568*** (0.0678)	0.1212** (0.0526)	-0.8476*** (0.0687)	0.1804** (0.0713)	0.5461*** (0.0763)
Australia Frozen	0.9317*** (0.1055)	-0.0148 (0.0732)	0.1397** (0.0543)	-0.6572*** (0.1171)	0.5324*** (0.0980)
Australia Chilled	0.9252*** (0.0497)	0.1046** (0.0377)	0.1962*** (0.0282)	0.2579*** (0.0474)	-0.5587*** (0.0594)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

2.3.3 Unconditional Elasticities

Unconditional elasticity estimates are reported in Table 6. Output price elasticities are not statistically significant, indicating that the domestic price of lamb may have no predictable impact on the quantities of lamb imported in the long run. Nevertheless, the estimated output price elasticities are 0.1931, 0.1158, 0.1426 and 0.1412 for NZF, NZC, AUF and AUC, respectively. This is characteristic of imports substituting for domestic production, where wholesale distributers shift the sourcing of lamb to imports. Relative to the elasticities estimated in MJH, the responsiveness of all imports to domestic price changes has decreased, or, considering the lack of statistical significance, any responsiveness that once existed has since dissipated.

While largely similar in sign, the unconditional own- and cross-price elasticities vary in magnitude and significance from those of MJH. All unconditional own-price elasticities are negative and statistically significant at the 1% level, consistent with MJH. Own-price elasticities are -0.2339, -1.0470, -0.5422 and -0.7801 for NZF, NZC, AUF and AUC, respectively. Unlike MJH, where all but NZF imports were elastic, the only elastic class of imports is chilled New Zealand lamb, further illustrating that importers have become less responsive to price changes. Cross-price elasticities indicate statistically significant relationships between all product/sources except both Australian products to both New Zealand products, New Zealand frozen to both Australian products, and NZC/NZF. However, unlike the consistent substitute relationships depicted by the conditional elasticities, the unconditional elasticities show both substitute and complementarity relationships. For instance, New Zealand frozen is a complement to New Zealand chilled. The most important deviation of these results from MJH is the loss of statistically significant relationships between New Zealand prices and Australian imports. This lack of statistical significance indicates that importers no longer change the quantity of Australian imports demanded if the price of New Zealand imports changes. This effect is not bilateral, as changes in Australian import prices do still exert some influence over the quantity of New Zealand chilled imports demanded.

Table 6. Unconditional Elasticities of the Derived Demand for Lamb Imports

		Unconditional Own- and Cross-Price			
Exporting Country/Good	Output Price	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	0.1931 (0.1243)	-0.2339*** (0.0830)	-0.2741*** (0.0895)	0.1457 (0.0976)	-0.1642 (0.1238)
New Zealand Chilled	0.1158 (0.0754)	-0.0908 (0.0638)	-1.0470*** (0.0871)	-0.2739*** (0.0885)	0.3650*** (0.1033)
Australia Frozen	0.1426 (0.0933)	-0.0522 (0.0856)	-0.1058 (0.0871)	-0.5422*** (0.1340)	0.3095** (0.1310)
Australia Chilled	0.1412 (0.0915)	0.0676 (0.0580)	-0.0475 (0.0691)	0.3721*** (0.0793)	-0.7801*** (0.1026)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

CHAPTER 3: ABSOLUTE PRICE ROTTERDAM MODEL

3.1 Methodology

The empirical basis for the differentiated product analysis is heavily based on the work of Muhammad and Hanson (2009), which uses the absolute price version of the Rotterdam model (Theil, 1980; Theil & Clements, 1987). To evaluate the role of quality in lamb imports, data are disaggregated by source country (Australia or New Zealand); and two quality distinctions (chilled or frozen), with further differentiation for either boneless or bone-in product. This disaggregation resulted in a total of eight classes or types of lamb imports. The AP Rotterdam, similar to the import demand system of the differential production model, defines demand for each class of imports as a function of total expenditures and import prices.

3.1.1 Base Model

Similar to Muhammad and Hanson (2009), we follow the notation of Mutondo and Henneberry (2007) in specifying the absolute price version of the Rotterdam model below:

$$(13)\quad \bar{g}_{m_{i_r}t}\Delta q_{m_{i_r}t} = \theta_{m_{i_r}}\Delta Q_t + \sum_{n=1}^{2}\sum_{j=1}^{2}\sum_{s=1}^{2}\pi_{m_{i_r}n_{j_s}}\Delta p_{n_{j_s}t} + \varepsilon_{m_{i_r}t}$$

In keeping with the notation of the differential production model, *i* and *j* denote the source country, *r* and *s* denote fresh or frozen product quality and *m* and *n* denote boneless or bone-in product quality.

Similar to the ΔX_t variable of the differential production model, the Divisia volume import index is defined as:

$$(14)\ \Delta Q_t = \sum_{m=1}^{2}\sum_{i=1}^{2}\sum_{r=1}^{2} \bar{g}_{m_{i_r}t}\Delta q_{m_{i_r}t}$$

With the index comprised of average import shares for period t and period t-1,

$$(15)\ \bar{g}_{m_{i_r}t} = (g_{m_{i_r}t} + g_{m_{i_r}t-1})/2$$

And $\Delta q_{m_{i_r}t} = log(q_{m_{i_r}t}/q_{m_{i_r}t-1})$. $g_{m_{i_r}}$ represents the share of each class of imports out of the total expenditure on lamb imports:

$$(16)\ g_{m_{i_r}} = (p_{m_{i_r}}q_{m_{i_r}}/\sum_{m}\sum_{i}\sum_{r} p_{m_{i_r}}q_{m_{i_r}})$$

In which $p_{m_{i_r}}$ is the price of each class of imported lamb and $q_{m_{i_r}}$ represents the quantity of each class of imported lamb;

$$(17)\quad \Delta q_{m_{i_r}} = \log(\Delta q_{m_{i_r}t}/\Delta q_{m_{i_r}t-1});$$

$$(18)\quad \Delta p_{m_{i_r}} = \log(\Delta p_{m_{i_r}t}/\Delta p_{m_{i_r}t-1}),$$

Note that, despite the similarities between these variables and those of the differential production model, these variables are differentiated by further disaggregation as well as a single month log change as opposed to the 12-month log change. Parameters to be estimated are $\theta_{m_{i_r}}$ and $\pi_{m_{i_r}n_{j_s}}$, which represent the marginal import share coefficient for each class of import in the system and the effect of a change in price on imports of each class, respectively. $\varepsilon_{m_{i_r}t}$ is the error term. Homogeneity and symmetry conditions[3] are again imposed, in accordance with economic theory, and tested using likelihood ratio tests. Despite their rejection, but similar to the case of the differential production model, they remain imposed within the final model, as precedent in the literature (Kastens and Brester, 1996; Laitinen, 1978; Meisner, 1979; Bera, 1982; Johnson,

[3] $\sum_m \sum_i \sum_r \pi_{m_{i_r}n_{j_s}} = 0$ (homogeneity) and $\pi_{m_{i_r}n_{j_s}} = \pi_{n_{j_s}m_{i_r}}$ (symmetry)

Green, Hasan, and Safyurtlu, 1986 as cited in Moschini and Moro, 1993). Adding up conditions ($\sum_m \sum_i \sum_r \theta_{m_{i_r}} = 1$) are also necessary in theoretical consideration, however they are implicitly satisfied by the construction of the Rotterdam model and therefore do not require imposition. Tests for product separability and product form aggregation were first run to determine the final form of the Rotterdam model for estimation.

3.1.2 Aggregation Tests

The specification of Equation (13) assumes importer preference for lamb products differs across the various defined classes. In the case that the distinction between boneless and bone-in product were irrelevant to importers, the product classes could be aggregated and the system would be reduced to the following:

$$(19)\ \bar{g}_{i_r t} \Delta q_{i_r t} = \theta_{i_r} \Delta Q_t + \sum_{j=1}^{2} \sum_{s=1}^{2} \pi_{i_r j_s} \Delta p_{j_s t} + \varepsilon_{i_r t}$$

Which, if not for the slight variation in variable definition (single month log change), is equivalent to the import supply system of the differential production model. Product aggregation across boneless and bone-in product would imply the following restrictions (Yang & Koo, 1994; Mutondo & Henneberry, 2007):

$$(20)\ \theta_{m_{i_r}} = \theta_{i_r}\ \forall\ m, n$$

$$(21)\ \pi_{m_{i_r} n_{j_s}} = \pi_{i_r j_s}\ \forall\ m, n$$

These restrictions indicate that changes in total expenditures and import prices impact demand for chilled and frozen lamb from either source country the same, regardless of whether that lamb is boneless or bone-in. By extension, and for the purposes of testing these restrictions, Equations (20) and (21) further imply that $\theta_{m_{i_r}} = \theta_{n_{i_r}}$ and $\pi_{m_{i_r} n_{j_s}} = \pi_{m_{i_r} m_{j_s}}$. Each of these restrictions is tested individually by class, using likelihood ratio tests, where other class characteristics are maintained (Australia/New Zealand and chilled/frozen), but boneless/bone-in product distinction is tested for equality. For example, the unrestricted system is tested against a system in which the parameters for chilled Australian boneless lamb are set equal to those of chilled Australian bone-in lamb. Following individual tests, all restrictions are tested jointly for complete aggregation of boneless/bone-in product in the lamb import market.

3.1.3 Separability

As with Muhammad and Hanson (2009), a foundational assumption of this work is the blockwise dependent nature of the lamb import industry relative to other imports as well as to domestic lamb products. Assuming blockwise dependence allows for the limitation of the system to imported lamb products only. This assumption is heavily supported by the findings of the differential production model, demonstrating an absence of influence of domestic prices on lamb imports. Under blockwise dependence, the following utility function acts as a representation of importer preferences (Muhammad and Hanson, 2009):

$$(22)\ U(q) = f(U_1(q_1), U_2(q_2), \ldots, U_H(q_H))$$

The above would imply that the change in marginal utility of a dollar spent on the *i*th import caused by another dollar spent on the *j*th import, where $i \in B_b$(B_b representing product group b) and $j \in B_c$, is equal to some constant a_{bc} for all i and j if $b \neq c$ (Muhammad and Hanson, 2009). As a result, this limits the utility interactions of any two classes of imports from different groups to the importer's preference for the group rather than the individual classes of imports in the group (Theil, 1980 as cited in Muhammad and Hanson, 2009). Ultimately, this aggregates the importer's reactions such that single classes of lamb imports are not impacted individually by changes in, for example, beef imports, but rather that lamb imports are uniformly impacted as a group given a change in importer preferences for beef relative to lamb. Furthermore, this limits the substitutability of different classes of lamb imports to its own group, such that importer decisions with respect to the quantity of chilled Australian boneless lamb are only impacted by the prices of other classes of lamb imports, not by those of beef or chicken imports. This would suggest that importers pre-determine the total quantity or expenditures of lamb imports at a stage prior to allocating expenditures amongst the various classes of lamb imports. As discussed by Muhammad and Hansen (2009), this assumption is shown by Theil and Clements (1987) to be sufficient for deriving a conditional demand system limited to the products within a given group. However, the distinction between these groups can be defined at an even finer level than represented within these examples. For instance, importers may treat boneless lamb and bone-in lamb as separate groups as much as they might treat lamb and beef as separate groups. Therefore, an investigation of separability must be conducted to determine how disaggregated importers' preferences are. Two types of separability are investigated: strong separability and product form separability. Strong separability would indicate that each class of imports operates as a separate group while product form separability would indicate that boneless products are separable from bone-in products.

Strong separability is investigated using the relative price version of the Rotterdam model. Without preference independence, the relative price version of the Rotterdam is the same as the AP Rotterdam defined in Equation (13), but is re-specified as:

$$(23)\ \bar{g}_{m_{i_r}t}\Delta q_{m_{i_r}t} = \theta_{m_{i_r}}\Delta Q_t + \varphi_{bb}\theta_{m_{i_r}}\Delta\left(\frac{p_{m_{i_r}t}}{P_t^*}\right) + \varphi_{bc}\theta_{m_{i_r}}\Delta\left(\frac{p_{n_{j_s}t}}{P_t^*}\right) + \varepsilon_{m_{i_r}t}$$

Where $P_t^* = \sum_m \sum_i \sum_r \theta_{m_{i_r}} \Delta p_{m_{i_r}}$ is the Frisch price index for the entire group of U.S. lamb imports and φ_{bb} and φ_{bc} are the Frisch own- and cross-price elasticities of each class of imports as a group. When estimated, the term $\Delta(\frac{p_{m_{i_r}t}}{P_t^*})$ is defined as:

$$(24)\ \ \Delta(\frac{p_{m_{i_r}t}}{P_t^*}) = \left(\Delta p_{m_{i_r}} - \Delta P^*\right) = \left(\Delta p_{m_{i_r}} - \sum_m \sum_i \sum_r \theta_{m_{i_r}} \Delta p_{m_{i_r}}\ \right)$$

Under preference independence, all Frisch cross-price elasticities would equal zero, meaning that the own Frisch-deflated price for a class is the only influence on demand for that class of imports (Theil, 1980). Consequently, under preference independence, there is no relationship between any of the import classes and each must be treated as a separate product just as beef or pork are treated as separate products. Given that Equation (23) is nested in Equation (13), both equations can be estimated and an LR test performed to test for strong separability among lamb imports (Seale et al., 1992).

Although, this investigation focuses on the quality characteristics of boneless or bone-in, product form/source separability is investigated for all three of the distinguishing characteristics of import classes. As with strong separability, product form/source separability would indicate the absence of any relationships between the prices and demands of the separable products. For example, if Australian and New Zealand lamb imports were found to be separable, changes in the prices of New Zealand lamb imports would exert no effect on importer demand for Australian lamb. Empirically, this would mean the following:

$$(25)\ \ \pi_{i_{m_r} j_{n_s}} = 0\ \ \forall\, i, j$$

$$(26)\ \ \pi_{m_{i_r} n_{j_s}} = 0\ \ \forall\, m, n$$

$$(27)\ \ \pi_{r_{i_m} s_{j_n}} = 0\ \ \forall\, r, s$$

Where, if Equations (25), (26) and (27) individually hold true, they indicate source, boneless/bone-in, and frozen/chilled product separability, respectively. In order to test for separability, each of the above three restrictions was imposed on Equation (13) and tested against the unrestricted model using likelihood ratio tests.

3.1.4 Final Model Specification and Likelihood Ratio Results

Likelihood ratio test results are presented in Table 7. Homogeneity and symmetry constraints were each tested against the unrestricted linear model, as well as jointly tested. Both homogeneity and symmetry were rejected at the 1% level, and jointly rejected. Nevertheless, to conform with economic theory, both homogeneity and symmetry restrictions were imposed in all final models.

Aggregation was tested for corresponding boneless/bone-in pairs, first for each pair individually and then for all products jointly. Aggregation was rejected both on the individual level as well as for all products jointly, meaning that there was evidence of differing reactions of importers to boneless and bone-in prices for each class of imports.

The tests for strong separability were conducted using a nonlinear specification of Equation (13) for the unrestricted model. Strong separability was rejected at all significance levels, indicating that expenditures are allocated in a groupwise fashion amongst some subset of classes of imports. However, likelihood ratio tests did find evidence of separability between boneless and bone-in products at the 1% and 5% levels, and at the 10% level when using the adjusted LR statistic (Moschini et al., 1994) as suggested by Muhammad and Hanson (2009). This indicates that importers treat boneless and bone-in lamb as separate products and cannot be treated homogenously in analysis, meaning that a separate system of equations must be estimated for each boneless and bone-in import markets.

Table 7. Likelihood Ratios Economic Constraints, Aggregation and Separability

Model	Log Likelihood Value	Chi-Square	Prob > Chi-Square
Unrestricted	7148.3526	-	-
Homogeneity	7128.1955	40.31 (7)	0.0000
Symmetry	7125.264	46.18 (21)	0.0012
Both	7109.6148	77.48 (28)	0.0000
Source Separability	7117.1571	62.39 (28)	0.0002
Frozen/Chilled Separability	7119.5188	57.67 (28)	0.0008
Boneless/Bone-In Separability (Test against first unrestricted)	7129.3128	38.08 (28)	0.0969
Boneless/Bone-In Separability (adjusted)		37.52 (28)	0.1079
Non-Linear Unrestricted	7125.264	-	-
Strong Separability	7084.7559	81.02 (28)	0.0000
Aggregation			
Unrestricted	7109.6148	-	-
Australia Frozen	7092.7573	33.72 (8)	0.0000
Australia Chilled	6856.8483	505.53 (8)	0.0000
NZ Frozen	7099.0775	21.07 (7)	0.0037
NZ Chilled	7006.344	206.54 (8)	0.0000
All Products	6747.6663	723.90 (25)	0.0000

The number of restrictions are in parenthesis
Prob > Chi-Square represents probability of failing to reject specified model in favor of unrestricted model
Source: Authors' estimations

3.1.5 Elasticities

Conditional expenditure, compensated and uncompensated elasticities are calculated using the following equations:

$$(28)\ \ \eta_{iQ} = \frac{\Delta q_{i_r}}{\Delta Q} = \frac{\theta_{i_r}}{\bar{g}_{i_r}}$$

$$(29)\ \ \eta_{i_r j_s} = \frac{\Delta q_{i_r}}{\Delta p_{j_s}} = \frac{\pi_{i_r j_s}}{\bar{g}_{i_r}}$$

$$(30)\ \ \eta^{*}{}_{i_r j_s} = \frac{\pi_{i_r j_s}}{\bar{g}_{i_r}} - \frac{\theta_{i_r}\bar{g}_{j_s}}{\bar{g}_{i_r}}$$

Because these elasticities are calculated on each separate system, there is no need to distinguish between boneless and bone-in (m and n denotations), with all elasticities limited to interactions between one or the other system. Equation (28) is the conditional expenditure elasticity, which measures the percent change in the demand for the ith class of imports from source r given a percent change in total expenditures in the import market. Equation (29) is the compensated own-/cross-price elasticities, and Equation (30) is the uncompensated own-/cross-price elasticities. Both measure, for the mth market, the change in demand for the ith class of imports from source r given a percent change in the price of the jth class of imports from source s. All elasticities are calculated at mean expenditure shares.

3.2 Data

The same import data retrieved from the U.S. Census Bureau's Trade Data (2017) was used, but with the addition of seven months of data, bringing the evaluated time period up to January 1989 to February 2017. However, due to the specific focus on product differentiation by quality, the data for the AP Rotterdam model uses only quantities of lamb specifically identified as bone-in and boneless were included, limiting both quantities and values of imports to lamb muscle cuts. Again, data is only used for Australia and New Zealand imports and is aggregated into eight categories, based on source country, product type (frozen or chilled) and product quality (boneless or bone-in).

3.2.1 Summary Statistics

Descriptive statistics are presented in Table 8. The classes with the highest mean price per cwt are mostly bone-in product, which is somewhat counterintuitive, given bone-in meat products generally have lower processing costs and more ultimate waste. However, in the case of lamb, many of the highest priced cuts which are generally associated with lamb as a luxury meat, such as frenched rib chops, crown roasts and bone-in leg of lamb, are bone-in cuts. With New Zealand lamb having branded itself as a particularly high-quality product, it then appears to make sense that the highest prices being seen in New Zealand bone-in lamb, $311.53 on average for frozen and $347.05 for chilled.

Despite higher prices for bone-in product, on average, imports are mostly comprised of bone-in product, with an average combined total of 5.43 million pounds of bone-in lamb imported compared to only 1.88 million pounds of boneless lamb. It's important to note that these quantities do not include carcasses, which could be destined for bone-in or boneless retail cuts. The combination of the highest average per unit prices and highest average quantities naturally results in bone-in cuts having the highest average values and, consequently, making up the majority of the market expenditure shares for the imported lamb market as a whole. That is to say, the vast majority of imported lamb is bone-in lamb, with boneless lamb on average only making up approximately 20% of imports.

When market expenditure shares are separately evaluated between boneless and bone-in lamb, two different patterns emerge. In the boneless market, it appears that Australia is the main source of imports, with chilled boneless lamb exceeding frozen boneless from both New Zealand and Australia, but Australian imports being nearly double their New Zealand counterparts, regardless of chilled/frozen distinction. In the bone-in market however, the preference trend reported by the differential production model is demonstrated in the summary statistics, with a preference for chilled bone-in lamb from Australia and frozen bone-in lamb preferred from New Zealand. Given the disparity between per-unit prices in frozen bone-in lamb from Australia and

New Zealand, it would appear that the branding of quality from New Zealand lamb may play a role in importer decision-making rather than price alone, though any number of other factors may be responsible for the disparity.

Ultimately, the summary statistics demonstrate a few trends in the imported lamb market. First, that imported lamb is primarily composed of bone-in products, which follow the emerging preference trends of chilled lamb preferred from Australia and frozen from New Zealand. Second, that importers appear to make decisions based not only on price but on other factors which make more expensive products more appealing to the importer (i.e. the cost minimizing importer's production function is influenced by more than just price).

Table 8. Summary Statistics: January 1990 - February 2017

	Boneless				**Bone-In**			
	Australia		New Zealand		Australia		New Zealand	
Statistic	Chilled	Frozen	Chilled	Frozen	Chilled	Frozen	Chilled	Frozen
	Price ($/cwt)							
Mean	292.39	209.35	304.97	228.16	327.68	187.27	347.05	311.53
St. Dev.	84.58	89.61	103.03	99.46	128.02	91.64	142.60	133.41
Min	154.77	54.29	123.29	41.70	106.84	63.27	121.66	103.14
Max	595.52	515.07	620.44	640.12	693.79	568.33	832.60	881.98
	Monthly Quantity (million lbs)							
Mean	0.70	0.67	0.29	0.22	2.19	1.14	0.65	1.45
St. Dev.	0.56	0.67	0.22	0.24	1.54	0.57	0.38	0.64
Min	0.16	0.01	0.00	0.01	0.13	0.13	0.04	0.29
Max	2.69	3.83	1.05	2.57	6.18	4.05	1.65	3.51
	Monthly Value (million $)							
Mean	2.19	1.82	0.93	0.42	8.30	2.42	2.53	4.92
St. Dev.	2.04	2.30	0.80	0.31	6.78	2.13	1.93	3.37
Min	0.4	0.02	0.00	0.02	0.21	0.10	0.12	0.40
Max	10.17	11.44	5.03	1.73	26.38	11.27	9.18	18.96
	Market Expenditure Share							
Mean	0.08	0.06	0.03	0.03	0.31	0.12	0.11	0.26
St. Dev.	0.03	0.04	0.02	0.03	0.09	0.06	0.03	0.10
Min	0.02	0.01	0.00	0.00	0.09	0.03	0.04	0.06
Max	0.16	0.22	0.08	0.17	0.51	0.38	0.27	0.55
	Boneless Market Expenditure Share				*Bone-In Market Expenditure Share*			
Mean	0.37	0.29	0.17	0.16	0.39	0.15	0.14	0.32
St. Dev.	0.12	0.13	0.08	0.15	0.12	0.08	0.04	0.11
Min	0.09	0.04	0.00	0.00	0.11	0.04	0.05	0.08
Max	0.64	0.64	0.39	0.66	0.46	0.46	0.31	0.62

Source: U.S. Census Bureau Trade Data, 2017 and authors' calculations.

3.3 Results

3.3.1 Empirical Results

Estimation was performed using Stata's (version 14.1), seemingly unrelated regression. A system of equations was estimated for all classes of boneless imports and all classes of bone-in imports, with homogeneity and symmetry imposed on both systems. Estimation results for both models are presented in Tables 9 and 10.

Marginal share coefficients for both systems again point to the emerging preferences of frozen lamb from New Zealand and chilled from Australia. All are positive and indicate that no class holds less than a 10% marginal share within its system, meaning of each additional dollar spent on imports, at least $0.10 goes to each class of imports. All own-price coefficients amongst both systems are negative, as would be expected, and significant at the 1% level except frozen, bone-in Australian lamb, which is significant at the 5% level. Similarly, nearly all cross-price relationship coefficients conform to economic expectations with positive coefficients for all statistically significant relationships. This indicates that, where there is evidence of any relationship between two classes of imports, all relationships are substitute relationships. The only cross-price relationships that are not statistically significant are those between New Zealand products and frozen Australian products, with those coefficients lacking significance across both systems. The R^2 values of the frozen Australian equations in both systems are also substantially lower than those of the other classes of imports, marking frozen Australian lamb as an outlier in both markets.

Table 9. AP Rotterdam Demand System Parameter Estimates for Boneless Lamb

Exporting Country/Good	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled	Marginal Share
New Zealand Frozen	-0.1065*** (0.0201)	0.0405*** (0.0092)	0.0037 (0.0159)	0.0623*** (0.0155)	0.3056** (0.0221)
New Zealand Chilled		-0.1897*** (0.0157)	0.0096 (0.0167)	0.1397*** (0.0167)	0.1575*** (0.0103)
Australia Frozen			-0.1159*** (0.0343)	0.1026*** (0.0268)	0.2120*** (0.0189)
Australia Chilled				-0.3046*** (0.0301)	0.3249*** (0.0173)
R^2 (AUC) = 0.5636		p-value = 0.0000			
R^2 (AUF) = 0.2804		p-value = 0.0000			
R^2 (NZC) = 0.4866		p-value = 0.0000			
R^2 (NZF) = 0.4177		p-value = 0.0000			

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

Table 10. AP Rotterdam Demand System Parameter Estimates for Bone-In Lamb

Exporting Country/Good	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled	Marginal Share
New Zealand Frozen	-0.0770*** (0.0281)	0.0181* (0.0103)	-0.0078 (0.0148)	0.0668*** (0.0240)	0.3275*** (0.0206)
New Zealand Chilled		-0.1011*** (0.0114)	0.0128 (0.0085)	0.0703*** (0.0121)	0.1148*** (0.0075)
Australia Frozen			-0.0415** (0.0165)	0.0365** (0.0173)	0.1321*** (0.0130)
Australia Chilled				-0.1736*** (0.0287)	0.4256*** (0.0185)
R^2 (AUC) = 0.6691		p-value = 0.0000			
R^2 (AUF) = 0.2394		p-value = 0.0000			
R^2 (NZC) = 0.4497		p-value = 0.0000			
R^2 (NZF) = 0.4259		p-value = 0.0000			

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

3.3.2 Conditional Expenditure and Compensated Elasticities

Conditional expenditure and compensated price elasticities are presented in Tables 11 and 12 for boneless and bone-in product, respectively. The conditional expenditure elasticities indicate the percent change in the quantity of a class of imports given a 1% change in total expenditures for the system. All conditional expenditure elasticities were significant at the 1%

level for boneless imports. For boneless imports, the conditional expenditure elasticity is inelastic for both Australia products and chilled New Zealand lamb, but is highly elastic for frozen New Zealand lamb (1.9104). This would indicate that frozen New Zealand lamb is one of the most rapidly expanding classes of lamb imports, with a 1% increase in boneless lamb expenditures resulting in a 1.91% increase in the total quantity of boneless frozen New Zealand lamb imports.

The statistically significant compensated own- and cross-price elasticities for boneless lamb all conform to economic expectations and largely support the findings of the differential production model. These elasticities indicate the percent change in demand for the *i*th class of imports given a percent change in the price of the *j*th class of imports, capturing only the substitution effect. All compensated own-price elasticities are negative, significant at the 1% level and all are inelastic except chilled New Zealand lamb which, like the unconditional elasticities of the differential production model, is very close to unit elasticity. These indicate that a 1% increase in the price of, for example, frozen boneless New Zealand lamb will result in a 0.67% decrease in the demand for frozen boneless New Zealand lamb. All compensated cross-price elasticities are positive and significant at the 1% level except for those between New Zealand lamb, both frozen and chilled, and frozen Australia lamb, which are statistically insignificant, despite all being positive. This indicates a lack of responsiveness in both directions for frozen Australian lamb. That is to say, a change in the price of frozen Australian lamb appears to have no effect on the quantities of lamb imported from New Zealand, and the prices of New Zealand lamb have no effect on frozen Australian lamb imports. This finding persists through all calculated elasticities and supports the earlier findings of the differential production model of a dwindling frozen Australian lamb market.

Table 11. Conditional Expenditure and Compensated Price Elasticities: Boneless Lamb

		Compensated Own- and Cross-Price			
Exporting Country/Good	Expenditure	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	1.9104*** (0.1384)	-0.6656*** (0.1259)	0.2532*** (0.0573)	0.0228 (0.0995)	0.3895*** (0.0971)
New Zealand Chilled	0.9046*** (0.0593)	0.2327*** (0.0527)	-1.0899*** (0.0903)	0.0549 (0.0959)	0.8022*** (0.0962)
Australia Frozen	0.7213*** (0.0643)	0.0124 (0.0541)	0.0325 (0.0568)	-0.3941*** (0.1167)	0.3491*** (0.0910)
Australia Chilled	0.8734*** (0.0466)	0.1675*** (0.0417)	0.3755*** (0.0450)	0.2759*** (0.0720)	-0.8188*** (0.0809)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

Table 12. Conditional Expenditure and Compensated Price Elasticities: Bone-In Lamb

		Compensated Own- and Cross-Price			
Exporting Country/Good	Expenditure	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	1.0278*** (0.0648)	-0.2418*** (0.0880)	0.0552 (0.0336)	-0.0245 (0.0463)	0.2111*** (0.0753)
New Zealand Chilled	0.8503*** (0.0556)	0.1339* (0.0760)	-0.7491*** (0.0842)	0.0945 (0.0630)	0.5206*** (0.0896)
Australia Frozen	0.8612*** (0.0848)	-0.0506 (0.0966)	0.0832 (0.0554)	-0.2707** (0.1076)	0.2381** (0.1127)
Australia Chilled	1.0833*** (0.0470)	0.1700*** (0.1127)	0.1789*** (0.0308)	0.0930** (0.0440)	-0.4419*** (0.0729)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

Similar to the boneless lamb system, the conditional expenditure elasticities for bone-in lamb are all positive and significant at the 1% level. For all four classes of bone-in lamb, the conditional expenditure elasticities are slightly inelastic or near unit elasticity. This would indicate that a 1% increase in bone-in import expenditures would result in an approximately proportionate increase in each of the classes of imports, with a slightly higher increase for frozen New Zealand (1.0278) and chilled Australian (1.0833) lamb, and slightly lower for chilled New Zealand (0.8503) and frozen Australian (0.8612).

Compensated own-price elasticities for bone-in product are all negative, inelastic and statistically significant at the 1% level, except frozen Australian lamb which is significant at the 5% level. Relative to boneless own-price elasticities, bone-in product is even more inelastic and insensitive to own-price changes. Again, chilled New Zealand land appears to be the most responsive to own-price changes with an own-price elasticity of -0.7491. Cross-price elasticities indicate a similarly decreased responsiveness compared to boneless products, with all statistically significant cross-price relationships, while still positive, being of far smaller magnitudes than their boneless counterparts. This would indicate that importers are less inclined to import more or less bone-in product based on a change in price of other bone-in products, especially compared to boneless imports. The cross-price relationship between New Zealand chilled and frozen lamb is only statistically different from zero at the 10% level and only for a change in chilled New Zealand quantity imported given a change in frozen New Zealand lamb's price. This means that, except for the one relationship between the New Zealand classes, all statistically significant relationships in the bone-in market are between chilled Australian lamb and the other classes. This might indicate that chilled Australian lamb is a market driver in the bone-in market, however it is also significantly responsive to all other classes of lamb. Again, results indicate that frozen Australian lamb evidences no statistically significant relationships with New Zealand lamb in any way.

3.3.3 Uncompensated Elasticities

Uncompensated elasticity estimates for both the boneless and bone-in system are presented in Tables 13 and 14, respectively. Similar to the compensated elasticities, these elasticities indicate the percent change in demand for the *i*th class of imports given a percent change in the price of the *j*th class of imports, however the uncompensated elasticities capture both the substitution and income effects. In both systems, there are no changes in the statistical significance of any of the elasticity estimates, relative to the compensated estimates. Rather, the uncompensated elasticities are all more inelastic than their compensated counterparts. As a result, all own-price elasticities in both systems are inelastic when the income effect is accounted for. All cross-price elasticities decrease substantially in magnitude relative to the compensated elasticities, indicating that the inclusion of the income effect truly demonstrates the inelastic nature of the imported lamb markets, regardless of boneless/bone-in product differentiation, though the bone-in market does appear to be even more inelastic than the boneless market. Even so, the change from compensated to uncompensated elasticities does not change the significance of the relationships, meaning that the relationships between New Zealand lamb and frozen Australian lamb, both boneless and bone-in, remain statistically insignificant. The statistically significant uncompensated elasticities continue to demonstrate substitute relationships, with, for example, a 1% increase in the price of chilled, bone-in Australian lamb resulting in a 0.46% increase in the quantity demanded of chilled, bone-in New Zealand lamb.

Table 13. Uncompensated Price Elasticities: Boneless Lamb

Exporting Country/Good	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	-0.4622*** (0.0907)	0.1759*** (0.0404)	0.0159 (0.0692)	0.2705*** (0.0684)
New Zealand Chilled	0.1960*** (0.0442)	-0.9182*** (0.0772)	0.0463 (0.0809)	0.6759*** (0.0810)
Australia Frozen	0.0098 (0.0426)	0.0256 (0.0447)	-0.3105*** (0.0909)	0.2751*** (0.0713)
Australia Chilled	0.1131*** (0.0280)	0.2535*** (0.0311)	0.1863*** (0.0495)	-0.5528*** (0.0574)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

Table 14. Uncompensated Price Elasticities: Bone-In Lamb

Exporting Country/Good	New Zealand Frozen	New Zealand Chilled	Australia Frozen	Australia Chilled
New Zealand Frozen	-0.1626*** (0.0583)	0.0371 (0.0225)	-0.0165 (0.0312)	0.1419*** (0.0498)
New Zealand Chilled	0.1186* (0.0675)	-0.6631*** (0.0745)	0.0837 (0.0559)	0.4609*** (0.0784)
Australia Frozen	-0.0439 (0.0838)	0.0722 (0.0481)	-0.2349** (0.0931)	0.2067** (0.0972)
Australia Chilled	0.0977*** (0.0359)	0.1027*** (0.0179)	0.0534** (0.0256)	-0.2538*** (0.0448)

Standard Errors are in parentheses.
Significance levels: * = 0.10; ** = 0.05; *** = 0.01
Source: Authors' estimations

3.4 Discussion

First and foremost among the findings of the AP Rotterdam models is the presence of separability in the imported lamb market on the basis of boneless/bone-in product differentiation. This means that, in conducting evaluations of the market, boneless and bone-in lamb products should not be treated as a homogenous product but rather must be distinguished. The finding of separability is of greater interest when one considers the similarity of the findings of the two estimated Rotterdam systems and their calculated elasticity estimates. Despite finding separability between the markets, it is clear from all calculated results that the two markets act in similar ways. Thus the finding of separability is not so important in distinguishing two markets with substantially differing behaviors but rather in identifying the lack of significant interaction between the two markets.

In both the boneless and bone-in market, import class interactions largely conform to economic expectations. All own-price elasticities indicate that increases in the price of a class of imports results in a decreased quantity demanded of that same import. When a statistically significant relationship does exist between two classes of imports, the results indicate that it is invariably a substitute relationship. Both models indicate a relative insignificance of frozen

Australian lamb to its respective boneless or bone-in market. Frozen Australian lamb is shown to exert no influence over demand for New Zealand lamb and also to not be affected by the price of New Zealand lamb. This would nearly imply that importer decisions regarding frozen Australian lamb are unimpacted by any other force in the market, however chilled Australian lamb does show a statistically significant bilateral effect. Therefore, the results would indicate that frozen Australian lamb is only impacted by its own price and that of chilled Australian lamb, within its respective quality differentiated market. This finding is somewhat visible in the conditional elasticities of the differential production model, but are especially highlighted by the results of the AP Rotterdam.

While the cross-price relationships in the boneless market exist between all of the classes of imports, except frozen Australian lamb, the bone-in market appears to exhibit slightly different results. Given the weaker results between New Zealand products in the bone-in market, the calculated elasticity estimates indicate that chilled Australian lamb is central to the bone-in market, being the primary driving price, besides own-price, behind demand for all other classes, and exhibiting the only significant responses to changes in price of the other classes.

Finally, the results of the AP Rotterdam complement and support the major findings of the differential production model. The emerging trend of decreased frozen Australian lamb market expenditure share in favor of a preference for frozen lamb from New Zealand and chilled lamb from Australia is corroborated in both Rotterdam models, regardless of quality differentiation. However, an analysis of summary statistics may indicate that this is primarily due to the pull of the large bone-in market, while the smaller boneless market may have yet to experience such preferential influence on market expenditure shares. Second, the results of the Rotterdam models overwhelmingly support the finding of increasing inelasticity of the imported lamb market. All but one of the compensated elasticities were inelastic and the inclusion of the income effect in the uncompensated elasticities resulted in a fully inelastic market. While both the boneless and bone-in market exhibited highly inelastic own- and cross-price relationships, the effect is more pronounced in the bone-in market. Given the higher quality designation of New Zealand lamb hinted at by the summary statistics as well as the targeted branding campaign for New Zealand lamb (Clemens and Babcock, 2004), it is possible that the potentially more luxury-oriented bone-in market is less sensitive to price changes and more responsive to qualitative factors not evaluated herein. Conversely, the boneless market, being less associated with the traditionally ‘luxury’ lamb cuts, could be more dependent on the quantitative factor of price. Regardless of the cause, the results clearly demonstrate that, even in the differentiated markets, lamb imports are highly inelastic.

CHAPTER 4: CONCLUSION

The two approaches taken in this investigation of the imported lamb market have revealed a clear, coherent story. From the outset, the differential production model demonstrates that lamb imports have remained relatively consistent over the few decades, with results being largely in line with those of MJH (2007). Two major divergences from the results of MJH (2007), however, are a loss of a statistically significant relationship between imported quantities and the domestic wholesale price of lamb, as well as an increasingly inelastic import market. Both of these findings are evidence of a stable import market, in which it appears that importers have become less sensitive to changes in prices, requiring a more jarring change in prices to change demand patterns rather than smaller, regular fluctuations. Results illustrate that the lamb import industry is one of low, and perhaps still decreasing, variability. Furthermore, the apparent loss of a relationship with the domestic price of lamb indicates that, not only are importers less sensitive to changes in import prices, but the domestic price of lamb may have little to no bearing on importer decisions in the long run.

These findings of a stable import market set the stage for a deeper investigation into the role of quality in importer decision-making. Even in the differential production model, some conclusions on the role of quality can be drawn. The differential production model results that show importer preference for different products from different sources highlight the need to differentiate chilled and frozen lamb in estimation. For example, frozen imports from New Zealand have increased, as have chilled imports from Australia. Furthermore, the distribution of imports has moved to be comprised of nearly equal levels of frozen and chilled[4]. In addition, the

[4] Frozen imports have 55% of market expenditure share instead of the 68% in MJH and chilled imports have grown to 45% of the market over 32%.

differential production model analysis indicates that the lamb import market has evolved to show import preferences for certain product types to originate from a specific source. Accordingly, frozen imports are primarily sourced from New Zealand and chilled imports are primarily sourced from Australia.

The importance of quality, as reflected in the results of the differential production model, merits further investigation through an evaluation of product differentiation. Accomplished with the AP Rotterdam model, the investigation of boneless/bone-in product differentiation corroborated all of the relevant results of the differential production model. The imported lamb market was found to be highly inelastic, especially in the case of the uncompensated elasticities, regardless of product differentiation. Preferences for chilled and frozen product from Australia and New Zealand, respectively, were also evident in the results of the quality differentiated models, but only in the bone-in market, which represents approximately 80% of lamb imports. The boneless market instead demonstrated importer preference for Australian lamb, regardless of frozen or chilled designation. This distinction is only visible in the AP Rotterdam models, which is a clear demonstration of one of the most important findings of this work: the separability of boneless and bone-in lamb. As imported lamb has traditionally been treated as a homogenous product, differences in importer treatment of boneless and bone-in lamb has gone unnoticed in the literature. However, both aggregation and separability tests indicate that importers treat boneless and bone-in lamb as wholly separate products, and so they should be differentiated in the literature as well.

Finally, the AP Rotterdam models expose in much clearer detail the nature of frozen Australian lamb’s place in the lamb market, for both boneless and bone-in products. Though somewhat visible in the conditional elasticities estimated from the differential production model, the AP Rotterdam results make it evident that frozen Australian lamb demand has become nearly irresponsive to New Zealand imports, having a statistically significant relationship only with its own price and that of chilled Australian lamb. This, combined with the finding of decreasing market expenditure shares for frozen Australian lamb and an apparently growing demand and preference for frozen New Zealand lamb could potentially indicate that frozen Australian lamb is moving towards a place of obsolescence in the imported lamb market for the U.S. This finding, however, in no way extends to chilled Australian lamb, which conversely shows evidence of being a market leader, with all classes of imports being responsive to changes in the price of chilled Australian lamb. Ultimately, though, these findings in conjunction with those of a highly inelastic market, could be pointing to a role of quality in the imported lamb market even greater than that evaluated herein. Further investigation may be merited into the role of quality on the domestic consumer side of imports, or possibly into the role of COOL branding on the part of New Zealand in influencing importer demand. Whatever the role of quality in the preferences of importers, it is clear that importers take quality into account enough so that lamb imports should not be viewed as a homogenous product and, as imports become more and more important in meeting U.S. demand for lamb, quality will be an important determinant in imported lamb demand within a price inelastic market.

4.1 Policy Implications

In an era of increasing trade protectionism in the U.S., it is vital for policymakers to recognize the increasingly irreplaceable role imports play in meeting consumer demand in many markets. With domestic production in continuous decline, the American lamb consumer’s dependence on lamb imports is rising, demonstrating how essential imported lamb has become in the U.S. lamb market. This study has shown that lamb imports are highly inelastic as well as relatively independent of the U.S. domestic price of lamb. Furthermore, product quality, in the form of boneless and bone-in differentiation, plays an important role in importer decision-making and, as such, should be taken into consideration by policymakers. If the American lamb consumer is to be protected from the potential scarcities imposed by excessively protectionist policies, policymakers need to understand not only the importance of imports in meeting lamb demand but also the importance of factors beyond price, such as quality differentiation, that affect import behavior in this inelastic market.

4.2 Limitations and Further Research

Despite this work's comprehensive approach to both the price and quality influences on lamb imports, there remains room for improvement as well as further investigation. This study is limited first by the format of the available data. Where importers use current wholesale prices, differentiated by cut and form, this study uses total import values as a proxy for wholesale prices. Although this in no way invalidates the relationships found between price and quantity, there is undoubtedly some information loss that occurs as a result of the use of a proxy.

While this study takes the first steps into incorporating quality into evaluation of lamb imports, there remain many places for further investigation. First, with respect to the differential production model, in order to better track the evolution of inelasticity within the market over time, it would be of value to take a rolling regression approach to estimating annual elasticities. However, the similarities between the results of the differential production models in this work and that of MJH (2007) may indicate that such an approach may not lead to additional insight into price responsiveness over time. Further investigation into the role of quality on imports may also be of value, possibly evaluating different quality grades of lamb. Additionally, the changing landscape of American lamb consumer demographics may merit investigation, looking at both consumer attitudes toward domestic versus imported lamb, as well as consumer attitudes toward varying qualities of lamb. Ideally, future research will incorporate additional analysis focused on further differentiation of quality, given the price inelasticity of the imported lamb market further supported herein, as well as the findings of the importance of quality to importers in the market.

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