Import Demand Systems for Genetic Products

by

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Abstract

Genetic products have been traded internationally since the 1970s. Over 190 countries have participated in trading genetic products including bovine semen, live bovine animals for breeding purposes, and live swine animal for breeding purposes. The goal of his research is to study the international market for genetic products and answer three research questions: 1. If importers' farm cash income or the number of animals in stock changes, do importers increase or decrease their expenditures on genetic products from specific exporters? 2. If genetic product prices change, how will importers change their expenditures on genetic products from different exporters? 3. If importers' total genetic product expenditures change due to trade policies such as subsidies and quotas, how will importers change their expenditures on genetic products from different exporters? In this research, I conducted an econometric analysis of the import demand for genetic products. Overall, 15 two-stage demand systems are estimated for 15 major bovine semen importing countries and regions. The estimation results, the elasticities, and model simulation results of three major Canadian bovine semen importers (Australia, Japan, and the Netherlands) are used to answer the three research questions of this research.

The result shows that the effects of Farm Cash Income and Animal Number increase on importers' total bovine semen expenditure vary across importers. Overall, the elasticities and simulations suggest that three importers would change Canadian bovine semen import value if their total bovine semen expenditures change due to Farm Cash Income and Animal Number changes. An increase in Canadian bovine semen export price would cause less import demand for Canadian bovine semen. Importers are more likely to increase their Canadian bovine semen import values if their governments provide subsidy to bovine semen import and increase their total genetic product expenditures.

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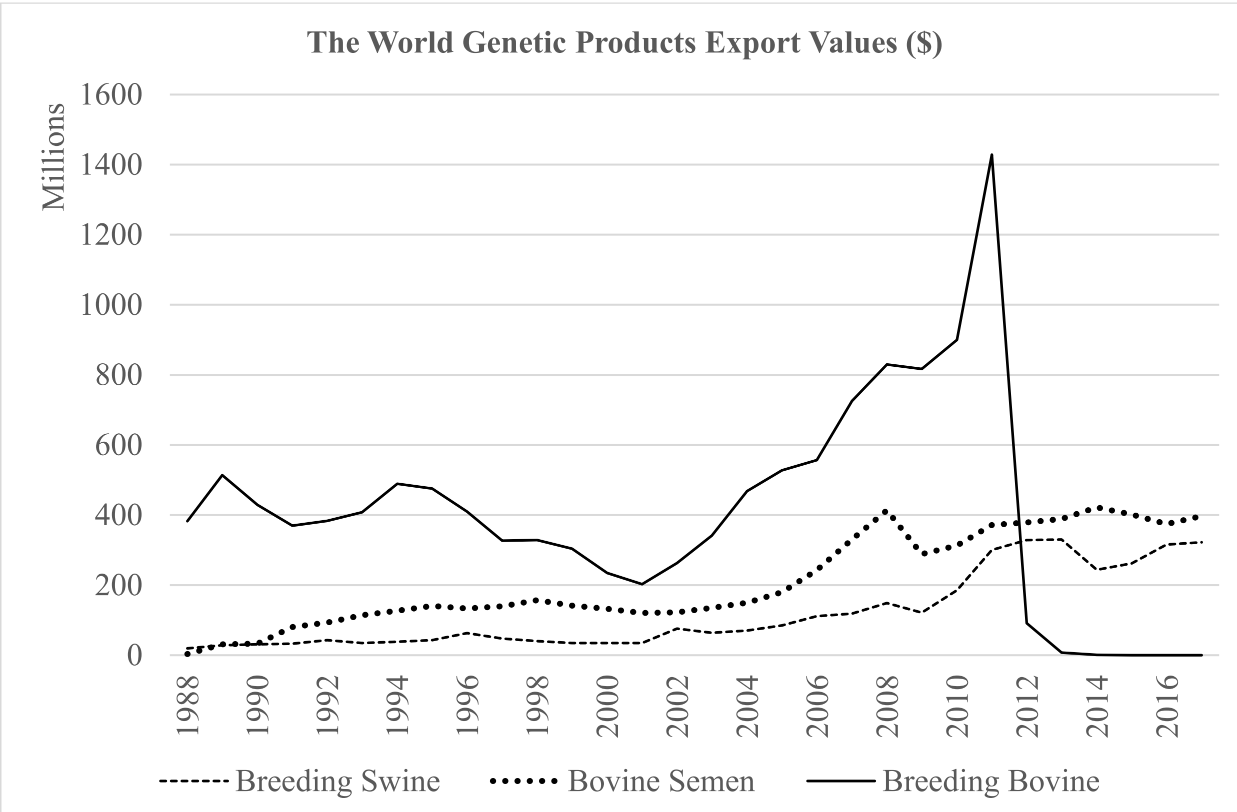
Chapter One: Introduction

Over the last several decades, genetic products have received increasing attention from the livestock industry (Thornton, 2010). The most common genetic products are live breeding animals, animal semen, and animal embryos (Gollin et al., 2009). With economic growth and increasing income, the demand for animal protein has also been growing (Steinfeld et al., 2006). To meet the increasing demand, livestock companies require genetic products with better animal characteristics to raise more "productive" livestock (Thornton, 2010). However, the increased demand has not been adequately met in domestic markets, and livestock companies import substantial volumes of foreign genetic products from other countries (Gollin et al., 2009).

Genetic products have been traded internationally since the 1970s (United Nations Comtrade, 2017). Figure 1.1 shows trade in the international genetic product market by plotting the total export value of three most commonly internationally traded genetic products -- bovine semen, live bovine animal for breeding purpose and live swine animal for breeding purpose. Breeding bovine is the first genetic product traded in the history from 1970, and the other two genetic products were first traded at the end of the 1980s. Because bovine semen has no animal welfare concern and less transportation cost, bovine semen is treated as a substite to live breeding bovine animal (Eriksson et al. 2018). While live breeding bovine animal trade has been decreasing, bovine semen and live breeding swine have exhibited an increasing trend over the last decade (Figure 1.1). From 2012, bovine semen has become the genetic product with the highest trade value. In 2017, the total trade value of these three genetic products reached 719,059,007 US dollars (United Nations Comtrade, 2017).

Figure 1.1 The World Genetic Products Export Values (1970- 2017) (United Nation, 2017)



The international market for genetic products has been increasing rapidly and the export of genetic products is becoming more important to the agricultural industry of many countries. Based on data from United Nation Comtrade (2018), from 1988 to 2018, the world bovine semen trade value has been increasing from 3 million US dollars to 397 million US dollars with a 40% annual increase rate on average. The world breeding swine trade value has been increasing from 19 million US dollars to 321 million US dollars with a 13.65% annual increase rate on average. The bovine semen and breeding swine export value of Canada, which is the second-largest bovine semen exporter and fourth-largest breeding swine exporter globally in 2018, has been facing a 6.3% and 64% annual increase rate on average, respectively. More importantly, the data shows that the trade values of bovine semen and breeding swine are likely to increase rapidly in the future. The trade of genetic products is playing a more important role in agriculture products export and understanding the economic factors that affect the world supply and changes in importers' purchasing behaviour of genetics products is critical for policymakers.

Since genetic products are purchased as livestock production inputs, importers' purchase behavior is often affected by the export prices of genetic products and their livestock industry production demands (Goddard, 1988). Farm cash income (FCI) shows the production revenue of the livestock industry, and the number of animals in stock (AN) is often used as an indicator of the scale of livestock industry (Goddard, 1988). Both FCI and AN are critical economic factors that affect importers' production demand for genetic products (Goddard, 1988). Therefore, the key questions that need urgent answering are: 1) If importers' farm cash income or the stock of animals changes, do importers increase or decrease their genetic import expenditures from specific exporters? 2) If genetic product prices change, how will importers change their genetic import expenditures from different exporters? 3) If importers' total genetic product expenditures change due to trade policies such as subsidies and quotas, how do importers change their genetic import expenditures from different exporters? While these questions hold key implications for welfare in large importing countries (e.g., Germany), large exporting countries such as Canada and the U.S need to understand them as well to retain their market share. However, despite these outstanding issues and the large scale of genetic products traded internationally, no empirical econometric research has been done to study the international market for genetic products.

The primary objective of this research is to provide answers to the three foundational questions posed above by conducting an econometric analysis of the import demand for genetic products. Estimates from the model will yield quantitative answers to the three questions: 1)

Elasticities of farm cash income and animal numbers in stock capture the influence of importers' farm cash income and number of animals in stock change on their expenditures on genetic products from specific exporters. 2) *Price elasticities* yielded by the model will show the effect of relative price changes on importers' expenditure on genetic products from different exporters. 3) *Expenditure elasticities* will show how trade policies would directly or indirectly affect importers' expenditure on genetics from different suppliers.

To meet my objective I use a source-differentiated 2-stage demand system where the first stage models how importers decide the total budget they will allocate to genetic products; and second stage models how they expend that budget between alternative exporters or suppliers of genetic products. Specifically, the first stage is an expenditure equation that specifies how importers' expenditure on genetic products are influenced by export prices and livestock industry development. The second stage is a Translog import demand system which specifies how importers allocate genetic product expenditure to different exporters based on export prices. This empirical econometric method has been broadly applied for agricultural products. For example, it has been applied to study the international markets of wheat (Copel and Rigaux, 1974; Konandreas and Bushnell, 1978; Alston et al. 1990), cotton (Duffy et al, 1990; Chang and Nguyen, 2002), and other commodities (Wang and Reed, 2014; Sun and Niquidet, 2017). But no research has applied this method to study the import demand for genetic products.

This research uses five annual datasets. The data period is from 1988 to 2016. The first dataset is the annual genetic products import data from United Nations Comrade (UN Comtrade, 2017). The second and third datasets are country farm cash income and animal numbers in stock from Food and Agriculture Organization (FAO, 2017), which are used as the expenditure equation variables. The fourth dataset is annual Consumer Price Index (CPI) by country from the World

Bank (World Bank, 2017) and used to deflate the prices. Further, the fifth dataset is annual country population from Food and Agriculture Organization (FAO, 2017) and used as the weight when exporting countries are grouped into exporting regions.

My study makes several novel contributions to the genetic products international trade literature. Despite various studies applying demand theories to international markets, this is the first study applying demand theory to the international market of genetic products. Specifically, this is the first study that examines the influence of price change, expenditure change, the farm cash income, and animal numbers change on the import of genetic products.

The remainder of the thesis is structured as follows. The second chapter reviews the literature on current studies of genetic product international market and gene technologies, followed by a discussion of consumer demand theories and empirical applications of consumer demand theories in the international market. The third chapter introduces the conceptual framework and empirical method of this research. Dataset employed for estimation is also discussed. The estimation result is presented and discussed in section four. The final section of the thesis summarizes the results and draws conclusions from a policy perspective.

Chapter Two: Literature Review

To better understand genetic products trade and the relevant theories about estimating import demand systems, four sections are included in this chapter. The first section discusses the background of livestock companies' demand for genetic products. The second section reviews research studying genetic products for international trade and reveals a lack of attention to my specific research questions. The third section reviews consumer demand theories about how demand is estimated in the domestic market. The fourth section reviews how studies apply consumer demand theory to empirically estimate import demand systems. Because genetic products are purchased for production purposes, it is important to understand the major genetic products demanded by livestock companies. Further, as technologies change, the nature of genetic products are also changing. I seek to provide a description of these changes as well.

2.1 Livestock Companies' Demand for Genetic Products

Breeding-animals have the longest trade history because of conventional selective breeding (Clark et al., 2006). The most conventional and widely used reproductive technology is selective breeding (Clark et al., 2006). By carefully choosing the breeds of male and female animals, particular phenotypic traits can be developed (Clark et al., 2006). To take advantage of this approach, livestock companies purchase live breeding animals as genetic products. The invention and adoption of Artificial Insemination (AI) and Embryo Transfer (ET) continue to change livestock companies' genetic product preferences from breeding-animals to semen and embryo. Artificial insemination was first applied to cattle breeding in the 1940s, and embryo transfer to recipient females in cattle was developed in 1970 (Eriksson et al., 2018). AI and ET were adopted by the swine industry in the 1990s (Bortolozzo et al., 2015). AI and ET are thought to be more cost-effective and have more desired attributes, for example, semen and embryo are easier to store and transport. AI and ET are safer in case of disease transmission, and there is no animal welfare concern (Bortolozzo et al., 2015). Because of the innovation and adoption of these two technologies, livestock companies purchase animal semen and embryos as substitutes for live breeding-animals. However, semen is only internationally traded in the bovine market but not in the swine market. Boar semen is highly sensitive to cold shock (Yeste 2015) and can only be stored using liquid storage methods at temperatures between 16 to 18 °C for 3 to 5 days (Riesenbeck, 2011). This relative short shelf life makes long-distance transportation very difficult (Riesenbeck, 2011). Therefore, for swine livestock producers, live breeding swine is still the main genetic product in the international market.

In recent years, new technologies have been invented and may potentially influence livestock companies' preferences for genetic products. Gene technologies, including Genomic Selection (GS), Genetic Modification (GM), and Gene Editing (GE) are being tested and applied to the livestock industry. Genomic Selection (GS) is currently used in the livestock industry. Instead of observing phenotypes, GS allows farmers to selectively breed livestock based on specific genetic information or genotype (Eriksson et al., 2017). This technology can speed up the selection process and help the livestock companies produce the desired animals in a shorter period (Eriksson et al., 2017). The second type of genetic technology is gene engineer technologies, including GM and GE. Both these two technologies involve altering the genes of animals by inserting genes from different species (GM) or the same species (GE) and deleting unwanted genes of the target animal (Eriksson et al., 2017). Currently, there are no long-term, large scale livestock breeding programs incorporating GM and GE for food production because the process is complex and requires continuous selection (Eriksson et al. 2018). These technologies can potentially help livestock companies better make use of genetic products and change their current preferences for genetic products. However, the influence of gene technologies on livestock companies' preferences for genetic products is still unstudied and needs further research.

In conclusion, breeding animals, semen, and embryo are three common genetic products purchased by livestock companies. And, because of the technology development and restriction, semen and embryo are more preferred by livestock companies in the bovine genetic products international market, and live breeding swine is still the main product in swine genetic product international market.

2.2 International Trade of Animal Genetic Products

I am aware of one paper (Gollin et al., 2009) that conducted an economic assessment of the international market for genetic products. Using genetic products trade data from the United Nations Comtrade from 1990 to 2005, the study assesses how much developing countries are affected by genetic products export. The study examines market share changes of different exporters in the genetic products international market using only descriptive analysis. They conclude that developing countries are not major genetic products exporters and, hence, are slightly influenced by genetic products export. Other research (Tvedt et al., 2007; Hiemstra et al., 2006) studying the international market of animal genetic products are limited to focus on how to improve the legal framework for trade fairness, biosecurity, and environment protection. Overall, there are no studies based on economic models and rigorous econometric analysis of international genetic product markets—in particular, related to the questions posed in this thesis.

2.3 Consumer Demand Theories Comparison

The literature shows consumer demand theories are often applied by researchers to estimate import demand systems, therefore, a review of this literature is important for the objective of this research which involves estimating econometric import demand systems for genetic products. Different demand theories have been invented and applied to estimate demand systems for various goods. Researchers have used relatively traditional demand systems such as Linear Expenditure Systems (Stone, 1954) and Rotterdam Demand Model (Theil, 1965; Barten, 1967). There are also flexible functional forms such as the generalized Leontief (Diewert, 1971), and the generalized Box-Cox (Box and David, 1964). The Translog Demand Systems (Christensen et al., 1975) and Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980) are the most recent demand systems, which are widely used in consumer demand estimation. Based on the literature review, studies (Appelbaum, 1979; Lewbel, 1989; Vuong, 1989; Alston and Chalfant, 1993; Wang et al., 1996; Barnett and Seck, 2008) have shown the global properties of different methods are unclear, and the criteria of choosing methods to estimate demands are ambiguous and debatable. This lack of clarity is clearly stated by Deaton and Muellbauer (1980, P. 79), "using flexible functional form demand systems to test economic theory is exactly on par with using the earlier Rotterdam models; we cannot know whether the hypothesis is false or whether the approximation is inaccurate." There is no clear rule to help choose a demand system or model over others in a specific context. It is basically up to the researchers to select a functional form (Goddard, 1989).

The Translog Demand System was developed by Christensen et al. (1975). Christensen et al. (1975) claimed that additive and homothetic utility functions played an important role in formulating tests of the former demand theories, and the consequences are the expenditure proportions are independent of total expenditure and elasticities of substitution among commodities are constant and equal. To develop a demand theory without the assumption of additivity or homotheticity and fit the demand duality theory, a translog utility function was proposed.

The Almost Ideal Demand System (AIDS) was developed by Deaton and Muellbauer (1980), which combines the desirable properties of both the Rotterdam or Translog demand models. AIDS is a first-order approximation to any demand system, consistent with household budget data and easy to estimate. However, in the practical demand system estimations, studies show that the statistical differences among AIDS, Translog, and Rotterdam are insignificant (Alston and Chalfant, 1993; Barnett and Seck, 2008; Lewbel, 1989; Wang et al., 1996). The relevant studies are discussed below.

Studies comparing AIDS and Rotterdam models show the two models yield similar results. Alston and Chalfant (1993) used a compound – model approach to test the AIDS and Rotterdam models. The estimation result failed to reject the null hypothesis that Rotterdam is correct but rejected the null hypothesis that AIDS is correct. But in the paper, the authors also suggested that this result shouldn't be interpreted as evidence that Rotterdam is superior and different datasets may get the opposite result. And the calculated mean elasticities using two methods show very similar results. Barnett and Seck (2008) conducted a Monte Carlo study comparing the AIDS, AIDS and Rotterdam. The result suggested that three methods yielded similar income elasticities and all performed well when substitution is low and high. But when substitution is very high, non-linear AIDS performs better. Both studies concluded that AIDS and Rotterdam are similar.

Studies compared AIDS and the Translog model, and only one study suggested that the Translog has uniformly high explanatory power. Lewbel (1989) nested the AIDS and Translog demand system to estimate the aggregated U.S demand data. The result indicated that neither model is better than the others. Either both models are accepted, or both rejected. The estimated elasticities of the two models are also similar. Wang et al. (1996) used a non-nested test to directly compare the explanatory power of the AIDS and Translog demand system. The result indicated that both AIDS and Translog are rejected at the 1% level as compared with the Lewbel model and there is no conclusion showing any difference of relative explanatory power between AIDS and Translog. And there is also no significant difference in elasticity estimates. In the paper (Goddard and Glance, 1989), the authors used both AIDS and Translog models to estimate the oil and fats demand in Canada, the United States, and Japan. Translog was used as the basis for further analysis because the Translog was believed by the authors to have uniformly high explanatory power.

In conclusion, no research shows one model has better explanatory power than the other one globally. Despite the theoretical difference, Rotterdam, AIDS, and Translog all gave similar results in terms of elasticities estimation. But Translog model is a non-linear demand model, and its flexibility can potentially provide more accurate results (Goddard and Glance, 1989).

2.4 Two-Stage Demand Systems

The demand theories discussed above are one-stage demand systems only estimating how consumers allocate their budget among goods. However, studies (Gorman, 1959; Deaton and Muellbauer, 1980; Edgerton, 1997) show that two-stage demand system, including a second stage which estimates how consumer decide their total budget on a commodity, is tested to give more accurate estimation results.

Gorman (1959), Deaton and Muellbauer (1980), and Edgerton (1997) discussed the two-stage demand system that total expenditure is allocated to different groups of goods in the first stage and group expenditures are allocated over goods in the same group in the second stages. And, they claimed that the two-stage demand system is tested to give more accurate estimation results than one stage demand systems (Gorman, 1959; Deaton and Muellbauer, 1980; Edgerton, 1997). Edgerton (1997) claimed that two assumptions need to be met to build two-stage demand systems. First, commodities need to be weakly separable. Second, the price index for each group in the utility function needs to have low sensitiveness and better be normalized. If these two requirements are met, the two-stage demand system estimated in Time Series Processor (TSP) will lead to an approximately correct allocation Edgerton (1997).

Two-stage demand systems have been widely applied to estimate consumers' demand for various goods. Fan et al. (1995) applied a two-stage Linear Expenditure System (LES) – AIDS model to estimate the demand systems for multiple commodity groups (cloth, food, fuel, and others) with provincial data from 1982 to 1990. Michalek and Keyzer (1992) also applied the two-stage LES-AIDS model to estimate demand systems for ten food products of eight EC countries. Other studies, including Menezes et al. (2008) calculated demand elasticities for food from Brazil by Lin-log, AIDS two-stage demand systems, Goddard and Glance(1988) used log-log and Translog two-stage demand system to estimate export demand for fats and oils in Canada, the US, and Japan.

In conclusion, the two-stage demand system has been widely applied to empirically estimate consumers’ demand and is thought superior to the one-stage demand system. And, Edgerton (1997) shows that two requirements need to be met when estimating the two-stage demand system.

2.5 Censored Dependent Variable

The two-stage demand system is designed to estimate how consumers decide their total expenditure on a group of goods and how the expenditure is allocated to different goods. However, consumers may spend zero money on a group of products and no longer need to allocate the budget for a period of time. When consumers’ expenditure on the goods is zero, the two-stage demand system fails to explain consumers’ zero-purchase behavior, and the two-stage demand system estimation will be biased (Heckman, 1976). In this case, the budget shares of consumers are censored from zero and are referred to as the censored dependent variable problem in the literature.

The literature review provides two methods to solve the censored dependent variable problem.

The first method to deal with censored dependent variables is the Tobit model (Tobin, 1958) which assumes that the observed dependent variable is limited, and the observed dependent variable is an expression of the unobserved latent variable. Tobin (1958) claimed that observable dependent variable is equal to the latent variable when the latent variable is above zero, and observable dependent variable is equal zero when the latent variable is equal to or smaller than zero. Another econometric approach is Truncated regression model proposed by Amemiya (1974). Observations with values below or above certain thresholds are systematically excluded from the sample. However, this method causes fewer observations and higher mean values than the censored sample (Heckman, 1976).

Heien and Wessells (1990) proposed a two-step Heckman model. In the first step, the decision of whether to buy or consume a product is modeled as a dichotomous choice problem. The dependent variable is one when products are consumed or purchased. The dependent variable is zero when products are not consumed or purchased. The dependent variable is a function of prices, income, and related demographic variables. The inverse Mills ratio is calculated accordingly. The second step is a two-stage demand system with the inverse Mills ratio included in the demand systems. Heien and Wesselss (1990) compared the Heckman model with the traditional two-stage demand system using US household food consumption data. The result suggested that the HW model significantly increased the goodness of fit for the censored model. Also, the result showed that the own-price elasticities are significantly different when there is a large proportion of zero observations.

The second approach to solve the censored dependent problem is the Kuhn-Tucker approach proposed by Wales and Woodland (1983) and the associated dual approach suggested by

Lee and Pitt (1986). Demand share equations are derived by using the Kuhn-Tucker approach from the maximization of a specified random utility function with a set of non-negativity and budget constraints. Lee and Pitt (1986) used Roy's identity from a random indirect utility function to derive the demand equations and assumed that consumers compare virtual prices to actual market prices when making purchase decisions. The main issue of this approach is that it can be difficult to specify a direct or indirect utility function allowing for a specific demand system (Dong et al., 2004). Furthermore, the incoherency occurs when the sum of budget shares is not equal to one. However, the Kuhn-Tucker approach and associated dual approach have shortcomings in the field of demand estimation. The approach is designed to fix the censored dependent problem in a single equation framework. The approach is biased when estimating a systematic demand system simultaneously andt he adding up restriction for observed shares can't be met (Heien and Wessells, 1990).

In conclusion, when consumers' expenditure on a group of goods is zero or budget shares are censored from zero to one, the censored budget shares need to be solved to get the unbiased demand system estimation. The literature review shows that the two-step Heckman model brought by Heien and Wessells (1990) is the most commonly used solution and can be incorporated into the two-stage demand model.

2.6 Empirical Studies Estimating Import and Export Demand Systems

This section reviews the literature regarding of how import demands are empirically estimated. Overall, studies of which empirically estimated import demand are divided into two parts. The first part of the literature (1969-1993) is about the Armington model and the tests of Armington's assumptions. The second part of the literature (1988-2017) is the studies, that apply consumer demand models as a production maximization perspective to estimate import demand systems.

Armington (1969) first proposed that products should be distinguished not only by their type but also by place of production. Compared to the old theory that products supplied by different countries are perfectly substitutable and the elasticities of substitution are infinite, Armington (1969) assumed products from different regions or countries are weakly separable and have constant elasticities of substitution. Armington (1969) also made the assumption of homotheticity, which implies that each country's market share is unaffected by the size of the market or the total expenditure but only by the relative price changes. The Armington model assumes that an importer's demand for a commodity is a function of the export price ratio. The Armington model has been widely used to estimate import demands, and its two assumptions have also been empirically tested. The assumption of homotheticity was tested to be invalid by other research (Duffy et al., 1990; Davis and Kruse, 1993). The assumption that goods from different regions are weakly separable was widely used by other studies (Goddard and Glance, 1988; Wilson, 1994; Muhammad, 2007; Parikh, 1988; etc.) estimating import demand.

Duffy et al. (1990) applied the Armington model to estimate the export demand for American cotton. Duffy et al. (1990) calculated the elasticities of substitution for American cotton and used the elasticities of substitution to estimate the Armington equations. The individual and total import demand elasticities for US cotton were estimated, and the results suggested that import demand price elasticities for US cotton were elastic. In the paper, the authors argued that the assumptions of constant elasticity of substitution and homothetic were unrealistic and probably biased the result.

Davis and Kruse (1993) discussed the empirical miscues of the Armington model and proposed an improved Armington model. Davis and Kruse (1993) claimed that the first miscue is that products from different export sources are not always treated as imperfect substitutes but perfect substitutes. The second miscue is that the parameter restrictions required to make the two-stage budgeting procedure consistent with a single-stage utility maximization problem are not imposed and tested. Davis and Kruse (1993) proposed a conditional Marshallian approach to improve the Armington model and tested the improved version using Japanese wheat import data. The results suggested that the improved Armington model is preferred to the traditional one and produces more consistent parameter estimates. At the end of the paper, Davis and Kruse (1993) wrote, “The CES aggregator function imposes weak separability between import sources and, as Alston et al. show, such separability is unlikely. Because other functional forms, including AIDS or Rotterdam models, do not impose such restrictions and are no more difficult to estimate than is the correct primal model presented here, it may be time to let the empirical Armington model wither”.

Alston et al. (1990) used the wheat and cotton import data of five countries to test the separability and homotheticity assumptions of the Armington model. Both parametric and nonparametric tests were performed, and the results rejected the assumptions. Alston et al. (1990) also claimed that the Armington model understates the elasticities substantially by 50% compared to the double log and Almost Ideal Demand System (AIDS). Even though the homothetic assumption and the CES form of the Armington model were empirically proved wrong, the assumption that products from different countries are weakly separable and the assumption has been widely adopted when other studies estimate import demands.

The second part of the literature includes studies, which applied consumer demand systems to estimate import demand systems. Most of those studies maintain Armington’s assumption that products from different regions are weakly separable. Instead of using the Armington CES function, more flexible two-stage consumer demand systems such as the Rotterdam model, AIDS, and Translog Demand System have been applied to estimate the import demands for various commodities.

Goddard (1988) applied a two-stage demand system to estimate the beef export demand elasticities of eight regions. In the first stage, the expenditures of importers on beef were assumed to be a function of quantity-weighted average export price and income. In the second stage, to avoid the problem of constant elasticities of substitution, demand equations based on indirect utility with Generalized Box-Cox functional form were applied. The result suggests that the assumption of perfect substitutability can bias the elasticities substantially.

Goddard and Glance (1988) applied a two-stage demand to estimate the import demand for fats and oils in Canada, the United States, and Japan. The first stage was also assumed to be a function of weighted average prices, income, trend variables, and other economic variables. In the second stage, Translog was estimated using Maximum Likelihood Estimation. The study claimed that both AIDS and Translog were used to estimate the export elasticities, and Translog gave better results in general. The results suggest significant gross complementarity between fats and oils. This demand system was later used to simulate the effect of tariff removal in different scenarios.

Wilson (1994) also applied Translog demand systems to estimate the import demands for wheat by Pacific Rim countries. This study compared the Armington model, AIDS, and Translog. Their result indicates Translog is preferable because the Translog demand system allows expenditure to have a non-linear impact on import shares. Furthermore, Translog allows the elasticities of substitution to vary across importers compared to the CES form of Armington.

Two studies used a Rotterdam production model to estimate the import demand elasticities.

Muhammad (2007) argued that most imported goods need further processing like handling, storage, packaging, and retailing before final demand delivery. Therefore, compared to the traditional two-stage model assuming the utility-maximizing in the first stage, a production profit-maximizing equation in the first stage was proposed to decide importers' total expenditure. Likewise, the study claimed that the unconditional demand elasticities derived from a production profit-maximizing first stage equation differ significantly from the traditional two-stage unconditional consumer demand elasticities. Muhammad (2007) used the Rotterdam production model in the second stage to estimate the EU import demand for fish. The conditional and unconditional elasticities were calculated accordingly. The two-stage model was used to simulate the effect of tariff reduction in 3 possible scenarios in Time Series Processor (TSP). Wang and Reed (2014) applied the same model as Muhammad (2007) and estimated the US demand for imported shrimp. Unconditional elasticities were used to simulate the effect of tariff policies change. Overall, these studies show that first stage equations based on production profit-maximizing design are better than the first stage equations based on consumer utility-maximizing design when products are purchased for production purposes.

The AIDS model has been broadly applied to empirically estimate import demand systems. Parikh (1988) used a trade matrix and estimated AIDS import share equations for 67 importers. Syriopoulos and Thea (1993) applied AIDS to estimate tourism demands for the US and West European countries. The paper (Syriopoulos and Thea, 1993) argued that one advantage of AIDS is that the theory restrictions can be easily tested before being adopted. The empirical estimation result indicates that both symmetry and homogeneity are rejected in this case, and the AIDS estimation is econometrically satisfactory. Mohanty and Peterson (1999) applied dynamic AIDS to estimate the demand for wheat by classes for the US and the EU. The study (Mohanty and

Peterson, 1999) claimed that it is more accurate to differentiate wheat by both end-user and origin, and dynamic AIDS is more accurate than static AIDS. Chang and Nguyen (2002) used AIDS to estimate the demand for Australian cotton in Japan. Result suggests that autocorrelation was detected, and homogeneity was rejected. The paper (Chang and Nguyen, 2002) claims that estimating elasticities without considering the possibility of rejecting theory restrictions can bias the result. Furthermore, Sun and Niquidet (2017) used AIDS to estimate the EU demand for wood pellets. The result suggests the wood pellets from different countries show both substitutability and complementarity.

2.7 Summary

Overall, the literature review shows that Armington's assumption (Armington, 1969) of differentiating products by their countries of origin is often adopted by studies estimating import demands. The literature review also shows that the two-stage demand system is more preferred than one-stage demand system (Gorman, 1959; Deaton and Muellbauer, 1980; Edgerton, 1997). In the first step, an expenditure equation from the profit-maximizing perspective is preferred to estimate how importers decide their total budget when goods are imported for production purposes (Muhammad, 2007). In the second stage, consumer demand models such as Translog and AIDS are used to estimate how budget is allocated to different suppliers. And, Translog can potentially generate more accurate results (Goddard and Glance, 1988). Furthermore, the Heckman model (Heckman, 1976) should be applied when importers' expenditure on the goods are zero or budget shares are censored from zero to one. The model specifications are presented and discussed in the next chapter.

Chapter Three: Methods

Based on the literature review from chapter two, the conceptual model is presented in the first section titled 'conceptual framework.' The model specifications, including demand equations, elasticities, and restrictions are described in the second section titled 'Empirical Method.' In addition, the third section titled 'Data Preparation' shows how data is collected, cleaned and grouped. Furthermore, the descriptive analysis of the data is discussed in the fourth section 'Descriptive Statistics.' Last but not least, the fifth section summarizes the whole chapter. The overall design of this research is presented in two parts based on the literature review of consumer demand theories and import demand estimations. The first part is the underlying assumption of this research, which is the product differentiation based on its country of origin. The second part discusses the three-stage demand model design.

3.1 Empirical Approach

The conceptual framework can be described in two steps. First, I rely on the country of origin differentiation assumption (Armington， 1969). Armington (1969) first argued that products from different countries should be distinguished not only by the commodity type but also by the place of production. There are two reasons for his arguments. The first reason is related to the actual heterogeneity in the quality of the same good (Armington， 1969; Goddard, 1988). The second reason is related to the fact that heterogeneity can also at the supplier-level rather than the product-level (Armington， 1969; Johnson, Grennes and Thursby, 1979). For instance, reputations and reliabilities of suppliers vary and influence how importers perceive their products (Johnson, Grennes and Thursby, 1979). It is important to note that different suppliers also have longer or shorter transport distances and different transportation costs (Johnson, Grennes, and Thursby, 1979). In this research, genetic products from different producers are assumed to be heterogeneous in both of these dimensions.

Second, based on the literature review, I use a three-stage demand system to model the import demand decision. The three stages are constructed to address three decisions: 1) whether to import genetic products or not? 2) conditional on importing, how much of their total budget to allocate to imports of genetic products? 3) how to allocate the import budget for genetic products among different suppliers or exporters?

In the first stage, corresponding to the first question about zero import of genetic products or budget shares are censored from zero to one, a Heckman model based on Heien and Wessells (1990) is used to solve the censored dependent variables problem. Heien and Wessells (1990) indicated that the possibility of whether importers spend money on products is a function of import prices and socio-economic variables. As genetic products are purchased for further production purposes, consequently, farm cash income and animal numbers in stock are chosen to be the socio-economic variables in this research from a profit-maximizing perspective. The inverse Mills ratio is calculated accordingly and further used as a independent variable in the second and third stages to take account of the censored dependent variable.

In the second stage, corresponding to the second question about how importers decide their total expenditure on genetic products, a log-log expenditure equation based on Goddard and Glance (1988) is used to determine importers' total budget or expenditure on genetic products. Because genetic products aren't purchased for consumer consumption but further production purposes, from a profit-maximizing perspective, total expenditure is expressed as a function of the sum of weighted prices, farm cash income, and animal numbers in stock.

In the third stage, corresponding to the third question about how importers allocate their budget, an indirect Translog demand system (Christensen et al., 1975) is used to estimate how importers allocate their budget among different exporters. In order to achieve the highest output, importers allocate their total budgets on genetic products from different suppliers or exporters according to the prices of their products.

The main estimates of the three-stage demand model are elasticities. Both conditional and unconditional elasticities are calculated using the parameter estimates: conditional elasticities are calculated based only on how do importers allocate genetic products expenditures (second stage budget share equations) without taking account of how importers decide their total expenditure (first stage). Unconditional elasticities are calculated based on both the first and second stage equations. *The unconditional farm cash income elasticity* shows the percentage change of the quantity of semen imported from an exporter in response to one percent change of the importer's farm cash income, and the *animal number* elasticity responds to the number of animals held in stock. The *conditional expenditure elasticity* shows the percentage change of the quantity of imported in response to one percent change of the importer's total expenditure on genetic products. The *conditional and unconditional price elasticities* shows the percentage change of imported quantities in response to one percent change of different exporters' prices. The elasticities yielded from the import demand model provide the answer for the three research questions.

3.2 Empirical Method

3.2.1 The Econometric Model

Based on the three-stage demand model, which is discussed in the previous section, the model specifications are discussed below. The first stage is the Heckman model (Heien and Wessels, 1990) and is specified as follows:

Y_k = f ($p_1 \ldots\ldots p_n$, FCI_k , AN_k) (eq.1)

Where Y_k is one if importer k purchases genetic products in that year and zero otherwise, p_i is the exporting price of the genetic products from exporter n, FCI_k and AN_k are the farm cash income and animal numbers in stock for importer k. The inverse Mills ratio for importer k according to the Heckman model is calculated as follows:

$R_k = \phi\,(p_1 \ldots\ldots p_i, FCI_k\, , AN_k) / \Phi\,(p_1 \ldots\ldots p_i, FCI_k\, , AN_k\,)$ (eq.2)

$R_k = \phi\,(p_1 \ldots\ldots p_i, FCI_k\, , AN_k) / (1 - \Phi\,(p_1 \ldots\ldots p_i, FCI_k\, , AN_k\,)$ (eq.3)

Where $R_k$the inverse Mills ratio for importer k. is ϕ is the normal density function and Φ is the cumulative-probability function.[1]

The second stage is estimating how importers decide their total expenditure on genetic products conditional on the first stage. Based on Goddard and Glance (1988), expenditure equation is designed as follows:

$\ln Exp_k = \alpha_{0,k} + \alpha_{1,k}\ \sum_{i=1}^{n} W_{i,k} \ln P_{i,k} + \alpha_{2,k} \ln FCI_k + \alpha_{3,k} \ln AN_k + \alpha_{4,k}\varepsilon_{i,k}$ (eq.4)

Where $\ln Exp_k$ is the logarithm of the total expenditure of importer k on genetic products. $W_{i,k}$ is the budget share of importer k on genetic products from exporter i. $\ln P_{i,k}$, $\ln FCI_k$, and $\ln AN_k$ are the logarithm of exporter i's exporting price to importer k, farm cash income, and animal numbers in stock for importer k.

The third stage is estimating how importers allocate their genetic products expenditure among exporters from different countries. The third stage of the import demand system is specified

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[1] In cases that the importers' total genetic product import annual expenditures are all positive and there is no censored dependent variable problem, the first stage is removed and the model is reduced to a two-stage import demand system.

as an Tanslogmodel following Christensen et al. (1975) and Christensen and Manser (1975):

$$W_{i,k} = \frac{P_{i,k}X_{i,k}}{Exp_k} = \frac{\alpha_i + \sum_j \beta_{ij} \ln(P_{j,k}/Exp_k) + \gamma_i R_k}{\sum_j \alpha_j + \sum_j \sum_i \beta_{ij} \ln(P_{j,k}/Exp_k) + \sum_i \gamma_i R_k} + \varepsilon_i \qquad \text{(eq.5)}$$

Where $W_{i,k}$ is the budget share of importer k on genetic products from exporter i, $X_{i,k}$ is the importer k's import quantity from exporter i. p_i and p_j are the exporting prices of the genetic products from exporter i and exporter j. $LnExp_k$ is the logarithm of the total expenditure of importer k on genetic products. R_k is the inverse Mills ratio for importer k. Based on a paper by Edgerton (1997), in order to avoid biased results, exporting prices are normalized by 2010 exporting prices.

Figure 3.1 Schematic Presentation of Model Estimation

First stage: binary dependent variable models for each of 27 importers (12 breeding swine importers and 15 bovine semen importers).

⇩

Second stage: regression models of importers' genetic products expenditures for each of 27 importers.

⇩

Third stage: budget share equation systems for each of 27 importers (one budget share equation for each of the importer's supplier or exporter).

Taken together we have (Figure 3.1): In the first stage, for each of the 27 importers, I regress a 0/1 variable of whether an importer engaged in positive amount of imports or not using a binary dependent variable model on importers' import prices, farm cash income, and number of animals held in stock. In the second stage, for each of the same 27 importers, a regression model of expenditures on the importers' prices from different exporters, farm cash income, and number of animals held in stock. In the third stage, for each importer, I estimate a system of budget share equations as a function of the importer' prices from different exporters, importers' total expenditure on genetic products. For instance, if an importer imported genetic products from five exporters, I estimate five budget share equations for each of its suppliers or exporters. In my results, I present 1) estimates of the first stage (single equation); 2) estimates of the second stage (single equation); and 3) a system of equations for each importer and its suppliers or exporters.

3.2.2 Estimation

The three stage equations were estimated simultaneously for each importer. A nonlinear multivariate regression method with least squares (LSQ) command in the Time Series Processor (TSP) program is used to get maximum likelihood estimates. Standard errors are computed from a heteroscedastic-consistent matrix in order to provide asymptotically efficient coefficients and consistent standard errors. The budget share equations are the homogeneous of degree zero in the parameters. Hence, the following normalization of the parameters for the third stage is required for estimation:

$\alpha_M = \sum \alpha_i$= -1 (eq.6)

For the purpose of simplifying the notation of the equations, the following notations are adopted:

$\alpha_M = \sum \alpha_i$ (eq.7)

$\beta_{Mj} = \sum_i \beta_{ij}$ (eq.8)

3.2.3 Elasticities

For the purpose of using the coefficients estimated from the three stages of the demand system, based on the paper (Christensen and Manser, 1977; Edgerton, 1997), the conditional and unconditional price elasticities, unconditional expenditure elasticities and farm cash income elasticities, and animal number elasticities are calculated as follows:

Because $W_i = \frac{X_i * P_i}{Exp}$, (eq.9)

Then, ln W_i = ln P_i + ln X_i – ln Exp (eq.10)

$$\frac{\partial \ln W_i}{\partial lnP_i} = 1 + \frac{\partial lnX_i}{\partial lnP_i} \qquad \text{(eq.11)}$$

$$\varepsilon_{ii} = w_{ii} - 1 \qquad \text{(eq.12)}$$

$$= \frac{\partial W_i}{\partial lnP_i}\frac{1}{W_i} - 1 \qquad \text{(eq.13)}$$

Conditional own price elasticity is calculated as follows:

$$= \frac{\frac{\beta_{ii}}{W_i} - \beta_{Mi}}{\alpha_M + \sum_j \sum_i \beta_{ij}\,(lnP_{j,k} - \ln Exp_k) + \sum_i \gamma_{i,k} R_{i,k}} - 1 \qquad \text{(eq.14)}$$

To calculate the unconditional price elasticities, Expenditure is now expressed as the expenditure equation of the first stage:

(4) $LnExp_k = \alpha_{0,k} + \alpha_{1,k} * \sum_{i=1}^{n} W_{i,k} lnP_{i,k} + \alpha_{2,k} * \ln FCI_k + \alpha_{3,k} * lnAN_k + \alpha_{4,k}\varepsilon_{i,k}$ (eq.15)

$\ln W_i = \ln P_i + \ln X_i - \ln \text{Exp}$ (eq.16)

$$\frac{\partial \ln W_i}{\partial p_i} = \frac{1}{P_i} + \frac{\partial lnX_i}{\partial P_i} - \frac{\partial lnExp}{\partial p_i} \qquad \text{(eq.17)}$$

$$\varepsilon_{ii} = w_{ii} - 1 + \alpha_1 * W_i \qquad \text{(eq.18)}$$

Unconditional own price elasticity is calculated as follow:

$$= \frac{(\beta_{ii} - \alpha_1 * W_i * \sum_j \beta_{ij}) \,/\, W_i - \beta_{Mi} + \alpha_1 * W_i * \sum_j \beta_{Mj}}{\alpha_M + \sum_j \sum_i \beta_{ij}\,(lnP_{j,k} - (\ln\alpha_{0,k} + \alpha_{1,k} * \sum_{i=1}^{n} W_{i,k} lnP_{i,k} + \alpha_{2,k} * \ln FCI_k + \alpha_{3,k} * lnAN_k + \alpha_{4,k}\varepsilon_{i,k})) + \sum_i \gamma_{i,k} R_{i,k}} - 1 +$$

$\alpha_1 * W_i$ (eq.19)

Conditional cross price elasticity is calculated as follow:

$\ln W_i = \ln P_i + \ln X_i - \ln \text{Exp}$ (eq.20)

$$\frac{\partial \ln W_i}{\partial lnP_j} = \frac{\partial lnX_i}{\partial lnP_j} \qquad \text{(eq.21)}$$

then get $\varepsilon_{ij} = w_{ij}$ (eq.22)

$$= \frac{\partial W}{\partial lnP_j}\frac{1}{W_i} \qquad \text{(eq.23)}$$

$$= \frac{\frac{\beta_{ij}}{W_i} - \beta_{Mi}}{\alpha_M + \sum_j \sum_i \beta_{ij} \left(lnP_{j,k} - \ln Exp_k \right) + \sum_i \gamma_{i,k} R_{i,k}} \qquad \text{(eq.24)}$$

Unconditional cross price elasticity is calculated as follow:

$$\ln W_i = \ln P_i + \ln X_i - \ln \text{Exp} \qquad \text{(eq.25)}$$

$$\frac{\partial \ln W_i}{\partial P_j} = \frac{\partial lnX_i}{\partial P_j} - \frac{\partial lnExp}{\partial P_j} \qquad \text{(eq.26)}$$

$$\varepsilon_{ij} = w_{ij} + \alpha_1 * W_j \qquad \text{(eq.27)}$$

$$= \frac{(\beta_{ij} - \alpha_1 * W_j * \sum_j \beta_{ij}) \,/\, W_j - \beta_{Mj} + \alpha_1 * W_j * \sum_j \beta_{Mj}}{\alpha_M + \sum_j \sum_i \beta_{ij} \left(lnP_{j,k} - (\ln\alpha_{0,k} + \alpha_{1,k} * \sum_{i=1}^{n} W_{i,k} lnP_{i,k} + \alpha_{2,k} * \ln FCI_k + \alpha_{3,k} * lnAN_k + \alpha_{4,k}\varepsilon_{i,k}) \right) + \sum_i \gamma_{i,k} R_{i,k}} + \alpha_1 * W_j$$

(eq.28)

Because *Exp* only exists in the third stage as a variable, *conditional expenditure elasticity* is calculated based on the third stage:

$$\frac{\partial \ln W_i}{\partial lnExp} = \frac{\partial lnX_i}{\partial lnExp} + 1 \qquad \text{(eq.29)}$$

$$\varepsilon_{iExp} = w_{iExp} + 1 \qquad \text{(eq.30)}$$

$$= \frac{\partial w_i}{\partial lnExp} \frac{1}{W_i} + 1 \qquad \text{(eq.31)}$$

$$= \frac{-\frac{\sum_j \beta_{ij}}{W_i} - \sum_j \beta_{Mj}}{\alpha_M + \sum_j \sum_i \beta_{ij} \left(lnP_{j,k} - \ln Exp_k \right) + \sum_i \gamma_{i,k} R_{i,k}} + 1 \qquad \text{(eq.32)}$$

The *unconditional elasticities of farm cash income and animal numbers in stock* are calculated as follow:

$$\frac{\partial \ln W_i}{\partial FC} = \frac{\partial lnX_i}{\partial FC} - \frac{\partial lnExp}{\partial FC} \qquad \text{(eq.33)}$$

$$\varepsilon_{iFC} = w_{iFC} + \alpha_2 \qquad \text{(eq.34)}$$

$$= \frac{(-\alpha_2 * \sum_j \beta_{ij}) \,/\, W_i + \alpha_2 * \sum_j \beta_{Mj}}{\alpha_M + \sum_j \sum_i \beta_{ij} \left(lnP_{j,k} - (\ln\alpha_{0,k} + \alpha_{1,k} * \sum_{i=1}^{n} W_{i,k} lnP_{i,k} + \alpha_{2,k} * \ln FCI_k + \alpha_{3,k} * lnAN_k + \alpha_{4,k}\varepsilon_{i,k}) \right) + \sum_i \gamma_{i,k} R_{i,k}} + \alpha_2$$

(eq.35)

$\varepsilon_{iAN} = w_{iAN} + \alpha_3$ (eq.36)

$$= \frac{(-\alpha_3 * \sum_j \beta_{ij}) / W_i + \alpha_3 * \sum_j \beta_{Mj}}{\alpha_M + \sum_j \sum_i \beta_{ij} (lnP_{j,k} - (\ln\alpha_{0,k} + \alpha_{1,k} * \sum_{i=1}^{n} W_{i,k} lnP_{i,k} + \alpha_{2,k} * \ln FCI_k + \alpha_{3,k} * lnAN_k + \alpha_{4,k}\varepsilon_{i,k})) + \sum_i \gamma_{i,k} R_{i,k}} + \alpha_3$$

(eq.37)

3.2.3 Restrictions

Since our main results hinge on the validity of the import demand estimates, adhering to restrictions consistent with demand is important. Following Christensen et al. (1975), the general demand conditions for import behavior are imposed for the Translog model. The conditions are:

Symmetry: $\beta_{ij} = \beta_{ji}$ (eq.38)

Adding up: $\alpha_M = \sum \alpha_i = -1$; $\beta_{Mj} = \sum_i \beta_{ij} = 0$; $\sum_i \gamma_k = 0$ (eq.39)

Homogeneity: $\beta_{Mj} = \sum_i \beta_{ij} = 0$; (eq.40)

Since the equations for the budget shares are homogeneous of degree zero in the parameters, a normalization of the parameters is required for estimation. I adopt the normalization $\sum \alpha_i = -1$.

3.3 Data

Overall, this research uses five datasets for 194 countries. Each dataset spans the period from 1988 to 2016. Five parts are included in this section to explain the data preparation. The first part is ‘Data Composition,’ which discusses the content of five datasets. The second part is ‘Missing data,’ which discusses how problems of missing quantities and prices from the trade dataset are addressed. The third part is ‘Exporters and Importers Grouping,’ which shows how 194 individual importing and exporting countries are grouped into 27 trade regions in three steps to improve the model performance. The fourth part is ‘Descriptive Statistics,’ which gives descriptive statistics for the prepared data.

3.3.1 Data Composition

This research used five sets of data, and the period of the datasets is from 1988 to 2016. The first dataset is international genetic trade data for bovine semen, live bovine animals for breeding purpose, and live swine for breeding purposes. Trade data is downloaded from the United Nations Comtrade (https://comtrade.un.org/data/). The trade data from the UN Comtrade includes the annual import/export value($) and net weight(kg) by country. The unit import prices are calculated as importing values divided by importing quantities. Due to the fact that the data shows that breeding bovine trade has almost stopped after 2012, this research only uses the trade data of bovine semen and breeding swine.

The second dataset, annual farm cash income, is downloaded from FAO (http://www.fao.org/faostat/en/#data/QV). FAO describes the data as ‘Farm Cash Income has been compiled by multiplying gross production in physical terms by output prices at the farm gate. The value of production measures production in monetary terms at the farm gate level.’ The unit of the data is the American dollar. For swine, it includes pork gross production value. For bovine, it contains the gross production value for cattle meat, buffalo meat, cow milk, and buffalo milk.

The third data is the live animal in stock by country from FAO (http://www.fao.org/faostat/en/#data/QA). This data records how many livestock animals are held in stock by the country for each year. For swine, it includes the number of pigs. For bovine, this data contains the cattle and buffalo number in stock by country. The fourth dataset is the annual country population data downloaded from FAO (http://www.fao.org/faostat/en/#data/OA). This data records the total population of all countries by year.

The fifth dataset is the annual Consumer Price Index (CPI) by country downloaded from the World Bank (https://data.worldbank.org/indicator/FP.CPI.TOTranslog), and the base year is

2010. The Consumer Price Index measures changes in the price level of a market basket of consumer goods and services purchased by households (World Bank, 2019). CPI is used to deflate the prices and farm cash income.

3.3.2 Missing Data

For the first dataset - international genetic trade data, part of the import quantities are not reported by the UN Comtrade database. However, both import prices and quantities are required to estimate the three-stage demand systems. In cases that the import quantities are missing, the annual unit import prices can't be calculated. For breeding swine import data, there are 627 missing quantities out of 5633 observations. For bovine semen import data, there are 2247 missing quantities out of 15763 observations.

Missing unit import price problems are addressed in two steps. Missing import quantities are imputed by dividing the importing values using recovered importing prices. In the first step, the missing import prices is replaced using the export prices. Due to the fact that exporters sometimes reported the quantity of a trade when the importer didn't, the export price can be calculated and used to replace the missing import price for the trade. After the first step, there are still 414 left, and 1148 missing importing prices left for breeding swine and bovine semen import data.

In the second step, annual average export prices are used to replace remained missing import prices when both importers and exporters fail to report trade quantities. The annual average export price of an exporter in a year is calculated as the annual total export value of an exporter by its annual total export quantity in that year. The missing import prices in a year are replaced using corresponding exporters' annual average export prices in that year. After the second step, all missing import price problems are addressed, and the missing quantities are recovered by dividing the importing values using recovered importing prices.

3.3.3 The Procedure to Decide the Sample of Importers and Exporters

Data for a set of importers are needed to estimate the 3-stage import demand systems (box 1 and box 2 of Figure 3.1). A system of suppliers of exporters for each importers needs to be specified (box 3 of Figure 3.1). However, the data is not available in this useful form. So following Goddard (1988), I undertake a process grouping countries with different levels of imports and exports and create a sample of 27 importers (12 breeding swine importers and 15 bovine semen importers) and 2 to 5 exporters for each of the importers.

There are 12 importers in total in the breeding swine international market. The final list of importers and their suppliers or exporters are shown in Table 3.1. In each import/export group, the major import/export countries are picked as individual importers/exporters. The rest of countries in a region are put into a trade region. For example, Denmark and the Netherlands are German two major suppliers. All other EU countries, excluding Denmark and the Netherlands, are put into a trade region called 'The rest of the EU countries' in the import demand system of Germany. Another example is that China and Korea are two major breeding swine importers. The rest of breeding swine Asian import countries are grouped into 'The rest of the Asian countries'. For breeding swine import, there are three 2-goods demand systems (Belgium, Mexico, Netherlands), four 3-goods demand systems (Eastern Europe, South America, the rest of the EU countries, Spain), and five 4-goods demand systems (China, Germany, Italy, Korea, the rest of the Asian countries).

Table 3.1 Breeding Swine Importers and Exporter

Importer	Suppliers			
	1st	2nd	3rd	4th
Belgium	France	The rest of the EU Countries		
China	Canada	Denmark	The rest of the EU Countries	United States
Eastern Europe	Canada	Denmark	The rest of the EU Countries	
Germany	Denmark	Netherlands	The rest of the EU Countries	United States
Italy	Denmark	France	Netherlands	The rest of the EU Countries
Korea	Canada	Denmark	The rest of the EU Countries	United States
Mexico	Canada	United States		
Netherlands	France	The rest of the EU Countries		
The rest of Asia Countries	Canada	Denmark	The rest of the EU Countries	United States
The rest of the EU Countries	Denmark	France	Netherlands	
South America	Canada	The rest of the EU Countries	United States	
Spain	Denmark	France	Netherlands	

There are 15 importers in total in the bovine semen international market. The final list of importers and their suppliers or exporters are shown in Table 3.2. For bovine semen import, three are one 2-goods demand systems (China), eight 3-goods demand systems (Australia, France, Japan, Mexico, Netherlands, the rest of Asia countries, the rest of South American countries, and the UK), three 4-goods demand systems (Africa, Brazil, and Germany), and three 5-goods demand systems (Italy, the rest of the EU countries, and Switzerland).

Table 3.2 Bovine Semen Importers and Exporter

Importer	Suppliers				
	1st	2nd	3rd	4th	5th
Africa	Canada	France	The rest of the EU Countries	United States	
Australia	Canada	The rest of the EU Countries	United States		
Brazil	Canada	Netherlands	The rest of the EU Countries	United States	
China	Canada	United States			
France	Canada	The rest of the EU Countries	United States		
Germany	Canada	Netherlands	The rest of the EU Countries	United States	
Italy	Canada	Netherlands	The rest of the EU Countries	United Kingdom	United States
Japan	Canada	The rest of the EU Countries	United States		
Mexico	Canada	The rest of the EU Countries	United States		
Netherlands	Canada	The rest of the EU Countries	United States		
The rest of Asian Countries	Canada	The rest of the EU Countries	United States		
The rest of the EU Countries	Canada	France	Germany	Netherlan ds	United States
The rest of South American Countries	Canada	The rest of the EU Countries	United States		
Switzerland	Canada	France	Germany	The rest of the EU Countries	United States
UK	Canada	The rest of the EU Countries	United States		

For each breeding swine and bovine semen importer (Figure 3.1), the three-stage demand system is estimated. In the first stage, whether the importer imported breeding swine or bovine semen from its chosen suppliers in each year is estimated using the Heckman model. In the second stage, the total genetic products expenditure of the importer is equal to total genetic products import value of the importer from its chosen suppliers and is estimated using log-log expenditure equation. In the third stage, the budget shares of the suppliers are equal to importer's total import value from that supplier divided by importers' total import values from all chosen suppliers. For example, Belgium is a breeding swine importer with two major suppliers (France, and the rest of the EU countries). In the first stage, whether Belgium imported any breeding swine from France and the rest of the EU countries is estimated using a Heckman model as a function of the breeding swine export prices of the two exporters to Belgium, the farm cash income of Belgium, and number of animals held in stock by Belgium. In the second stage, the Belgium total breeding swine expenditure is equal to its total breeding swine import value from the two exporters. And, the total breeding swine expenditure of Belgium is estimated using a log-log expenditure equation as a function of the breeding swine export prices of the two exporters to Belgium, the farm cash income of Belgium, and the number of animals held in stock by Belgium. In the third stage, the budget shares of the two exporters are equal to their total breeding swine export values to Belgium divided by Belgium's total breeding swine import values from two exporters, and are estimated as a function of the breeding swine export prices of the two exporters to Belgium, and the total breeding swine expenditure of Belgium.

3.3.4 Descriptive Statistics

The descriptive statistics for breeding swine and bovine semen importers are presented in Tables 3.3 and 3.4. In the sector of the breeding swine import, among the individual importing countries, Netherlands, Germany, and China have the highest average annual import value. Among the importing regions, Eastern Europe and the rest of the EU have the highest average annual import value. Even though most importers began the import from 1988 to 1992, Ukraine and Eastern Europe first imported breeding swine in 1996, and their import value maintained a relatively quick increase afterward. China and the rest of the EU are the individual importing country and region with the highest average farm cash income and average alive swine animal in stock.

Table 3.3 Descriptive Statistics for live Breeding Swine Importers

Importer	Time Frame		AIV		FCI		AN	
	From	To	Mean	S.D	Mean	S.D	Mean	S.D
Belgium	1988	2016	8.58	7.95	1944	60	6.64	0.42
Canada	1988	2016	0.83	0.47	2136	461	12.56	1.5
Carribean	1990	2016	1.11	0.72	202	51	6.47	0.83
China	1992	2016	8.97	10.12	63565	14240	436.98	35.96
Eastern European Countries	1996	2016	14.95	15.64	6986	1513	25.31	2.24
Germany	1988	2016	10.24	11.66	7440	1221	27.41	3
Italy	1988	2016	2.43	1.78	3334	278	8.77	0.44
Mexico	1989	2016	5.72	2.82	2461	417	15.63	0.53
Netherlands	1988	2016	9.27	15.58	2375	271	12.71	0.99
Korea	1989	2016	3.59	2.26	3234	701	8.09	1.83
The rest of Asian Countries	1988	2016	6.58	4.98	13010	1401	83.91	11.67
The rest of EU Countries	1988	2016	14.04	12.92	17858	966	81.27	8.94
South America	1989	2016	3.2	1.77	4287	1314	54.98	6.04
Spain	1988	2016	5.73	4.32	5021	1202	22.44	4.02
Ukraine	1996	2016	2.61	2.53	1489	193	8.3	1.68
USA	1989	2016	0.95	0.97	13837	1941	61.7	4.38

AIV (Million US $): Annual Import Value
FCI (Million US $): Farm Cash Income
AN (Million Heads): Animal Number in Stock

In the sector of the bovine semen import, among the individual importing countries, the US and the United Kingdom have the highest average annual bovine semen import values. Among the importing regions, the rest of the EU and the rest of South America have the highest average annual import values. All importers first imported the bovine semen between 1988 and 1994. The US and the rest of Asian countries are the individual importing country and region with the highest average farm cash income and average alive bovine animal in stock.

Table 3.4 Descriptive Statistics for Bovine Semen Importers

Importer	Time Frame		AIV		FCI		AN	
	From	To	Mean	S.D	Mean	S.D	Mean	S.D
Africa	1988	2016	4.05	3.02	16221	4348	211.47	47.16
Australia	1988	2016	5.91	1.67	7072	893	26.49	2.01
Brazil	1989	2016	12.75	9.88	14913	4002	371.27	51.08
Canada	1989	2016	5.16	2.47	7357	560	12.82	1.09
China	1992	2016	6.69	9.92	23934	10841	225.36	16.93
France	1993	2016	6.71	3.8	15272	432	19.91	0.63
Germany	1988	2016	8.16	2.06	14962	1262	17.9	4.77
Italy	1994	2016	10.58	3.45	10372	780	13.44	0.96
Japan	1988	2016	7.35	3.37	16971	1001	4.52	0.33
Meixco	1990	2016	12.19	6.28	7148	1113	31.69	0.94
Netherlands	1992	2016	9.7	6.28	6987	603	4.15	0.35
The rest of Asian Countries	1988	2016	10.13	6.89	57603	17965	921.42	58.58
The rest of EU Countries	1988	2016	27.36	19.4	29981	1916	45.93	3.53
The rest of South American Countries	1989	2016	22.03	26.93	14064	1679	134.4	7.1
Switzerland	1988	2016	4.54	1.44	3235	81	1.65	0.11
UK	1988	2016	19.44	1.22	8261	442	10.7	0.77
USA	1991	2016	21.64	13.49	64969	4270	96.19	3.99

AIV (Million US $): Annual Import Value
FCI (Million US $): Farm Cash Income
AN (Million Heads): Animal Number in Stock

3.4 Chapter Summary

This chapter covers the discussion of the conceptual framework, the empirical methods, and the data preparation. The five datasets of 197 countries are grouped into importing countries and regions. The final data prepared shows two facts. First, market shares of breeding swine importing countries and regions are extremely volatile (UN Comtrade, 2017). For example, Canada is one of the major suppliers for Mexico, the Canadian market shares in Mexico import market from 2011 to 2016 are 32.97%, 17.07%, 40.17%, 57.79%, 10.33%, and 26.12%. In five years, Canadian market shares change 27.74% on average. Another example is that Denmark market shares in Italy import market are 3.87% in 2008, but it increased to 100% from 2009 to

2012, and the market share dropped to zero in 2014. Likewise, the American market shares in the Chinese import market are 71% in 2009, 0% in 2010, 29% in 2011. For most importers, their major suppliers' market shares all have high variance. Since the data shows that unit prices remain relatively steady, it is clear that factors beyond price changes are driving these market changes. Also, the attempt to estimate three-stage demand systems for breeding swine importers failed. In this case, applying 3-stage model to explain importers' purchase behavior in the breeding swine market failed. Only the result of bovine semen import demand systems will be presented and discussed in next chapter.

Second, importers' annual expenditures on bovine semen are always positive. Since there is no zero-import for bovine semen importers, the first step Heckman model is no longer necessary and is not estimated. Therefore the import demand systems for bovine semen reduce to a 2-stage demand system. Only the total expenditure equations and budget share equations are estimated. In chapter four, the estimation results for bovine semen import are presented and discussed.

Chapter Four: Results

4.1 Introduction

This chapter addresses the research questions by discussing the model estimation results, resulting elasticities, and the simulation results for three scenarios. The 3-stage model was first designed with a limited subset of data. However, the final data shows that the first stage of Heckman model is unnecessary since all importers' bovine semen import expenditures are always positive across the data period. Therefore, the final model is reduced to a two-stage import demand model: 1) The First stage is a log-log expenditure equation by importers. 2) The second stage is a system of budget allocation equations by importers.

The research questions are: 1) If importers' farm cash income or the stock of animals changes, do importers increase or decrease their expenditures on genetic imports from specific exporters? 2) If genetic product prices change, how will importers change their expenditures on genetic imports from different exporters? 3) If importers' total genetic product expenditures change due to trade policies such as subsidies and quotas, how do importers change their expenditures on genetic importers from different exporters? Since there are 15 import demand systems estimated and 1247 elasticities generated, interpretation of all these results is beyond the scope of this thesis. This chapter focuses only on Canadian bovine semen exports and discusses estimation results, the elasticities, and model simulation results for the three largest Canadian bovine semen importers (Australia, Netherlands, and Japan). The complete report of all importers' model estimation results and elasticities is presented in Appendices A and B.

In terms of the estimation consider first, the explanatory power, heteroscedasticity tests, and coefficients of the two-stage demand system. Next, five sets of elasticities resulting from the model are presented and discussed. As discussed in the third chapter, conditional elasticities are calculated based on how importers allocate genetic product expenditures (second stage budget share equations) without taking account into how importers decide their total expenditure (first stage). Unconditional elasticities are calculated based on both the first and second stage equations. *The unconditional farm cash income elasticity* shows the quantity percentage change of semen imported from an exporter in response to a one percent change in the importer's farm cash income, and the *animal number* elasticity responds to the number of animals held in stock. The *conditional expenditure elasticity* shows the percentage change of the quantity imported in response to one percent change of the importer's total expenditure on genetic products. The *conditional and unconditional price elasticities* show the percentage change of imported quantities in response to one percent change of different exporters' prices.

Third, the simulation results for three policy scenarios are discussed. A simulation over the estimation period provides a set of base values for the endogenous variables. Then, three sets of exogenous variables are shocked, which forces changes in the values of endogenous variables as the model moves to a new equilibrium. Corresponding to research questions, the three shocks are importer's farm cash income increases by ten percent, importer's numbers of animal increases by ten percent, and Canadian bovine semen export prices increase by ten percent. The direction and magnitude of changes in the variables are compared to the base model to show the influence of exogenous variable changes on importers' import behaviors. The simulation results are compared to the model coefficients and elasticities. At the end of this chapter, results are summarized to answer the research questions, and policy implications based on the results are discussed.

Table 4.1 shows the estimation results for the three major importers (first stage equations) and budget share equations (second stage equations). These estimates result in significant heteroscedasticity. Heteroscedastic-consistent standard errors are computed to provide asymptotically efficient coefficients and consistent standard errors. All dependent and explanatory variables in this Table have been logged. The following sections discuss the demand systems for each importer in turn.

Table 4.1 Model Estimation Results

		Importer	(1)Australia		(2)Japan		(3)Netherlands	
	Exporter	Log likelihood	62.2		146.19		47.33	
First Stage		R-squared	0.23		0.8		0.74	
		LM het. Test	6.11	**	0.41		0.82	
		Constant	-0.44		78.89	**	-39.1	**
		Sum (Share*Log of Price)	0.13		-0.75	**	0.04	
		Log of Farm Cash Income	-0.76	*	1.35		-4.08	**
		Log of Animal Number	1.28		-4.47	**	5.97	**
Second Stage (Exporters)	**Canada**	R-squared	0.3		0.22		0.4	
		LM het. Test	1.12		0.97		0.22	
		Constant	-1.43	**	0.13		0.1	
		Canada- Ca	0.49		0.82	**	1.23	**
		Canada- EU	-0.09		-0.07	**	0.21	
		Canada- US	0.68	**	-1.32	**	-1.96	**
	EU	R-squared	0.1		0.23		0.67	
		LM het. Test	5.23	**	3.96	**	0.41	
		Constant	-0.14		-0.02		0.36	**
		EU- Canada	-0.09		-0.07	**	0.21	
		EU- EU	0.24		0.01		0.04	
		EU- US	-0.15		0.07	**	-0.86	**
	US	Constant	0.56	**	-1.11	**	-1.46	**
		US- Canada	0.68	**	-1.32	**	-1.96	**
		US- EU	-0.15		0.07	**	-0.86	**
		US- US	-0.53	**	1.25	**	2.83	**

Where: *= 10% significant level; ** =5% significant level: ***= 1% significant level

4.2 Australian Bovine Semen Import Demand

In this section, the estimation results, elasticities, simulation results for Australian bovine semen import demand system are discussed. Table 4.1 shows the estimation results for Australian expenditure equations (first stage equations) and budget share equations (second stage equations). In the first stage, the explanatory power is relatively low (R^2 =0.23). The coefficient on the weighted exporter price is positive but insignificant. This positive coefficient shows that the increase of bovine semen import price will lower the quantity demanded by importers. However, the total bovine semen import value can still increase because semen demand is price inelastic. The coefficient of log farm cash income is the only significant coefficient and unexpectedly negative, which indicates that Australian bovine semen expenditure would reduce bovine semen expenditure if its FCI increases. The coefficient of log AN is insignificant but positive. According to the Australian Bureau of Meteorology (2019), Australia has been constantly facing drought for the late 20th century and 21st century due to El Niño weather conditions. That includes the severe droughts from 1996 to 2000, 2001 to 2009, and from 2013 to the present. According to the report from the United States Department of Agriculture (Levin Flake, 2019), Australian cattle numbers and beef production are heavily influenced by weather conditions. Extreme drought caused poor pasture conditions and reduced feed availability which in turn caused the stock of Australian cattle to contract. As a result beef slaughter increased. The higher FCI is mostly driven by increased cattle slaughter. The reduction in the herd results in decreased input demand for bovine semen. So these historical weather conditions provide a possible explanation to the negative FCI coefficient. The coefficient on animal numbers (AN) is positive but insignificant. However, as the cattle industry recovers, animal numbers will increase and the demand for bovine semen should also increase.

Table 4.2 Farm Cash Income, Animal Number, and Expenditure Elasticities for Australia

Source	FCI	AN	Expenditure	
Canada	-3.07	5.20	4.05	***
EU	-0.75	1.27	0.99	
US	0.89	-1.51	-1.18	***

Where: *= 10% significant level; ** =5% significant level: *** =1% significant level
FCI: farm cash income
AN: number of animals in stock
Expenditure: importer's total bovine semen expenditure

Table 4.2 shows the unconditional FCI and AN elasticities and the conditional expenditure import demand elasticities for Australia. As expected the unconditional FCI (-3.07) and AN (5.2) elasticities are insignificant. The expenditure elasticity of Canadian bovine semen is significant and positive, which indicates that when cattle increase and when Australia is in a position to increase expenditures on bull semen it will import more Canadian semen.

Table 4.3 Price Elasticities for Australia

Export	Canadian Export Price				EU Export Price				US Export Price			
Quantity	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-2.38**	***	**-2.19**	***	0.24		0.32		-1.91	***	-1.65	***
EU	0.59		0.63		**-2.63**	**	**-2.61**	**	1.05		1.12	
US	0.81	**	0.76	**	0.31		0.29		**0.06**		**-0.02**	

*: 10% significant level; ** 5% significant level: *** 1% significant level

Table 4.3 shows the conditional and unconditional price import demand elasticities for Australia. For Canadian exports, the own-price elasticity is negative and significant. The cross-price elasticity with respect to US prices is also significant and negative. This result suggests that Australia would import less Canadian bovine semen if the export prices of Canadian semen increases. As well, Canadian and US semen are complements in the Australian market.

In order to gain a better understanding of the Australian cattle market, the difficulties it faces and the implications for Canada's potential to sell bovine genetics to Australia, several simulations are conducted. The econometric results are limited because I was not able to properly identify and isolate the impact of farm cash income on semen expenditures. The variable which was estimated compounds the effects of the drought on FCI and the concurrent reduction in breeding herds which in turn led to less expenditures on genetics. Rather the variable can be thought of as reduced form indicator of the severity of the drought on the Australian cattle sector, and therefore of the overall impact of drought on Australian bovine semen demand. Table 4.4 shows the simulation results of this shock to the sector which is illustrated as a 10% increase in FCI.

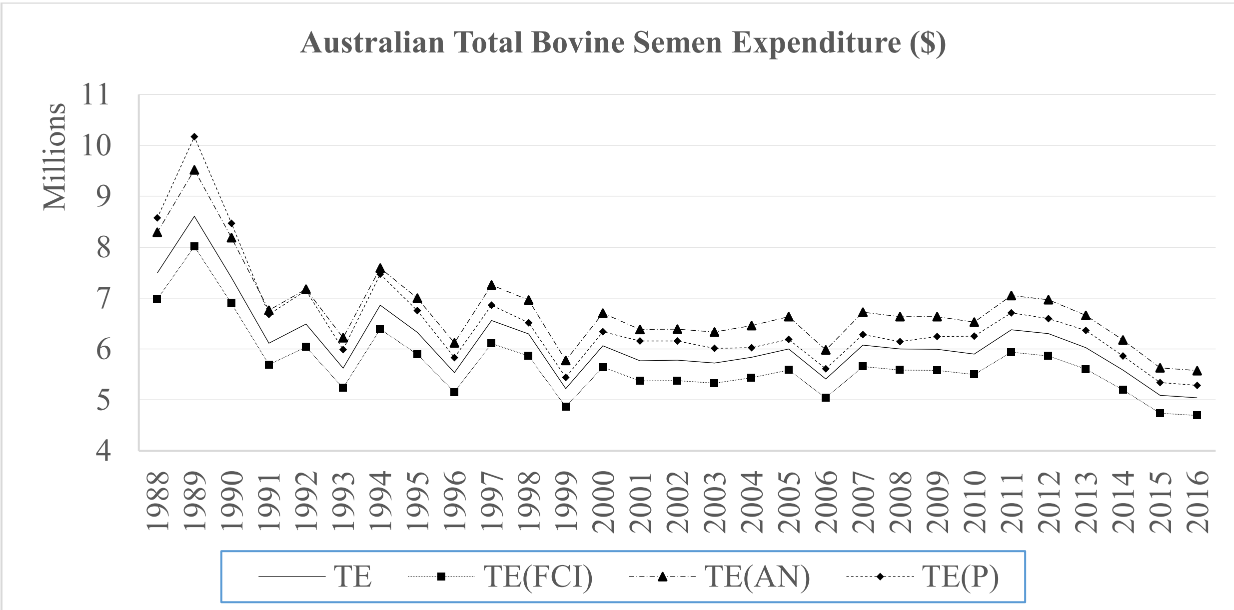
Table 4.4 Simulation Results for Australia

	TE		W(ca)		IV(Ca)		IQ(Ca)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Base	6.12	0.75	34.86%	7.12%	2.18	0.74	2524.47	937.61
APC (FCI)	-6.89%	0.00%	2.52%	0.56%	-4.55%	0.52%	-4.55%	0.52%
APC(AN)	10.60%	0.00%	-3.56%	0.79%	6.67%	0.87%	6.67%	0.87%
APC(Pc)	6.40%	3.71%	0.46%	0.98%	6.85%	2.67%	-2.86%	2.42%

Base: average base value.
APC: average change as a percentage of the average base level (change value/ base value x 100).
APC (FCI): average percentage change if farm cash income increases by ten percent.
APC (AN): average percentage change if the number of animals in stock increases by ten percent.
APC (Pc): average percentage change if Canadian bovine semen export price increases by ten percent.
TE (Million $): total bovine semen expenditure of Australia.
W: budget shares of bovine semen from the exporters.
IV (Million $): import values of bovine semen from the exporters.
IQ: import quantity of bovine semen from the exporters.

The resulting change is also illustrated as TR (FCI) in Figure 4.1. If the drought gets worse and beef production continues to increase, the average total bovine semen expenditure decreased by 6.89% due to the high slaughter rate. Since the Canadian bovine semen export price is held constant, the Australian import quantity and value of Canadian bovine semen both decrease for 4.55%. Canadian bovine semen exports would be limited by a more severe weather shock

Figure 4.1 Australian Total Bovine Semen Expenditure



TE: Australian total bovine semen expenditure of base model.
TE (FCI): Australian total bovine semen expenditure if FCI increases by 10%.
TE (AN): Australian total bovine semen expenditure of base model if AN increases by 10%.
TE (P): Australian total bovine semen expenditure of base model if Canadian export price increases by 10%.

In the second scenario, the drought is assumed to end and Australia decides to restock cattle. I was able to estimate the coefficient with the correct sign for semen expenditures with respect to animal numbers. Australian AN is shocked to increase by 10%. In this case, Australia would increase its bovine semen import budget by 10.6% to improve and increase its herd (Figure 4.1). Since Canadian bovine semen export price remains unchanged, Australian import quantity and value of Canadian bovine semen both increase for 6.67%. Canadian bovine semen exports benefit in this recovery scenario.

The third scenario considers the case where the Canadian export price of bovine semen increases by 10% due to an unspecified regulatory change. Australia would increase bovine semen import expenditures by 6.4% (Figure 4.1). However, quantities of Canadian semen export decreases by 2.86% due to price increase. Overall, the Australian total import value of Canadian bovine semen would increase by 6.85%.

Overall, the simulation results reflect the model estimation results and elasticities. If the drought in Australia gets worse and Australian FCI increases consequently, Canadian bovine semen export would lose revenue. If the drought ends or gets better, and the Australian AN increases, the Australian import value of Canadian bovine semen would also increase. Further, if Canadian bovine semen export increases due to higher demand, Australia would spend more on bovine semen import and Canadian bovine semen export benefits in this case.

4.3 Japanese Bovine Semen Import Demand

Table 4.1 shows the estimation results for Japanese expenditure equations (first stage equations) and budget share equations (second stage equations). In the first stage, the explanatory power is relatively high (R^2=0.8). The coefficient on the weighted exporter price is significant and negative. The increase of bovine semen import price will lower the quantity demanded by importers. Furthermore, the total import value decreases because Japanese total bovine semen expenditure is price elastic. The coefficient of log farm cash income is insignificant and positive. Finally, the coefficient of log of animal numbers (AN) is significant but negative (-4.47). Not surprisingly, the signs of these two coefficients are different from the Australian results, given the very different natures of the two sectors. According to (Obara, 2010), 'high prices for feeder calves and high feed costs, together with a relatively small-scale feedlot industry, prevent Japanese production from increasing.' Growth for the Japanese cattle industry is limited by its high production cost and its demand for bovine semen as cattle production inputs would decrease when its cattle industry reaches a certain scale. Instead of producing more cattle, Japan imports beef and dairy products from North America and Oceania to meet increasing consumer demand for beef and dairy products (Aki Imaizumi, 2018). However, this does not explain the negative coefficient on the animal numbers coefficient with a declining cattle inventory. One possible explanation is that as the industry contracts Japanese producers are attempting to increase the quality of some segments of the herd through increase semen imports. Since the herd size is limited, the only way for Japanese producers to lower their production costs is to increase productivity. In this case, Japan uses genetic improvements to improve the performance and productivity of herd and it demands these genetic traits in the form of semen from the international market. So high Japanese production cost can be consistent with a significant and negatively signed coefficient for log AN.

Table 4.5 Farm Cash Income, Animal Number, and Expenditure Elasticities for Japan

Source	FCI	AN		Expenditure	
Canada	-0.51	1.67		-0.37	
EU	3.55	-11.73	*	2.63	*
US	2.65	-8.77	***	1.96	***

*: 10% significant level; ** 5% significant level: *** 1% significant level)
FCI: farm cash income
AN: number of animals in stock
Expenditure: importer’s total bovine semen expenditure

Table 4.5 shows the unconditional FCI elasticities and AN elasticities and the conditional expenditure import demand elasticities for Japan. All the elasticities for Canadian bovine semen are insignificant. As expected, the unconditional FCI elasticity for Canadian bovine semen is negative and inelastic (-0.51). The AN unconditional elasticity for Canadian bovine semen is positive and elastic (1.67). The expenditure elasticity is negative (-0.37) and insignificant. The effect of Japanese bovine semen expenditure increase on its Canadian bovine semen import quantity is very limited.

Table 4.6 Price Elasticities for Japan

Export	Canadian Export Price				EU Export Price				US Export Price			
Quantity	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-2.98**	***	**-2.86**	***	0.16	***	0.16	***	3.19	***	3.35	***
EU	9.07	***	8.25	***	**-1.69**	***	**-1.70**	***	-10.01	**	-11.15	**
US	1.30	***	0.69	**	-0.11	***	-0.12	***	**-3.16**	***	**-4.01**	***

*: 10% significant level; ** 5% significant level: *** 1% significant level

The conditional and unconditional import demand price elasticities for Japan are found in Table 4.6. All price elasticities are significant. For Canadian exports, the own-price elasticity is negative and elastic (<-2.8). Japan would import less Canadian bovine semen if Canadian bovine semen export price increases. The cross-price elasticities of Canadian bovine semen to EU and US bovine semen are both positive. Price elasticities suggest that Canadian bovine semen is substitutable to EU and US bovine semen. However, the substitutability between Canadian and the EU bovine semen is very small.

In order to better understand the Japanese cattle market, and the implications for Canada's potential to sell bovine genetics to Japan, three shocks are considered below. The first shock considers a 10% increase in FCI and is described in Table 4.7

Table 4.7 Simulation Results for Japan

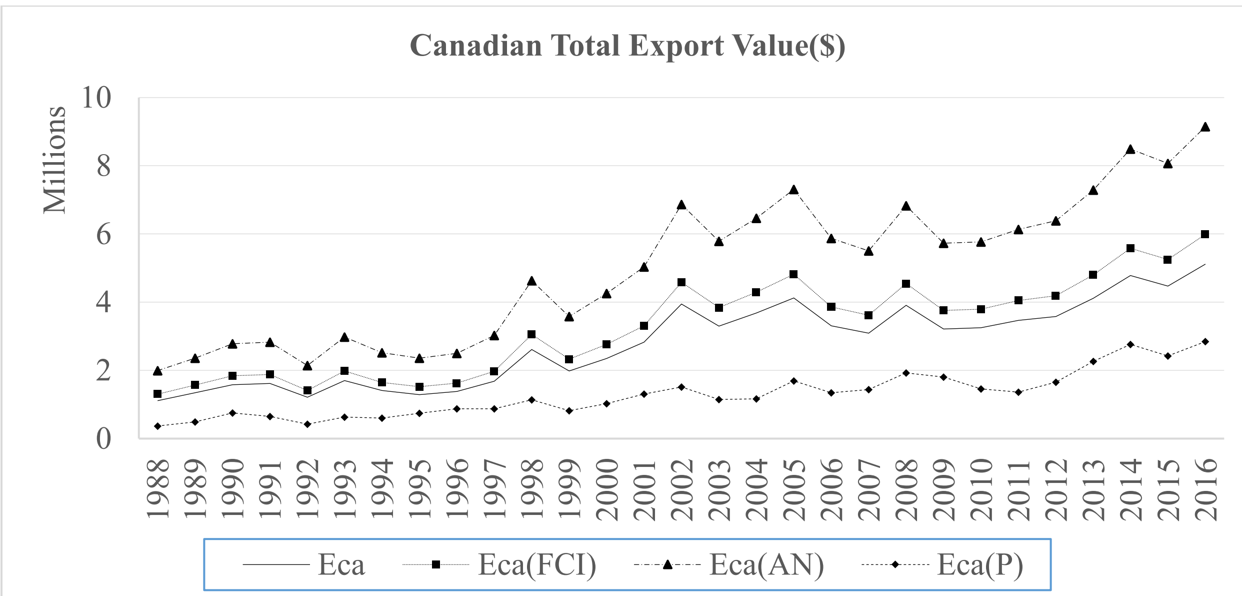
	TE		Wca		IV(Ca)		IQ(Ca)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Base	6.79	2.9	41.38%	4.75%	2.18	0.74	78.37	54.31
APC (FCI)	13.43%	0.00%	3.06%	0.35%	16.90%	0.40%	16.90%	0.40%
APC(AN)	59.71%	0.00%	11.36%	1.32%	77.86%	2.10%	77.86%	2.10%
APC(Pc)	-50.06%	7.55%	-9.83%	3.19%	-54.75%	8.40%	-58.86%	7.64%

Base: average base value.
APC: average change as a percentage of the average base level (change value/ base value x 100).
APC (FCI): average percentage change if farm cash income increases by ten percent.
APC (AN): average percentage change if the number of animals in stock decreases by ten percent.
APC (Pc): average percentage change if Canadian bovine semen export price increases by ten percent.
TE (Million $): total bovine semen expenditure of Australia.
W: budget shares of bovine semen from the exporters.
IV (Million $): import values of bovine semen from the exporters.

IQ: import quantity of bovine semen from the exporters.

The resulting change is shown as TR (FCI) in Figure 4.2., assuming constant Japanese animal numbers (AN) and prices. Semen import expenditures increase by 13.43% (Figure 4.2). Since the Canadian bovine semen export price is held constant, the Japanese import quantity and value of Canadian bovine semen increase by 16.9%.

Figure 4.2 Japanese Total Bovine Semen Expenditure



TE: Japan total bovine semen expenditure of base model.
TE (FCI): Japan total bovine semen expenditure if FCI increases by 10%.
TE (AN): Japan total bovine semen expenditure of base model if AN decrease by 10%.
TE (P): Japan total bovine semen expenditure of base model if Canadian export price increases by 10%.

The second scenario considers a further 10% contraction of the Japanese herd. In order to improve the productivity of Japanese cattle, imports of semen increase and expenditures on these imports increase by 59.71%. Since prices are held constant, both the import quantity and value of Canadian bovine semen increase by 77.86%. Canadian bovine semen export to Japan would significantly grow in this scenario.

The third scenario considers the case where the Canadian bovine semen export price increases by 10% due to an unspecified regulatory change. Japan would decrease bovine semen expenditures by 50.06% (Table 4.7). Japanese import quantity of Canadian bovine semen decreases by 58.86% due to price increase. Overall, the Japanese import value decreases by 58.86%. Japanese bovine semen import is highly sensitive to price changes.

Overall, the simulation results reflect the model estimation results and elasticities. Since Japanese AN is limited due to its high production cost, an animal number AN decrease would cause Japan to increase its demand for bovine semen in order to improve the quality of the herd. However, if Japanese AN remains the same but FCI continues to increase, Japan would demand more Canadian bovine semen to improve its cattle productivity. Further, Japanese bovine semen import is highly responsive to price change. Canadian bovine semen would significantly shrink if its export price increases.

4.4 Dutch Bovine Semen Import Demand

The Dutch cattle industry is different than either of the markets considered above. The industry focuses on milk, and as a result there is very little beef produced in the Netherlands. Given the small area and fierce competition for land there is virtually no room for growth. Furthermore, environmental regulations and pressures actually reduce animal numbers. Table 4.1 shows the estimation results for Dutch expenditure equations (first stage equations) and budget share equations (second stage equations). In the first stage, the explanatory power is relatively high (0.74). The signs of coefficients are as same as the Australian import demand system. The coefficient on the weighted exporter price is positive but insignificant. Dutch bovine semen import expenditure is price inelastic. Both coefficients for logged farm cash income and logged animal numbers are significant. As with Australia the coefficient for logged farm cash income is negative, and the coefficient for logged animal number is positive. Again, the driving force behind these coefficient signs is likely reduction in herd size. High rates of Dutch cattle slaughter rate results from the EU requirement to reduce its dairy farm phosphate production (Bob Flach, 2017). According to the report from USDA (Bob Flach, 2017), since 2006, a derogation (a special exemption) granted by the European Commission (EC) has allowed Dutch farmers to use more manure on their pastureland than elsewhere in the European Union (EU). One condition of the measure was that the Dutch livestock sector should not exceed the phosphate production levels reached in 2002, namely 172.9 million kg (Bob Flach, 2017). Since 2006, the Netherlands have been trying to control phosphate production by cutting dairy herds and increasing feeding efficiency. Based on Eurostat statistics (2018), since 2014 the Netherlands has cut its dairy herd by 6.6 percent or about 160,000 animals. Moreover, the slaughter of cows and heifers has caused Dutch beef production increase by 11.6% since 2014. The slaughter of cows and heifers has been causing higher beef production and smaller cattle herd. These factors increase producer farm incomes but also reduce Dutch import demand for bovine semen. As result the farm income coefficient for overall semen demand with respect to farm income produces a negative coefficient in contrast to expectations. Furthermore, the regulated reduction in the dairy herd results in a positive coefficient for total semen expenditure with respect to logged animal numbers.

Table 4.8 shows the second stage unconditional FCI and AN elasticities, and conditional expenditure elasticity for Canadian bovine semen are all statistically insignificant. The FCI and AN elasticities are -2.25 and 3.29. The expenditure elasticity is inelastic and negative (-0.55). Similar, but significant results hold for US exports, while the signs are reversed to EU exporters. Certainly, the Netherlands is very integrated into the European Union so the behavior with respect to EU exporters can naturally be expected to be different within an integrated regulatory regime.

Table 4.8 Farm Cash Income, Animal Number, and Expenditure Elasticities for the Netherlands

Source	FCI		AN		Expenditure	
Canada	-2.25		3.29		-0.55	
EU	10.47	***	-15.32	***	-2.57	***
US	-13.68	***	20.01	***	3.35	***

*: 10% significant level; ** 5% significant level: *** 1% significant level
FCI: farm cash income
AN: number of animals in stock
Expenditure: importer's total bovine semen expenditure

The conditional and unconditional price import demand elasticities for the Netherlands are found in Table 4.9. For Canadian exports, the own-price elasticity is significant and highly elastic (<-4). This result suggests that the Dutch import quantity of Canadian bovine semen is highly responsive to Canadian bovine semen export price. One concern is that the Canada/US cross-price elasticity is significant, positive and larger than the own price elasticity (>5). Nonetheless this result suggests that Canadian and US bovine semen are highly substitutable.

Table 4.9 Price Elasticities for the Netherlands

Export Quantity	Canadian Export Price				EU Export Price		US Export Price			
	Conditional		Unconditional		Conditional	Unconditional	Conditional		Unconditional	
Canada	**-4.59**	***	**-4.60**	***	-0.60	-0.60	5.74	***	5.73	***
EU	-1.19		-1.22		**-1.26**	**-1.27**	5.02	***	4.97	***
US	2.95	***	2.99	***	0.51	0.53	**-6.81**	***	**-6.75**	***

*: 10% significant level; ** 5% significant level: *** 1% significant level

In order to better understand the Dutch cattle market, and the implications for Canada's potential to sell bovine genetics to the Netherlands, several simulations are conducted. Consider first the variable FCI which can be thought of as a proxy for tightening EU dairy regulations, and not as a measure of sector profitability. Table 4.10 and Figure 4.3 show the simulation results of a 10% increase in FCI. If the Netherlands is further required by the EU to lower its phosphate production and its FCI increases by 10% due to cow slaughter, the average total bovine semen expenditure decreases by 32.32% due to higher cow slaughter rate (Figure 4.2). Since the prices are held constant, Canadian export quantity and value to Netherlands both decrease by 36.58%. Canadian bovine semen export would lose a considerable amount of revenue in this case.

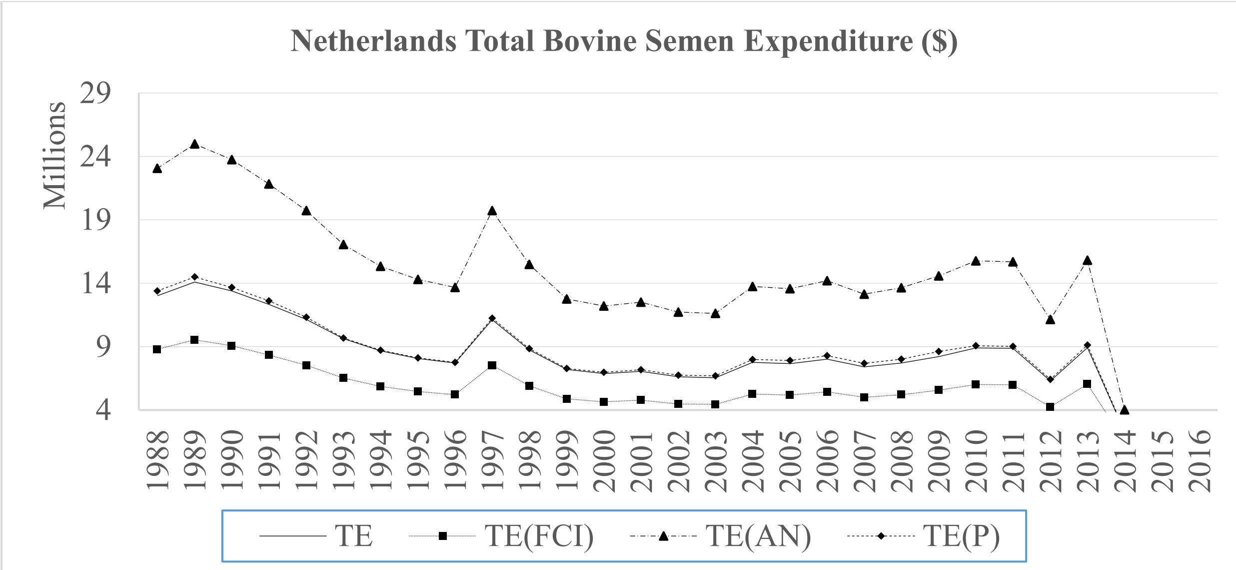
Table 4.10 Simulation Results for the Netherlands

	TE		Wca		IV(Ca)		IQ(Ca)	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Base	8.92	2.27	34.94%	10.55%	3.07	1.09	2487.13	2863.42
APC (FCI)	-32.32%	0.00%	-6.29%	2.79%	-36.58%	1.89%	-36.58%	1.89%
APC(AN)	77.23%	0.00%	9.21%	4.08%	93.56%	7.24%	93.56%	7.24%
APC(Pc)	2.14%	1.18%	8.65%	3.69%	10.95%	3.33%	0.86%	3.02%

Base: average base value.
APC: average change as a percentage of the average base level (change value/ base value x 100).
FCI: farm cash income.
AN: number of animals in stock.
Pc: Canadian bovine semen export price.
TE (Million $): total bovine semen expenditure of the Netherlands.
W: budget shares of bovine semen from the exporters.
IV (Million $): import values of bovine semen from the exporters.

In the second scenario, if the Netherlands is successful in reducing its phosphate residuals to or lower than 2002 levels, then EU regulations would allow the Netherlands to grow its dairy herd. The Netherlands could then restock breeding animals and the AN is increased by 10%. Import expenditures for bovine semen growth by 77.23%. Canadian export quantities and dollar values by 93.56%. However, it is unlikely that regulatory pressures will be relaxed, and even with the elimination of EU dairy production quotas, dairy herds are unlikely to grow.

Figure 4.3 Dutch Total Bovine Semen Expenditure



TE: Dutch total bovine semen expenditure of base model.
TE (FCI): Dutch total bovine semen expenditure if FCI increases by 10%.
TE (AN): Dutch total bovine semen expenditure of base model if AN increases by 10%.
TE (P): Dutch total bovine semen expenditure of base model if Canadian export price increases by 10%.

The third scenario considers the case where the Canadian export price increases by 10% due to an unspecified regulatory change. Dutch bovine semen expenditure slightly increases by 2.14%. Canadian export quantity slightly increases by 0.86% and Canadian export value increases by 10.95%. Since the coefficient of weighted exporter price in the first stage is insignificant, the Dutch bovine semen expenditure increase due to price increase is insignificant. As a consequence, Canadian bovine semen exports still benefit in this scenario.

4.5 Summary

This chapter addressed the research questions applying estimation results for three major Canadian bovine semen importers (Australia, Japan, and the Netherlands). Based on the discussions made above, the research questions and corresponding answers are summarized as follows:

1) If importers' FCI and AN changes, how will importers change their bovine semen

expenditures and the allocation of the expenditures among suppliers?

The effects of FCI and AN change on importers' bovine semen import behaviors vary across importers. Overall, the elasticities and simulations suggest if the importers increase budgets on bovine semen import due to FCI and AN changes, they will increase their Canadian bovine semen import value. If the three importers have lower budgets on bovine semen import due to FCI and AN changes, they will decrease their Canadian bovine semen import value. If the FCI increase is caused by higher beef production while AN decreases due to high cattle slaughter rate, increasing FCI and decreasing AN reduce importers' bovine semen import budget as cattle production inputs. One example is Australia. Australia has been facing drought in history. A severe drought since 2013 has been causing insufficient pasture for the Australian cattle industry. Due to the lack of pasture, the Australian cattle slaughter rate and beef production have increased significantly. Since Australia is cutting cattle herd, Australian bovine semen expenditure has been decreasing consequently. Similar changes also happened to the Netherlands. The Netherlands has been cutting cattle herds and increasing beef production because it has been required by the EU to reduce its phosphate production. As a result, the Netherlands has been demanding less bovine semen as a production input. On the other hand, if the FCI increase is caused by higher production of beef, dairy, or cattle while cattle number remains increasing or unchanged, increasing FCI and AN are likely to increase importers' bovine semen import budget. China and Mexico are expanding their cattle, beef, dairy industry to meet increasing domestic demand for beef and dairy products. In this case, China and Mexico spend more money on bovine semen import when their FCI and AN are increasing.

2) If genetic product prices change, how will importers change their expenditures on genetic imports from different exporters?

Canadian bovine semen export price increase would cause importers to lower their Canadian bovine semen import quantity. All Canadian bovine semen own-price elasticities are negative, which suggests that higher Canadian bovine semen export price would reduce Canadian bovine semen import quantity. Both the first-stage equations of Australia and Dutch show that Australian and Dutch total bovine semen expenditure is price inelastic. In this case, Australia and Netherlands only decrease Canadian bovine semen import quantity by a small amount. Canadian bovine semen export value can benefit from own price increase in the import market of Australia and the Netherlands. However, the first-stage equation of Japan shows that Japanese bovine semen import is highly responsive to price changes. In this case, if Canada raises bovine semen export price, Japan would significantly reduce its total bovine semen expenditure in the first stage and its Canadian bovine semen import value in the second stage.

The cross-piece elasticities suggest that Canadian and EU bovine semen are weakly substitutable in the import market of Japan. If the EU increases its bovine semen export price, Japanese demand for Canadian bovine semen increases. The cross-piece elasticities show that Canadian and American bovine semen are complementary in the Australian import market but substitutable in Japanese and Dutch import markets. If the US increases its bovine semen export price, Canada would benefit in Japanese and Dutch import markets but hurt in the Australian import market.

3) If importers' total genetic product expenditures change due to trade policies such as subsidies, how do importers change their expenditures on genetic importers from different exporters?

Importers are more likely to increase their Canadian bovine semen import values if their governments provide subsidy to bovine semen import and the importers have more budget on bovine semen import. First, the expenditure elasticities suggest that Australia would increase Canadian bovine semen import quantity by four percent if its expenditure on bovine semen increases by one percent. Canadian bovine semen expenditure elasticities in Japan and the Netherlands are negative but inelastic. Japan and the Netherlands would decrease Canadian bovine semen import quantity for a small amount if their bovine semen expenditures increase. However, simulation results suggest that Japan and the Netherlands would increase Canadian bovine semen import value if their bovine semen expenditures increase due to FCI, AN, and prices change. Overall, Canada is more likely to benefit from the bovine semen import expenditure increase of importers.

Canadian bovine semen export to Australia and the Netherlands is expected to shrink in the near future. Since Australia and the Netherlands are both cutting cattle herd size, they are likely to continue to lower their overall bovine semen import expenditure and also Canadian bovine semen import value in the near future. However, Japanese AN is limited and is expected to import more Canadian bovine semen to improve its cattle productivity. In the long run, the situation is expected to improve. If Australian weather condition improves and the Netherlands is no longer required to cut its dairy herds, their demand for Canadian bovine semen will increase. The results also suggest Canada can generate higher bovine semen export revenue by increasing export prices to Australia and the Netherlands, and decreasing export prices to Japan.

Chapter Five: Conclusions, Limitations and Future Research

5.1 Conclusions

Genetic products have been traded internationally since the 1970s. Over 190 countries have participated in trading genetic products including bovine semen, live bovine animal for breeding purpose and live swine animal for breeding purpose. Because the trade value of genetic products has been quickly increasing for the last 30 years (1988- 2018) with a 40% and 14% increase rates for bovine semen and breeding swine export, it is crucial for policymakers to understand economic factors that affect the world supply and changes in importers' purchase behavior. The export prices of genetic products, FCI, and AN are three main economic factors affect importers' livestock production demands for genetic products. Therefore, three research questions were asked in this thesis: 1) If importers' FCI or AN changes, do importers increase or decrease their expenditures on genetic imports from specific exporters? 2) If genetic product prices change, how will importers change their expenditures on genetic imports from different exporters? 3) If importers' total genetic product expenditures change due to trade policies such as subsidies and quotas, how do importers change their expenditures on genetic importers from different exporters?)

This research conducted an econometric analysis of the import demand for genetic products to answer the research questions. Since bovine animals for breeding purposes are no longer internationally traded and the international market of swine animals for breeding purposes is too volatile, only the import demand systems for bovine semen importers are estimated. Based on the literature review and bovine semen international trade data, 15 two-stage demand systems are estimated for 15 major bovine semen importing countries and regions. The first stage is a Log-Log expenditure equation estimating importers' total import expenditure on bovine semen import. The second stage is a Tanslogdemand model estimating how importers allocating their expenditure among suppliers or exporters. The estimation results, resulting elasticities, and simulation results of three major Canadian bovine semen importers (Australia, Japan, and the Netherlands) are chosen as examples to answer research questions and make policy suggestions.

The effects of FCI, AN, and export prices on importer's purchase behavior vary across importers. If importers increase their bovine semen import budget because of FCI and AN changes, they would also increase their import value of Canadian bovine semen. Due to the fact that Australia and the Netherlands are both cutting cattle herd sizes and increase their beef productions, they are expected to lower their bovine semen import budget and import less Canadian bovine semen. The Japanese cattle industry is facing ceiling due to high production costs. Japan continues to import more bovine semen to improve cattle productivity. Japan is expected to increase its bovine semen budget and import more Canadian bovine semen. Results also suggest Australian and Dutch bovine semen import expenditure is price inelastic while Japanese bovine semen import expenditure is price elastic. Canada can generate higher bovine semen export revenue by increasing export prices to Australia and the Netherlands, but decreasing the export price to Japan.

5.2 Limitations and Suggestions for Future Research

This thesis lack of detailed data to examine the effect of drought on Australian bovine semen import and the effect of phosphate reduction on Dutch bovine semen import. This thesis only uses a reduced form approach to explain Australian and Dutch bovine semen import change. Future research is recommended to collect Australian drought index data and Dutch phosphate production data to examine the detail of drought and phosphate production effect on Australian and Dutch bovine semen import.

Factors influencing the international market, such as international trade policies and diseases are not considered in this study. This research studies the international market of genetic products by estimating econometric demand systems. The effect of international trade policy changes or animal diseases on genetic products international market is not considered. As discussed in the third chapter, market shares of breeding swine importers are extremely volatile and can't be explained just by prices. It is likely that none-economic factors such as trade barriers and animal diseases are influencing international markets. Future researches are recommended to study the impact of.

Genetic product features aren't differentiated by their product features in this research. This research is based on Armington country of origin differentiation assumption. Genetic products are differentiated only based on where they are produced. Due to the data limitation, what factors distinguish genetic products from different exporters are unknown. Future researches are recommended to gather details of genetic product features and differentiating genetic products by both their country of origin and their product feature differences. This approach can potentially generate better estimations and explain why bovine semen from different countries or trade regions are complementary or substitutable.

The effect of technology advancement on genetic products international trade isn't studied in this thesis. As discussed in chapter two, livestock companies' preference for genetic products is evolving along with technology advancement. Since gene technologies are widely being tested and discussed, it is possible that gene technologies such as GM and gene editing will be applied to modify genetic products and improve the features of genetic products. However, attitudes and preferences of livestock companies towards genetic technologies are unknown and not studies in this thesis. In cases that genetic technologies are adopted to modify genetic products, current genetic products import demand systems can potentially be reshaped. Future studies are recommended to interview livestock companies and collect data regard their attitudes towards genetic technologies.

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Appendix A Estimation Results

ROA: Rest of the Asian Countries.
ROE: Rest of the EU Countries.
ROS: Rest of the South American Countries.
Ca: Canada
NL: the Netherlands

The Estimation Results for Africa, Brazil, China, France.

	Importer	Africa		Brazil		China		France	
	Log likelihood	52.76		136.62		-52.32		87.21	
First Stage	R-squared	0.5		0.98		0.52		0.82	
	LM het. test	8.1	**	1.15		1.84		0.28	
	Constant	134.66	**	9.07		-114.76		108.46	**
	Sum (Share*Log of Price)	-0.47	*	1.24	**	1.16	**	0	
	Log of Farm Cash Income)	-4.13	**	-0.35	**	4.94	**	-2	**
	Log of Animal Number	-4.02	*	0.03		3.65		-4.4	**
Second Stage	Constants:								
	Ca	-0.09		0.34	**	0.06		-0.23	**
	France	-0.59	**						
	Germany								
	NL			0.69	**				
	ROE	-0.12		-0.32	**			0.1	
	UK								
	US	-0.2	**	-1.71	**	-1.06	**	-0.87	**
	R-squared	0.51		0.09		0.06		0.18	
	LM het. test	5.8	**	2.78	*	1.56		0.55	
	Ca- Ca	-0.23	*	0.42	**	0.71	**	0.14	
	Ca- France	0.04							
	Ca- Germany								
	Ca- NL			-0.11					

Ca- ROE	0.14		-0.35	**			-0.12	**
Ca- UK								
Ca- US	-0.02		-0.51	**	-1.45	**	-0.02	
R-squared	0.16							
LM het. test	16.2	**						
France- Ca	0.04							
France- France	0.44	**						
France- Germany								
France- NL								
France- ROE	-0.11							
France- UK								
France- US	0.02							
R-squared			0.79					
LM het. test			1.26					
NL- Ca			-0.11					
NL- France								
NL- Germany								
NL- NL			0.17	**				
NL- ROE			0.07	*				
NL- UK								
NL- US			-0.96	**				
R-squared	0.19		0.37				0.24	
LM het. test	0.05		0.64				0.23	
ROE- Ca	0.14		-0.35	**			-0.12	**
ROE- France	-0.11							
ROE- Germany								
ROE- NL			0.07					
ROE- ROE	0.07		0.77	**			-0.1	*
ROE- UK								
ROE- US	-0.26	**	-0.25	*			-0.09	
R-squared								

LM het. test								
US- Ca	-0.02		-0.51	**	-1.45	**	-0.02	
US- France	0.02							
US- Germany								
US- NL			-0.96	**				
US- ROE	-0.26	*	-0.25	*			-0.09	
US- UK								
US- US	0.26		1.72	**	1.45	**	0.11	

The Estimation Results for Germany, Italy, Mexico and ROA.

	Importer	Germany		Italy		Mexico		ROA	
	Log likelihood	118.61		170.35		111.63		89.75	
First Stage	R-squared	0.39		0.04		0.75		0.48	
	LM het. test	1		9.74	**	2.53		1.38	
	Constant	9.55	**	-8.88		-30.4	*	-67.09	*
	Sum (Share*Log of Price)	0.01		0.11	**	0.08	**	0.01	
	Log of Farm Cash Income)	0.26		0.23		0.4	**	0.21	
	Log of Animal Number	0.22		1.34	*	2.47	**	3.9	**
Second Stage	Constants:								
	Ca	-0.29		-0.01		-0.44	**	-0.2	**
	France								
	Germany								

NL	0.05		-0.27	**				
ROE	-0.15		0.28	*	-0.17	*	-0.14	**
UK			-1.07	**				
US	-0.61	**	0.07		-0.39	**	-0.66	**
R-squared	0.01		0.03		0.54		0.17	
LM het. test	0.4		0.44		3.16	*	1.45	
Ca- Ca	0.05		-0.09		-0.13	*	-0.09	
Ca- France								
Ca- Germany								
Ca- NL	-0.04		0.11	**				
Ca- ROE	0.04		-0.13	**	-0.03		-0.14	**
Ca- UK			-0.02					
Ca- US	-0.05		-0.01		0.43	**	0.21	**
R-squared	0.05		0.03					
LM het. test	0.15		0.44					
NL- Ca	-0.04		0.11	*				
NL- France								
NL- Germany								
NL- NL	-0.04		0.02					
NL- ROE	-0.03		-0.05					
NL- UK			-0.02					
NL- US	-0.07		0.12					
R-squared	0.04		0.4		0.17		0.29	
LM het. test	0.08		0.92		0.6		8.83	**
ROE- Ca	0.04		-0.13	**	-0.03		-0.14	**

ROE- France								
ROE- Germany								
ROE- NL	-0.03		-0.05					
ROE- ROE	0.15		0.1		-0.21	*	0.25	**
ROE- UK			-0.07					
ROE- US	-0.14	*	-0.35	**	0.31	**	-0.08	
R-squared								
LM het. test								
US- Ca	-0.05		-0.01		0.43	**	0.21	**
US- France								
US- Germany								
US- NL	-0.07		0.12	*				
US- ROE	-0.14		-0.35	**	0.31	**	-0.08	
US- UK			0.76	**				
US- US	0.25		-0.52	**	-0.74	**	-0.14	
R-squared			0.03					
LM het. test			0.59					
UK- Ca			-0.02					
UK- France								
UK- Germany								
UK- NL			-0.02					

UK- ROE	-0.07	
UK- UK	0.23	**
UK- US	0.76	**

The Estimation Results for for ROE, ROS, Switzerland and UK.

	Importer	ROE		ROS		Swizerland		UK	
	Log likelihood	218.55		123.8		191.95		76.02	
First Stage	R-squared	0.75		0.11		0.31		0.9	
	LM het. test	4.59	**	3.23	*	0.92		0.36	
	Constant	-33.75	**	-6.39		10.12		30.63	*
	Sum (Share*Log of Price)	-0.06		0.37	**	0		0.08	
	Log of Farm Cash Income)	-2.06	**	-0.66	**	-2.83	**	2.62	**
	Log of Animal Number	4.12	**	1.45		1.97		-2.37	*
Second Stage	Constants								
	Ca	-0.42	**	0.04		-0.16	**	-0.02	
	France	0.11	**			-0.28	**		
	Germany	0.34	**			0.11	*		
	NL	0.3	**						
	ROE			0.09	**	0.03		0.03	
	UK								
	US	-1.32	**	-1.13	**	-0.7	**	-1.01	**

R-squared	0.32		0.44		0.6		0.16	
LM het. test	2.09		3.39	*	0.89		7.31	**
Ca- Ca	0.05		0		0.11	*		
Ca- France	-0.04				0.2	**		
Ca- Germany	-0.05				0.01			
Ca- NL	0.02							
Ca- ROE			0.02		0.02		0.03	
Ca- UK								
Ca- US	0.22	*	-0.27	**	-0.31	**	-0.14	
R-squared	0.47				0.2			
LM het. test	0.46				6.32	**		
France- Ca	-0.04				0.2	**		
France- France	-0.03				0.22	**		
France- Germany	0.03				-0.25	**		
France- NL	0.01							
France- ROE					-0.34	**		
France- UK								
France- US	-0.17	**			0.25	**		
R-squared	0.55				0.48			
LM het. test	0.38				0.84			
Germany- Ca	-0.05				0.01			

Germany-France	0.03				-0.25	**	
Germany-Germany	-0.04				0.09		
Germany-NL	-0.1	**					
Germany-ROE					-0.09	*	
Germany-UK							
Germany-US	-0.34	**			0.02		
R-squared	0.54						
LM het. test	0.99						
NL- Ca	0.02						
NL- France	0.01						
NL-Germany	-0.1	**					
NL- NL	0.1						
NL- ROE							
NL- UK							
NL- US	-0.49	**					
R-squared			0.04		0.56		0.12
LM het. test			0.55		1.26		0.68
ROE- Ca			0.02		0.02		0.03
ROE-France					-0.34	**	

ROE- Germany					-0.09		
ROE- NL							
ROE- ROE			-0.02		-0.05		-0.02
ROE- UK							
ROE- US			-0.13	**	0.21	**	-0.12
R-squared LM het. test							
US- Ca	0.22	*	-0.27	**	-0.31	**	-0.14
US- France	-0.17	**			0.25	**	
US- Germany	-0.34	**			0.02		
US- NL	-0.49	**					
US- ROE			-0.13	**	0.21	*	-0.12
US- UK							
US- US	0.78	**	0.4	**	-0.17		0.26

Appendix B Elasticities

ROA: Rest of the Asian Countries.
ROE: Rest of the EU Countries.
ROS: Rest of the South American Countries.

Price Elasticities

Africa

Source	Canada		France		Rest of EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**0.59**	**0.55**	-0.30	-0.36	-0.93	-0.99	0.11	0.01
France	-0.19	-0.38	**-2.90** ***	**-3.19** ***	0.48	0.16	-0.09	-0.57
Rest of EU	-0.55	-0.57	0.45	0.41	**-1.30** ***	**-1.34** ***	1.05 **	0.99 **
US	-0.14	-0.18	1.00 ***	0.94 **	0.27	0.20	**-1.68** ***	**-1.78** ***

Australia

Source	Canada		EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-2.38** ***	**-2.19** ***	0.24	0.32	-1.91 ***	-1.65 ***
EU	0.59	0.63	**-2.63** **	**-2.61** **	1.05	1.12
US	0.81 **	0.76 **	0.31	0.29	**0.06**	**-0.02**

Brazil

Source	Canada		Netherlands		Rest of EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-3.13** ***	**-3.57** ***	0.54	0.35	1.78 ***	1.58 **	2.58 ***	1.21
Netherlands	1.20	-0.81	**-2.94** ***	**-3.85** ***	-0.82 *	-1.75 ***	10.73 ***	4.41 ***
Rest of EU	3.87 ***	4.78 ***	-0.81 *	-0.40	**-9.47** ***	**-9.05** ***	2.71 *	5.57 ***
US	-0.06	0.63 **	0.23	0.54 ***	0.79 ***	1.11 ***	**-3.76** ***	**-1.59** ***

China

Source	Canada				US			
	Conditional		Unconditional		Conditional		Unconditional	
Canada	**-2.57**	***	**-2.91**	***	3.22	***	2.81	***
US	1.29	**	2.51	**	**-3.64**	***	**-2.14**	***

France

Source	Canada				EU				US			
	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-1.60**	***	**-1.60**	***	0.50	**	0.50	**	0.06		0.07	
EU	0.71	**	0.71	**	**-0.43**		**-0.43**		0.56		0.55	
US	0.04		0.04		-0.37	***	-0.36	***	**-1.18**	***	**-1.18**	***

Germany

Source	Canada				Netherlands				Rest of EU				US			
	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-1.16**	*	**-1.16**	*	0.13		0.13		-0.13		-0.13		0.16		0.17	
Netherlands	0.28		0.28		**-0.71**	*	**-0.71**	*	0.26		0.26		0.50		0.49	
Rest of EU	-0.25		-0.25		0.23		0.23		**-1.99**	***	**-1.99**	***	0.92	*	0.93	*
US	0.11		0.12		-0.26		-0.25	*	0.36	*	0.36	*	**-1.59**	***	**-1.58**	***

Italy

Source	Canada				Netherlands				Rest of EU				UK			
	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-0.42**		**-0.41**		-0.69	**	-0.69	**	0.87	***	0.87	***	0.13		0.13	
Netherlands	-1.01	**	-0.96	**	**-1.22**	***	**-1.19**	***	0.48		0.53		0.16		0.22	
Rest of EU	0.65	***	0.63	***	0.25		0.23		**-1.50**	***	**-1.53**	***	0.32		0.30	
UK	0.11		0.20		0.09		0.16		0.35		0.48	*	**-2.23**	***	**-2.11**	***
US	-0.38		-0.39		0.17		0.17		-0.41	***	-0.42	***	0.35		0.35	

Source	US			
	Conditional		Unconditional	
Canada	0.08		0.08	

Netherlands	-1.15	-1.04
Rest of EU	1.71 ***	1.65 ***
UK	-4.06 ***	-3.85 ***
US	**0.47**	**0.46**

Japan

Source	Canada		EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-2.98** ***	**-2.86** ***	0.16 ***	0.16 ***	3.19 ***	3.35 ***
EU	9.07 ***	8.25 ***	**-1.69** ***	**-1.70** ***	-10.01 **	-11.15 **
US	1.30 ***	0.69 **	-0.11 ***	-0.12 ***	**-3.16** ***	**-4.01** ***

Mexico

Source	Canada		EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-0.09**	**-0.06**	0.22	0.25	-2.97 ***	-2.80 ***
EU	0.33	0.35	**1.12**	**1.13**	-3.10 ***	-3.00 ***
US	-0.22 *	-0.21 *	-0.32 **	-0.31 **	**-0.03**	**0.01**

Netherlands

Source	Canada		EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-4.59** ***	**-4.60** ***	-0.60	-0.60	5.74 ***	5.73 ***
EU	-1.19	-1.22	**-1.26**	**-1.27**	5.02 ***	4.97 ***
US	2.95 ***	2.99 ***	0.51	0.53	**-6.81** ***	**-6.75** ***

Rest of Asia

Source	Canada		EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-0.59**	**-0.59**	0.61 **	0.61 **	-0.96 **	-0.95 **
EU	2.41 **	2.41 **	**-5.44** ***	**-5.44** ***	1.35	1.36
US	-0.32 ***	-0.32 ***	0.16 **	0.16 **	**-0.81** ***	**-0.80** ***

Rest of EU

Source	Canada		France		Germany		Netherlands	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-1.23** ***	**-1.26** ***	0.16	0.15	0.25	0.23	-0.11	-0.13
France	0.35	0.37	**-0.68**	**-0.67**	-0.30	-0.29	-0.06	-0.05
Germany	0.32	0.35	-0.18	-0.17	**-0.78** ***	**-0.77** ***	0.61 **	0.62 **
Netherlands	-0.16	-0.13	-0.04	-0.03	0.66 **	0.68 **	**-1.68** ***	**-1.67** ***
US	-0.04	-0.08	-0.08	-0.10	-0.44 ***	-0.47	0.09	0.06

Source	US	
	Conditional	Unconditional
Canada	-1.02 *	-1.06 *
France	1.70 ***	1.72 ***
Germany	2.03 ***	2.07 ***
Netherlands	3.23 ***	3.27 ***
US	**-3.13** ***	**-3.20** ***

Rest of South of America

Source	Canada		Rest of EU		US	
	Conditional	Unconditional	Conditional	Unconditional	Conditional	Unconditional
Canada	**-1.00** ***	**-1.01** ***	-0.11	-0.11	1.27 ***	1.22 ***
Rest of EU	-0.69	-0.92	**-0.41**	**1.22** ***	4.00 ***	3.18 ***
US	0.03	0.15 **	0.00	0.02	**-1.53** ***	**-1.11** ***

Switzerland

Source	Canada				France				Germany				Rest of EU			
	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-1.75**	***	**-1.75**	***	-1.40	***	-1.40	***	-0.07		-0.07		-0.16		-0.16	
France	-1.05	***	-1.05	***	**-2.17**	***	**-2.17**	***	1.33	***	1.33	***	1.80	***	1.79	***
Germany	-0.12		-0.12		2.87	***	2.87	***	**-1.98**	**	**-1.98**	**	0.98	*	0.98	*
Rest of EU	-0.12		-0.12		1.81	***	1.81	***	0.46	*	0.46	*	**-0.72**		**-0.72**	
US	0.88	***	0.88	***	-0.44		-0.44		-0.63	***	-0.63	***	-1.18	***	-1.18	***

Source	US			
	Conditional		Unconditional	
Canada	2.16	***	2.16	***
France	-1.29	***	-1.29	***
Germany	-0.26		-0.26	
Rest of EU	-1.12	**	-1.12	**
US	**-0.56**		**-0.56**	

UK

Source	Canada				EU				US			
	Conditional		Unconditional		Conditional		Unconditional		Conditional		Unconditional	
Canada	**-0.31**		**-0.31**		-0.10		-0.10	*	0.41		0.41	
EU	-0.47		-0.48	*	**-0.74**	**	**-0.74**	**	1.67		1.65	
US	-0.35		-0.30		0.03		0.04		**-1.45**	***	**-1.37**	***

Farm Cash Income, Animal Number, and Expenditure Elasticities

Africa

Source	Farm Cash Income		Animal Number	Expenditure	
Canada	-2.21		-2.15	0.53	
France	-11.17	**	-10.87	2.70	***
ROE	-1.45		-1.41	0.35	
US	-2.32	**	-2.25	0.56	***

Australia

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-3.07		5.20		4.05	***
EU	-0.75		1.27		0.99	
US	0.89		-1.51		-1.18	***

Brazil

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.63	**	-0.06		-1.78	***
Netherlands	2.88	***	-0.25		-8.17	***
ROE	-1.30	***	0.11		3.69	***
US	-0.99	***	0.09		2.81	***

China

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-3.21	***	-2.38		-0.65	**
US	11.60	**	8.59		2.35	***

France

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-2.07	**	-4.56	**	1.04	***
EU	1.68	*	3.69	*	-0.84	**
US	-3.02	***	-6.64	***	1.51	***

Germany

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.26	*	0.22		1.00	***
Netherlands	-0.09		-0.07		-0.33	
EU	0.29		0.24		1.09	**
US	0.36	**	0.31	*	1.37	***

Italy

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.01		0.04		0.03	
Netherlands	0.62		3.65	**	2.73	***
EU	-0.32		-1.91	**	-1.43	***
UK	1.30		7.67	***	5.74	***
US	-0.05		-0.27		-0.20	

Japan

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-0.51		1.67		-0.37	
EU	3.55		-11.73	*	2.63	*
US	2.65		-8.77	***	1.96	***

Mexico

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	1.13	***	7.01	**	2.84	***
EU	0.66		4.09		1.66	
US	0.22	**	1.39	*	0.56	**

Netherlands

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-2.25		3.29		-0.55	
EU	10.47	***	-15.32	***	-2.57	***
US	-13.68	***	20.01	***	3.35	***

ROA

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.20		3.62		0.93	*
EU	0.36		6.56		1.68	
US	0.21		3.78		0.97	***

ROE

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-4.01	***	8.01	**	1.94	***
France	2.08	***	-4.15	**	-1.01	***
Germany	4.12	***	-8.22	***	-2.00	***
Netherlands	4.13	***	-8.24	***	-2.00	***
US	-7.43	***	14.81	***	3.60	***

ROS

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.11		-0.24		-0.16	
EU	1.92	**	-4.20		-2.90	**
US	-0.99	***	2.16		1.49	***

Switzerland

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	-3.45	*	2.41		1.22	**
France	-3.93		2.74		1.39	**
Germany	4.20		-2.93		-1.48	**
ROE	0.88		-0.61		-0.31	
US	-5.46	**	3.81		1.93	***

UK

Source	Farm Cash Income		Animal Number		Expenditure	
Canada	0.01		-0.01		0.00	
EU	-1.22		1.11		-0.47	
US	4.67	**	-4.23		1.78	***