Examining Quota Values with Consideration for Risk

by

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Abstract

The objective of this thesis was to determine the effect of income volatility risk on quota values in the Canadian dairy industry. A quota valuation model was developed to explain the relationship between quota value and its potential determinants, including a risk premium that accounted for dairy producer risk preferences and a measure of income volatility risk. The empirical analysis was applied to the Ontario dairy industry, and monthly data was collected for the period October 1990 through July 2009. Three econometric models were estimated using the ordinary least squares and generalized least squares approaches to estimate the relationship between quota value and the explanatory variables. The generalized least squares estimation approach was applied to the econometric models to account for the presence of autocorrelation. Robust standard errors were reported in the presence of heteroskedasticity. The first model included the discounted flows of expected returns and risk premiums as explanatory variables. The second model expanded on the first by adding policy risk and technological change as explanatory variables. The third model adjusted the second model by replacing the discounted flows of expected returns and risk premiums with the non-discounted values of these variables. Three models were specified and estimated to compare the estimation results and determine which specification best explained quota values over the sample period. The significance test for the first regression under ordinary least squares estimation concluded that the discounted risk premium flows were statistically significant at the 5% significance level. However, the discounted risk premium flows took on an unexpected sign that did not coincide with economic theory. Hypothesis tests for all other regression scenarios concluded that the risk premium was statistically insignificant at the 5% significance level. Therefore, given the functional form of the

econometric models, the dataset, and the estimation procedures, the empirical results did not provide definitive evidence that income volatility risk influenced quota values in the Ontario dairy industry for the period October 1990 through July 2009.

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Chapter 1: Introduction

1.1 Introduction

Canadian dairy producers are required to hold production quotas to produce and market milk under the supply management policy. Historically, dairy production quotas have maintained high values that are generated on monthly provincial quota exchanges administered by provincial milk marketing boards. These high values can be potentially attributed to economic variables such as the margin between dairy producer price and marginal cost (expected return), policy risk (Barichello 1996; Nogeuira et al. 2011), farm size and technical efficiency, and the expected growth of returns. If dairy producers are risk averse, then return volatility could influence their decisions on quota exchanges (for example, dairy producer bid and offer values submitted to the provincial exchange), and quota values could fluctuate in response to changing risk conditions. This thesis examines the potential relationship between quota value and income volatility risk by constructing a theoretical framework, econometric models, and utilizing historical quota exchange data to estimate the relationship between these two economic variables. If the estimated coefficient associated with income volatility risk is determined to be statistically significant, the econometric models and their parameter estimates can be used to predict the impact of changes in the level of income volatility risk on quota values.

Agricultural producers make production and marketing decisions under risk, which is often managed by producers using available risk management instruments, such as futures contracts, forward contracts, options on futures, and insurance policies. Risk is also commonly managed in agricultural markets by government, on behalf of producers, with risk-reducing policies. The Canadian dairy industry is an agricultural market that is regulated by a supply management policy that intends to reduce the risk faced by Canadian dairy producers. One objective of the supply management system is to stabilize dairy producer incomes (Schmitz, Furtan, and Baylis 2002) to reduce their income volatility risk. Under the supply management system, milk prices are administered by federal and provincial government agencies (where milk prices are adjusted according to changing costs), domestic milk output is restricted by production quotas, and tariff rate quotas (TRQs) are applied to imported dairy products. Pooling agreements are also in place to aggregate revenues, generated from the milk sales of provincial milk marketing boards, to provide dairy producers with an average return. If these components of the supply management policy have reduced income volatility risk, and if Canadian dairy producers are generally risk averse, then the historically high quota values generated on quota exchanges may be partially explained by the reduction in risk.

This thesis is a risk analysis of dairy producer behaviour on quota exchanges. A discounted cash flow model is specified as the economic model that relates quota value to the included explanatory variables. This quota valuation model builds on the economic model constructed by Barichello (1996) by including a risk premium that accounts for the potential relationship between quota value and income volatility risk. The quota valuation model provides the theoretical framework to construct the econometric models for the empirical analysis. Regressions are conducted to estimate the relationships between quota value and the explanatory variables, which includes the risk premium that contains a measure of income volatility risk. The econometric models are estimated using the ordinary least squares (OLS) and generalized least squares (GLS) approaches, which use the OLS and GLS estimators respectively to minimize the sum of squared errors under certain model assumptions.

Dairy production quotas are valuable capital assets that must be held by licensed dairy producers to produce and market milk within their respective provinces of operation. Quota is initially distributed to dairy producers by government agencies, and can be transferred between producers intra-provincially in a variety of ways, including quota exchanges. Monthly quota exchanges are administered by provincial milk marketing boards, and provide dairy producers with a facility to exchange production quotas at market prices[1]. Quota values are determined by producer expectations and quota exchange policies. Participants of a quota exchange submit bids and offers to buy or sell quota within a specified period each month. Quota exchange administrators then conduct an exchange clearing process, and notify participants of their successful or unsuccessful trades. Quota value is driven by the bids and offers submitted to quota exchanges, where bids represent willingness to buy and offers represent willingness to sell. Canadian dairy quota values have increased significantly on quota exchanges over time, and across all dairy producing provinces. To prevent quota values from reaching levels deemed to be unreasonably high by exchange operators, provinces belonging to the P5 Milk Pool under the Agreement on the Eastern Canadian Pooling (including Ontario, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island) implemented a price cap policy that restricts the quota exchange clearing price to a maximum of $25,000 per kilogram of butterfat per day. Provinces belonging to the Western Milk Pool (WMP) under the Western Milk Pooling Agreement (including British Columbia, Alberta, Saskatchewan, and Manitoba) do not have a price cap policy applied to their quota exchanges, which allows quota to trade at market clearing prices (Farm Credit Canada 2014). Production quotas have primarily traded at the price cap on the exchanges of the eastern provinces, whereas quota has traded on the exchanges of the western provinces in excess of this value.

[1] Provinces belonging to the P5 Milk Pool implemented a price cap policy on quota values in August of 2009. Quota values generated on provincial exchanges that belong to the P5 Milk Pool therefore do not reflect the market price beyond this implementation date.

1.2 Objective

The objective of this thesis is to determine the effect of income volatility risk on quota value. Econometric models are constructed to estimate the relationship between quota value and specified explanatory variables using the OLS and GLS estimation approaches. A risk premium variable is applied to the quota valuation and econometric models to account for dairy producer risk preferences and the measure of income volatility risk. If the estimated coefficient between quota value and the risk premium is determined to be statistically significant through hypothesis testing procedures, then the econometric models can be used to predict the impact of potential changes in income volatility risk on quota value. Two alternative pricing scenarios, United States of America (U.S.) and European Union (EU) farm-level milk prices, are considered to examine how quota values would respond to different income volatility risk levels, driven by U.S. and EU prices. The other explanatory variables included in the econometric models are evaluated to determine their impact on quota value, including expected returns, policy risk, and technological change. This empirical analysis provides insight into the factors that contribute to quota value, with particular interest in the contribution of income volatility risk.

1.3 Behavioural and Empirical Models

The quota valuation model is a discounted cash flow model that represents the relationship between quota value and the explanatory variables that may influence dairy producer decisions on quota exchanges. These explanatory variables include expected returns, the risk premium, policy risk, and technological change. Expected returns are defined as the difference between price, marginal cost, and the risk premium, and are derived under a mean-variance utility framework assuming normally distributed expected returns and constant absolute risk aversion. The expected return is treated as a perpetual cash flow to be received by dairy producers indefinitely, and the cash flows are discounted by the adjusted discount rate. An econometric approach is taken to estimate the relationships between the economic variables specified in the quota valuation model, and certain other variables that may influence quota values. Three econometric models are specified for estimation that differ by the explanatory variables included in the model[2]. The first model specifies quota value as the dependent variable, and the discounted flows of expected returns and risk premiums as the explanatory variables. The second model adds policy risk and technological change to the first model, and the third model replaces the discounted flows of expected returns and discounted risk premiums with their non-discounted values. The purpose of estimating three different models is to compare the results to determine which model specification best explains quota valuation on Ontario monthly quota exchanges. The OLS and GLS principles are used to estimate the coefficients of the econometric models.

1.4 Thesis Outline

Chapter two provides an overview of the Canadian dairy industry. First, a market analysis describes the current state of the dairy industry, and notable market trends over time. Second, the government agencies responsible for administering the supply management policy are described. Third, legislation and regulations that govern the Canadian dairy industry are identified, and the four major components of the dairy supply management system (administered pricing, production quotas, TRQs, and revenue pooling agreements) are described. Chapter three analyzes the Canadian production quota system. The chapter reviews quota exchange governance, quota allocation and transference processes among dairy producers, historical quota value data, and potential determinants of quota value. Chapter four describes agricultural risk concepts, including measurements of risk, risk preferences, and risk premiums. These risk

[2] A fourth econometric model was estimated to account for potential seasonal affects on quota values. This model also considered an alternative measure of expected returns that assumed the current period's expected return equaled the previous period's realized return. The results of this analysis are included in the appendix to this thesis.

concepts are applied to income volatility risk, where the risk premium measures producer responsiveness to changing income volatility risk levels. Chapter five is a literature review of past studies that utilized models and techniques to measure the impact of risk on producer behaviour under Canadian supply management systems, and quota valuation studies that utilized discounted cash flow models to explain quota values in agricultural markets. Chapter six develops the theoretical framework to model dairy producer behaviour on quota exchanges by specifying the quota valuation model. First, the expected return is derived, which contains the margin between producer price, marginal cost, and the risk premium, to account for income volatility risk. Second, the quota valuation model is constructed as a discounted cash flow model. Chapter seven is the empirical analysis that constructs an econometric framework and uses the OLS and GLS principles to estimate the relationships between quota value and the explanatory variables. The chapter describes the historical data used to estimate these economic relationships, which is collected from the Ontario dairy industry from the period October 1990 through July 2009. Given that time series data is used for the empirical analysis, tests for nonstationarity, autocorrelation, and heteroskedasticity are conducted. Significance tests are carried out for each estimated coefficient under each regression to determine whether a statistically significant relationship exists between quota value and each explanatory variable. If the estimated coefficient for the risk premium is determined to be statistically significant through hypothesis tests, the econometric models and their estimated coefficients could be used to predict the effect of potential changes to income volatility risk on quota value by assuming two different pricing scenarios. Under these pricing scenarios, Canadian dairy producers would be assumed to receive U.S. and EU farm-level milk prices, which lead to different levels of income volatility risk faced by dairy producers. Finally, the empirical results are analyzed. Chapter eight concludes the thesis by discussing the implications of the estimated results from the empirical analysis, and suggestions for future research into dairy quota valuation are provided.

Chapter 2: Overview of the Canadian Dairy Industry

2.1 Introduction

This chapter reviews the current state of the Canadian dairy industry, and notable trends over time. First, a market analysis reviews key industry statistics. Second, the Canadian milk marketing system is analyzed. The major government agencies involved in the milk marketing process are described, including the Canadian Dairy Commission (CDC), the Canadian Milk Supply Management Committee (CMSMC), provincial milk marketing boards, and milk revenue pools (the P5 Milk Pool and the WMP Milk Pool). Third, the main components of the supply management policy are explained, including administered pricing, production quotas, TRQs, and milk revenue pooling agreements. The chapter concludes with a data analysis of past quota exchange results, including quota prices and quantity exchanged.

2.2 Canadian Dairy Market Analysis

In 2014, Canada produced 78,259,854 hectolitres of milk, generating $6.073 billion in farm cash receipts from dairy operations (Canadian Dairy Information Centre 2015). The largest dairy producing provinces in 2014 were Quebec and Ontario, producing 37.14% and 32.55% of the total national production, respectively (Canadian Dairy Information Centre 2015b). The western provinces of British Columbia, Alberta, Saskatchewan, and Manitoba accounted for 8.82%, 8.54%, 2.99%, and 4.18% of national milk production, respectively (Canadian Dairy Information Centre 2015b). The maritime provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador accounted for a combined 5.77% of national milk production

(Canadian Dairy Information Centre 2015b). In 2014, there were an estimated 11,962 dairy farms in Canada with milk shipments, 959,300 dairy cows, and 444,200 dairy heifers (Canadian Dairy Information Centre 2015b). The average dairy farm size across Canada was approximately 80 dairy cows per farm. Although the majority of milk in Canada is produced in Ontario and Quebec, dairy farm sizes tend to be larger in the western provinces. Figure 2.1 shows the distribution of dairy farms and dairy cows across the Canadian provinces in 2014, and the average dairy farm size in each province.

Figure 2.1 Dairy farms in Canada by Province in 2014

Province	Number of Farms with Milk Shipments	Number of Dairy Cows	Dairy Cows per Farm
British Columbia	455	72,600	160
Alberta	566	80,700	143
Saskatchewan	166	27,400	165
Manitoba	308	43,200	140
Ontario	3,926	318,800	81
Quebec	5,894	354,800	60
New Brunswick	206	18,900	92
Nova Scotia	229	23,000	100
Prince Edward Island	180	13,900	77
Newfoundland and Labrador	32	6,000	188
Canada	11,962	959,300	80

Canadian Dairy Information Centre. 2015c. "Number of Farms, Dairy Cows, and Heifers." http://www.dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=farm-ferme&s3=nb. (accessed August 7, 2015).

Quebec and Ontario have the most dairy farms and dairy cows in Canada, which is expected, as they produce the most milk in Canada. Dairy farms are largest in the western provinces, with average farm sizes, measured by number of dairy cows per farm, far exceeding the national average.

Milk production by each province is determined by the amount of production quota available to dairy producers within the province. There are two types of production quota: fluid milk quota and industrial milk quota. Each province determines the amount of fluid milk quota that is available to dairy producers operating within the province (Schmitz, Furtan, and Baylis 2002). The amount of industrial milk quota, also known as market sharing quota (MSQ), is a national decision made by the CMSMC. This quota is held by dairy producers to produce milk for use in the production of industrial dairy products, which includes dairy products such as butter, skim milk powder, cheese, yogurt, and ice cream (Canadian Dairy Commission 2011). The CMSMC allocates MSQ to each province. There was 314,910,000 kg of fluid and industrial milk quota (measured as kg of butterfat) in Canada on August 1, 2014 (Canadian Dairy Information Centre 2014a). Figure 2.2 shows the distribution of fluid and industrial milk quota across provinces on August 1, 2014.

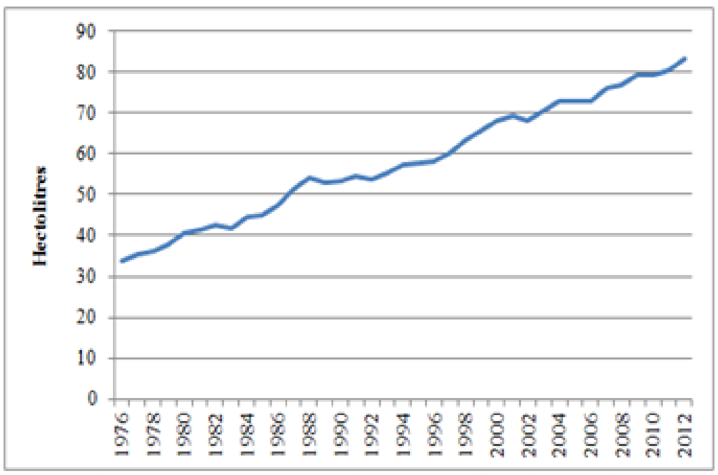
Figure 2.2 Provincial Distribution of Fluid and Industrial Milk Quota on August 1, 2014

Province	Quantity of Fluid and Industrial Milk Quota (Million kg of Butterfat)	Percentage of National Fluid and Industrial Quota
British Columbia	26.01	8.3%
Alberta	26.77	8.5%
Saskatchewan	9.75	3.1%
Manitoba	13.51	4.3%
Ontario	98.48	31.3%
Quebec	124.08	39.4%
New Brunswick	4.43	1.4%
Nova Scotia	5.39	1.7%
Prince Edward Island	4.53	1.4%
Newfoundland and Labrador	1.96	0.6%
Canada	314.91	100%

Source: Canadian Dairy Information Centre 2014a. "Distribution of Industrial and Fluid Milk Quota by Province." http://www.dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=quota&s3=if-tc. (Last accessed August 8, 2015).

The majority of fluid and industrial milk quota is held by Ontario and Quebec dairy producers, holding a combined 70.7% of the total share. British Columbia and Alberta held the most industrial and fluid milk quota among the western provinces, holding 8.3% and 8.5% of the national share, respectively (Canadian Dairy Information Centre 2014a). Canadian dairy farms have generally transitioned to larger operations, and milk output per cow has increased over time. The total number of dairy farms in Canada has declined significantly over time, and the remaining dairy farms have increased their herd sizes. Over the period 1967-2014, the number of dairy farms in Canada decreased from 174,139 in 1967 to 11,962 in 2014 (Canadian Dairy Information Centre 2015c). Over the same period, the average Canadian dairy farm size increased from 14 cows per farm in 1967 to 80 cows per farm in 2014 (Canadian Dairy Information Centre 2015c). Coinciding with increasing dairy farm sizes, milk output per cow has increased over time.

Figure 2.3 Milk Output per Cow in Canada (Hectolitres)

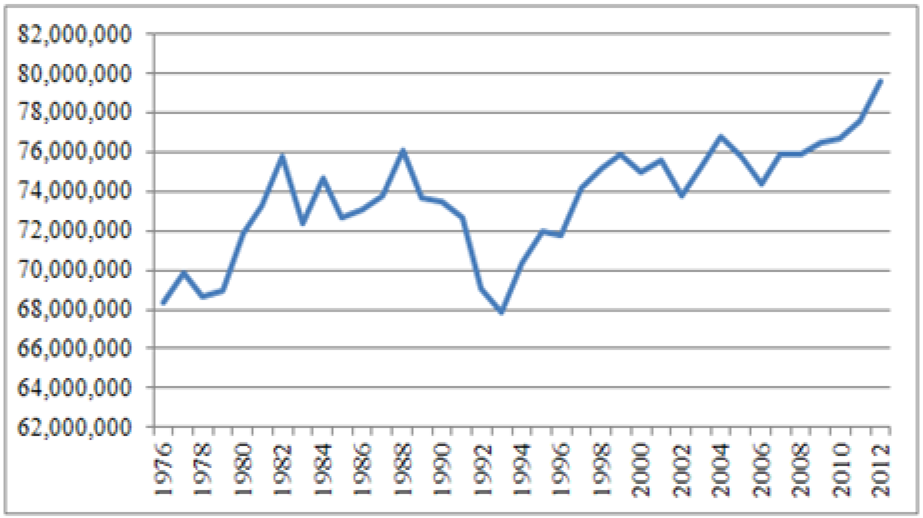


Summary Statistics
Mean = 58.22
Std.Dev. = 14.57
Min. = 33.79
Max. = 83.10

Source: CANSIM Multidimensional @ CHASS. 2014. "Total Milk Sold Off Farms (Kilolitres)." Table 003-0011, Series V382155. http://dc.chass.utoronto.ca.proxy1.lib.umanitoba.ca/cansimdim/ (accessed April 8, 2014).
Canadian Dairy Information Centre. 2014a. D042 – Number of Dairy Cows and Heifers by Province. http://aimis-simia-cdic-ccil.agr.gc.ca/rp/index-eng.cfm?action=pR&r=219&pdctc= (accessed April 9, 2014).

In 1976, the average dairy cow in Canada produced 33.79 hectolitres of milk. By 2012, the average increased to 83.10 hectolitres of milk per cow, a 146% increase (CANSIM 2014, Canadian Dairy Information Centre 2015c). Total milk production in Canada has varied historically over time, which depends on the amount of production quota available to producers.

Figure 2.4 Quantity of Milk Sold Off Farms in Canada (Hectolitres)



CANSIM Multidimensional @ CHASS, 2014. "Total Milk Sold Off Farms (Kilolitres)." Table 003-0011, Series V382155. http://dc.chass.utoronto.ca.proxy1.lib.umanitoba.ca/cansimdim/ (accessed April 8, 2014).

2.3 Canadian Milk Marketing Process

The Canadian dairy industry is regulated by a supply management system that controls milk prices, milk production, imported dairy products, and dairy producer revenues. Provincial milk marketing boards sell milk to processors on behalf of dairy producers operating within the province. The boards receive milk prices from processors based on a dairy product classification system, called the Harmonized Milk Classification System, and dairy producers receive average prices from revenue pooling agreements. Government agencies, including the CMSMC and provincial milk marketing boards, determine the quantity of milk produced by allocating industrial and fluid milk production quotas to dairy producers. TRQs are applied to imported dairy products to increase the prices of foreign dairy products, and reduce international competition. This section reviews the main regulatory bodies that govern the dairy supply management system, which include the CDC, CMSMC, and provincial milk marketing boards.

Revenue pooling agreements are also reviewed, as they are in place to contribute to the supply management policy's intended objective of stabilizing dairy producer incomes.

Canadian Dairy Commission (CDC)

The CDC is a federal crown corporation that has jurisdiction to regulate the Canadian dairy industry under the Canadian Dairy Commission Act. The CDC is responsible for setting support prices for butter and skim milk powder, monitoring demand for industrial dairy products, administering revenue pooling agreements and the Surplus Removal Program, and chairing the CMSMC (Canadian Dairy Commission 2013). The CDC buys and sells butter and skim milk powder at the support prices, and provincial milk marketing boards reference the support prices to establish milk prices for the production of industrial dairy products (Canadian Dairy Commission 2013). The CDC administers three milk pooling agreements: The Comprehensive Agreement on Pooling of Milk Revenues, the Agreement on the Eastern Canadian Milk Pooling (P5 Milk Pool), and the Western Milk Pooling Agreement (WMP Milk Pool) (Canadian Dairy Commission 2013). The purpose of the revenue pooling agreements is to establish an average milk price for dairy producers, by pooling the revenues of provincial milk marketing boards. Under the Surplus Removal Program, the CDC exports surplus butter, skim milk solids, and butter fat to remove overproduction in the domestic market (Canadian Dairy Commission 2013). Lastly, the CDC facilitates the operations of the CMSMC by mediating discussions and decisions of all voting members.

Canadian Milk Supply Management Committee (CMSMC)

The National Milk Marketing Plan is the federal-provincial agreement signed by all ten dairy producing provinces that governs the operations of the CMSMC. The CMSMC is the national body for dairy policy discussion and development in Canada (Canadian Dairy

Commission 2011). It is responsible for setting industrial milk quota levels (MSQ), adjusting MSQ throughout the dairy year (every two months), and allocating MSQ to provinces (Canadian Dairy Commission 2011). The CMSMC is chaired by the CDC, and voting members include the ten provincial government signatories of the National Milk Marketing Plan. Non-voting members include representatives from national consumer and producer organizations (Canadian Dairy Commission 2011). If the CMSMC cannot reach a unanimous decision for setting the MSQ level, the CDC mediates and sets the MSQ level on behalf of the CMSMC (Schmitz, Furtan, and Baylis 2002).

Provincial Milk Marketing Boards

Each of the ten milk producing provinces in Canada is represented by a provincial milk marketing board that is responsible for allocating its provincial share of MSQ to dairy producers, determining the quantity of fluid milk quota for allocation to dairy producers operating within the province, and selling milk to processors on behalf of dairy producers. Each provincial milk marketing board negotiates the price that processors must pay for milk according to the Harmonized Milk Classification System. Since August of 1995, the revenues of provincial milk marketing boards have been pooled under a revenue sharing system with the objective of determining an average price for dairy producers (Canadian Dairy Commission 2013b). Provincial milk marketing boards receive prices according to the Harmonized Milk Classification System, and dairy producers receive blend prices determined by the revenue pooling agreements.

Revenue Pooling Agreements

There are three federal-provincial milk revenue pooling agreements in Canada: The Comprehensive Agreement on Pooling of Milk Revenues, the Agreement on the Eastern

Canadian Milk Pooling, and the Western Milk Pooling Agreement. The Comprehensive Agreement on Pooling of Milk Revenues is an agreement between all ten dairy producing provinces in Canada that pools milk revenues generated under the Special Milk Class Permit Program (Canadian Dairy Commission 2013). This program coordinates the sale of milk for the production of dairy ingredients to be used for the production of further processed industrial dairy products (Canadian Dairy Commission 2013). Milk sold to processors under this program is designated to classes 5(a), 5(b), or 5(c) of the Harmonized Milk Classification System, and processors must hold a Special Class Permit issued by the CDC to purchase milk for the production of industrial dairy products in these classes (Canadian Dairy Commission 2013). The provinces of Ontario, Quebec, Nova Scotia, New Brunswick, and Prince Edward Island belong to the P5 Milk Pool under the Agreement on the Eastern Canadian Milk Pooling. The provinces of British Columbia, Alberta, Saskatchewan, and Manitoba belong to the WMP Milk Pool under the Western Milk Pooling Agreement. The P5 Milk Pool and WMP Milk Pool combine the revenues of provincial milk marketing boards to determine the P5 and WMP blend prices. All dairy producers belonging to the P5 Milk Pool receive the P5 blend price, and all dairy producers belonging to the WMP Milk Pool receive the WMP blend price. The CDC administers the three revenue pooling agreements, and calculates the blend prices on a monthly basis.

2.4 Regulation of the Canadian Dairy Industry

The Canadian dairy industry is jointly regulated by the federal and provincial governments. Pursuant to the Canadian Dairy Commission Act, the Dairy Products Marketing Regulations were established on June 23, 1994, to govern the marketing of dairy products in interprovincial or export trade (Government of Canada 2015). The Dairy Products Marketing Regulations give the CDC and CMSMC authority to determine the amount of industrial milk quota available for the production of industrial dairy products. Prior to each dairy year, the CDC calculates a figure, referred to as Canadian requirements, that is used as a benchmark by the CMSMC to determine how much industrial dairy quota will be available to Canadian dairy producers (Government of Canada 2015). The Dairy Products Marketing Regulations also designate authority to provincial milk marketing boards to market industrial dairy products, both intra-provincially and inter-provincially (Government of Canada 2015). Provincial regulations govern fluid milk marketing in Canada, where provincial milk marketing boards are responsible for selling milk to processors on behalf of dairy producers operating within the province. With this federal-provincial framework, the Canadian dairy industry operates under a supply management system. The following sub-sections review three of the main components of the dairy supply management system: administered pricing, production quotas, and TRQs.

Administered Pricing

Milk prices paid by processors are determined by provincial milk marketing boards using a system of cost of production and classified pricing. Provincial milk marketing boards act as intermediaries between dairy producers and processors, and have jurisdiction to market milk on behalf of dairy producers within the province to processors for the production of fluid and industrial dairy products. Milk is sold to processors through the Harmonized Milk Classification System that guides milk pricing according to dairy product classes. There are five classes within the Harmonized Milk Classification System, each containing a set of dairy products. Class one includes the set of fluid dairy products, and classes two through five include all industrial dairy products (Canadian Dairy Commission 2015). Fluid and industrial milk prices are determined using different processes. Fluid milk prices are determined by a formula, used by all provinces, to determine a base price (Barichello 1999). This formula price is then adjusted according to the fluid dairy product classification when sold to processors. Industrial milk prices are determined by a two part system using support prices and industrial dairy product classification. Each year, the CDC sets support prices for butter and skim milk powder, which are referenced by provincial milk marketing boards when they set milk prices for the production of industrial dairy products (Canadian Dairy Commission 2013). The CDC considers a number of factors when setting support prices. First, a national cost of production study is conducted in collaboration with the dairy producing provinces to estimate the costs of producing milk for a representative dairy farm in Canada. Second, the CDC holds pricing consultations with industry participants to gather price recommendations. Third, the CDC evaluates processor margins and economic indicators. Finally, CDC commissioners use this information, and their discretion, to announce the support prices for butter and skim milk powder in December, to take effect on February 1st (Canadian Dairy Commission 2014). Using the support prices as base prices, the provincial milk marketing boards set milk prices according to industrial dairy product classification. Dairy producers receive blend prices from either the P5 Milk Pool or the WMP Milk Pool. Dairy producers operating in provinces belonging to the P5 Milk Pool and the WMP Milk Pool are paid the P5 blend price and WMP blend price, respectively. The P5 and WMP blend prices are average prices determined by the pooled revenues of provincial milk marketing boards.

Production Quota

Dairy production quota is a valuable capital asset created by government policy that gives Canadian dairy producers the right to produce milk. The quantity of milk produced in Canada is determined by the amount of production quota distributed to dairy producers. MSQ is determined and allocated by the CMSMC to the provinces for industrial milk production. The CMSMC determines the MSQ at the beginning of each dairy year, and then adjusts the MSQ every two months to reflect changes in the CDC's Canadian requirement calculation (Canadian Dairy Commission 2011). Provincial milk marketing boards set the amount of fluid milk quota to produce milk for the fluid market (Barichello 1999). Production quota can be transferred between dairy producers operating within the same province in a number of ways, including an operation purchase, a within-family transfer, and through a quota exchange. Production quotas generate value on provincial quota exchanges through the bids and offers submitted by dairy producers.

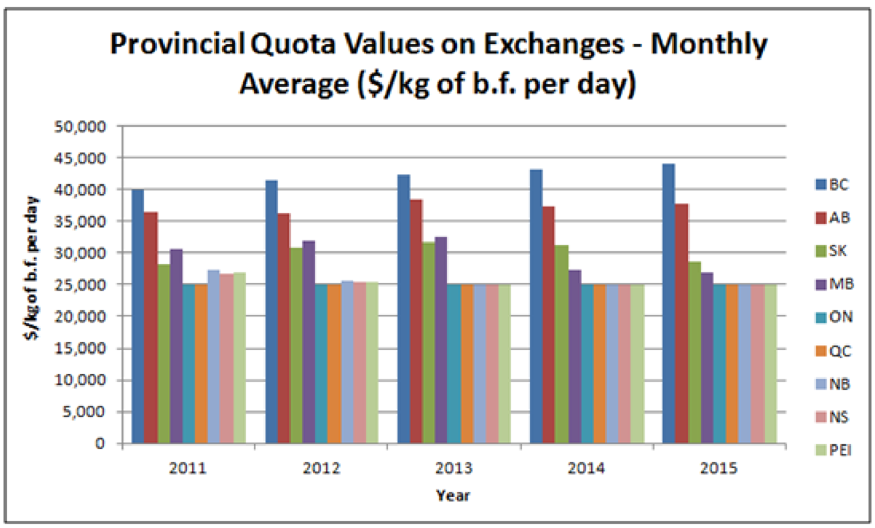
Tariff Rate Quotas (TRQs)

Imported dairy products into Canada are subject to TRQs, which increase the cost of foreign dairy products for Canadian importers. TRQs consist of two tariff rates, and the rate applied to the imported dairy product depends on a defined quantity threshold. A within access commitment tariff rate is applied to imported dairy products up to a minimum access level (Foreign Affairs, Trade, and Development Canada 2013). Beyond the minimum access level, imported dairy products are subject to an over access commitment tariff rate (Foreign Affairs, Trade, and Development Canada 2013), which tends to be much greater than the within access commitment tariff rate. Many of the over access commitment tariff rates restrict dairy imports to the quantity allowed to be imported with the within access commitment rate.

2.5 Monthly Quota Exchange Results

Dairy producers can buy and sell production quota on monthly quota exchanges administered by provincial milk marketing boards. Through a bid-ask framework, and certain exchange policies, exchange clearing prices are determined. The Canadian Dairy Information Centre publishes the monthly quota exchange results for all dairy producing provinces that administer a monthly quota exchange through a provincial milk marketing board. These results include the exchange clearing price and the quantity of quota exchanged for each province. Figure 2.5 displays the monthly average quota price for all provinces from 2011 through 2015. Over this period, quota values were highest in British Columbia, with an average monthly quota exchange price of over $40,000 per kg of quota. Provinces of the WMP Milk Pool do not have a price cap policy enacted on their respective quota exchanges. Provinces of the P5 Milk Pool have a price cap policy of $25,000 per kg of quota applied to their quota exchanges. Over the same period, quota prices in the P5 provinces remained primarily at the price cap of $25,000.

Figure 2.5 Provincial Quota Values - Monthly



Canadian Dairy Information Centre. 2015a. "Monthly Milk Quota Exchange by Province." http://www.dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=quota&s3=qe-tq (accessed June 13, 2015).

The following chapter provides a descriptive review of the Canadian dairy quota system, including quota exchange operations and results.

Chapter 3: Canadian Dairy Production Quota System

3.1 Introduction

Production quota is the component of the Canadian dairy supply management system that restricts domestic production to a level determined by government agencies. The Canadian dairy production quota system is administered federally and provincially by multiple government entities, including the CDC, the CMSMC, and provincial milk marketing boards. These entities operate under various acts, legislation, and regulations. The purpose of this chapter is to analyze how the Canadian dairy production quota system is governed, and how it operates under the control of the various government entities. First, federal and provincial involvement under the important acts and regulations are discussed. This discussion includes a review of the Dairy Products Marketing Regulations, the Canadian Dairy Commission Act, and the administration of the production quota system by the major government agencies. Second, monthly provincial quota exchanges are described, which includes a review of selected provincial quota exchanges, including the Dairy Farmers of Ontario, the British Columbia Milk Marketing Board, and Alberta Milk quota exchanges. The purpose of these selected reviews is to illustrate how provincial milk marketing boards operate monthly quota exchanges as a means to facilitate transactions of quota between dairy producers. Fourth, historical quota values are examined. Quota exchange historical data is gathered from the Canadian Dairy Information Centre, and is presented in table and graph format to illustrate how quota values have varied over time across all dairy producing provinces. The chapter concludes by explaining how production quota generates value on quota exchanges, and proposes potential determinants of demand for quota on these exchanges.

3.2 Federal and Provincial Administration of the Production Quota System

Canadian milk production and marketing is regulated jointly by the federal and provincial governments. The Dairy Products Marketing Regulations apply to the production and marketing of milk for interprovincial or export trade of dairy products (Government of Canada 2015), or more generally, industrial dairy product production and marketing. These regulations do not apply to the production and marketing of fluid milk products. Prior to the commencement of each dairy year, the CDC calculates a figure referred to as Canadian requirements for milk to be used for industrial dairy products. The CMSMC reviews this figure prior to each dairy year and determines the amount of quota that will be available to each provincial milk marketing board for the production of milk used for industrial dairy products (Government of Canada 2015). The National Milk Marketing Plan is a signed agreement between the dairy producing provinces in Canada and the CMSMC that provides for the allocation of quota by the CMSMC to the provincial milk marketing boards (Canadian Dairy Commission 2015b). Once the CMSMC allocates quota shares to the provinces, the provincial milk marketing boards allocate their share to licensed dairy producers operating within their respective provinces (Government of Canada 2015). The Dairy Products Marketing Regulations designate certain powers to provincial milk marketing boards, and enable the CDC to issue federal milk licenses, set and collect levies, and seize dairy products under specified circumstances (Government of Canada 2015).

Fluid milk production and marketing is regulated provincially by designated provincial milk marketing boards. Each province has its own acts and regulations in place to govern the operation of its provincial milk marketing board. One major responsibility of each provincial milk marketing board is to allocate federal and provincial (or industrial and fluid) production quota to licensed dairy producers operating within the province. Production quota is only allocated to dairy producers that operate licensed facilities, and milk can only be produced by a dairy producer that holds production quota. The quantity of industrial milk quota available to each province is determined by the CMSMC allocation process (Government of Canada 2015). The quantity of fluid milk quota is determined by each provincial milk marketing board. The total production quota within each province (industrial quota plus fluid quota) determines the amount of milk that will be produced provincially in a given dairy year. Production quota remains the property of provincial milk marketing boards after it is allocated to dairy producers operating within their respective provinces. However, dairy producers can transfer production quota intra-provincially in various ways, including within-family transfers, operation purchases, and quota exchange transactions. Monthly provincial quota exchanges allow dairy producers to buy and sell quota at market clearing prices.

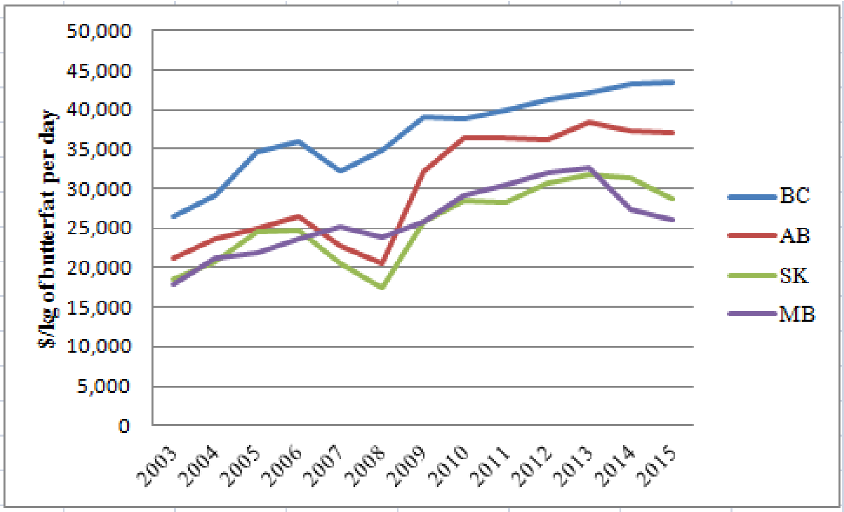
3.3 Production Quota Exchanges

Each milk-producing province in Canada has a provincial milk marketing board that operates a monthly quota exchange that facilitates the exchange of production quota between buyers and sellers. Authorized dairy producers are able to submit bids or offers during an exchange period to buy or sell quota. Each provincial quota exchange operates under its own policy, but all share commonalities. Every quota exchange is open for a specified period of time each month, in which dairy producers submit their bids or offers. Once the quota exchange closes, bids and offers are no longer accepted by the quota exchange, and the accepted bids and offers are processed by exchange administrators. Bids and offers are submitted by dairy producers anonymously either by using an application form or by electronic submission, and include the quantity of quota to be purchased or sold, price, method of payment, and other details. A dairy producer can only submit bids or offers on a given exchange, but not both, and there are restrictions that vary by quota exchange for how long a buyer or seller of quota must hold or wait to buy quota after a transaction has completed. There are also minimum and maximum quantities that dairy producers can bid or offer for quota. Once a quota exchange closes, a process is undertaken by the quota exchange administrators to determine an exchange clearing price, which establishes all successful buyers and sellers of quota. The exchange clearing price and method of allocating quota from successful sellers to successful buyers is prescribed by each exchange policy. Three quota exchanges are chosen as examples to illustrate several different methods of determining market clearing prices and the quota allocation process: the Dairy Farmers of Ontario Quota Exchange, the British Columbia Milk Marketing Board Quota Exchange, and the Alberta Milk Quota Exchange. On the Dairy Farmers of Ontario Quota Exchange, an exchange clearing price is established and compared to the price cap value of $25,000 per kg of quota. When the exchange clearing price exceeds the price cap, the price cap applies. When demand exceeds supply on the quota exchange, an allocation and proration process determines the movement of quota from successful sellers to successful buyers. First, all successful bidders will receive 0.1 kg of quota. Second, two new entrants receive 12 kg and up to 35 kg of quota respectively. Finally, if quota offered for sale still remains, 0.1 kg of quota is allocated to each successful bidder, and the remaining supply is prorated evenly across successful sellers. When supply volume exceeds demand volume, supply is prorated across each successful bidder to clear the market (Dairy Farmers of Ontario 2010). On the British Columbia Milk Marketing Board Quota Exchange, there is no price cap policy in place. Quota trades at the market clearing price, which is determined by a process that sets a benchmark price, and adjusts this price relative to buy and sell order volume. On the first quota exchange after July 31, 2010, the Market Clearing Price was set at $38,000 per kg of quota, which was a benchmark price for which future price adjustments would be made if necessary. The British Columbia Milk Marketing Board Quota Exchange rules state that the market clearing price will increase by $500 per kg of quota if the buy volume exceeds the sell volume for three consecutive exchanges, and buy orders have been filled to 50% or less. The market clearing price will decrease by $500 per kg of quota when the sell volume exceeds the buy volume on a given quota exchange. Quota is transferred from successful sellers to successful buyers on a prorated basis if the buy volume exceeds the sell volume (B.C. Milk Marketing Board 2013). On the Alberta Milk Quota Exchange, bids to buy and offers to sell quota are accepted and ranked according to highest bids and lowest offers. The total trade volume accumulates as the bid price decreases and the offer price increases. This process continues until the market clearing price is discovered, which is equal to the last bid that is priced higher than the remaining best offer. If the last bid and offer do not have equal volume, they will be prorated to clear the exchange. The Alberta Milk Quota Exchange operates as a pay-according-to-bid/receive-according-to-offer system, rather than quota trading at the market clearing price. Therefore, the amount of quota that is traded on each monthly exchange is determined by the market clearing price, but dairy producers with successful bids pay the amount submitted to the exchange, and successful sellers receive the amount indicated on their offers (Alberta Milk 2015). This review of the three selected quota exchanges illustrates how quota prices are derived, and how quota is allocated to participants of an exchange. The following section presents past provincial quota exchange results, including quota prices and quantity traded, to illustrate the upward trend in quota values over time across all dairy producing provinces. Since it is the interaction of bids and offers on an exchange that determine quota values (except in P5 provinces where the price cap applies), a review of potential determinants of bid and offer values will be discussed to conclude the chapter.

3.4 Historical Dairy Quota Exchange Results

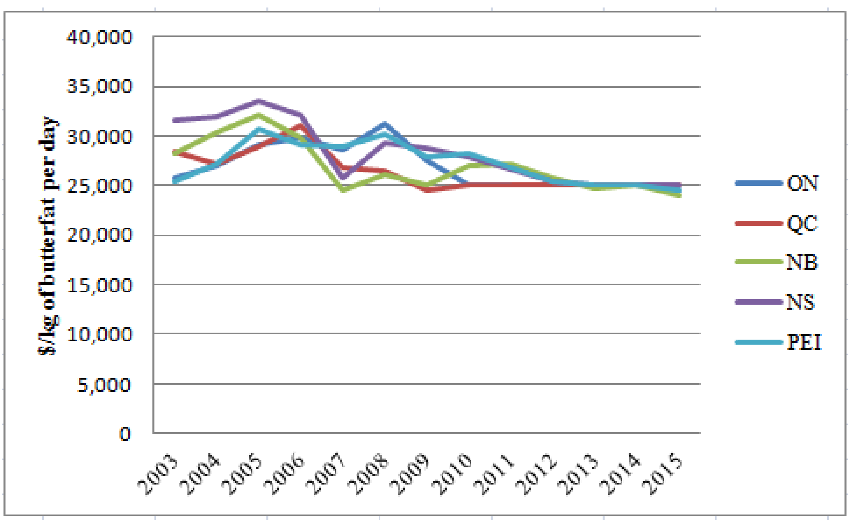
Dairy quota values have generally increased over time across all Canadian dairy producing provinces. Figures 3.1 and 3.2 illustrate the average annual quota values generated on monthly provincial quota exchanges for the western and eastern provinces respectively, from 2003 to 2015[3].

Figure 3.1 Annual Average Quota Values – Western Provinces



Canadian Dairy Information Centre. 2015d. "Monthly Milk Quota Exchange by Province."
http://www.dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=quota&s3=qe-tq (accessed December 13, 2015).

Figure 3.2 Annual Average Quota Values – Eastern Provinces



Canadian Dairy Information Centre. 2015d. "Monthly Milk Quota Exchange by Province."
http://www.dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=quota&s3=qe-tq (accessed December 13, 2015).

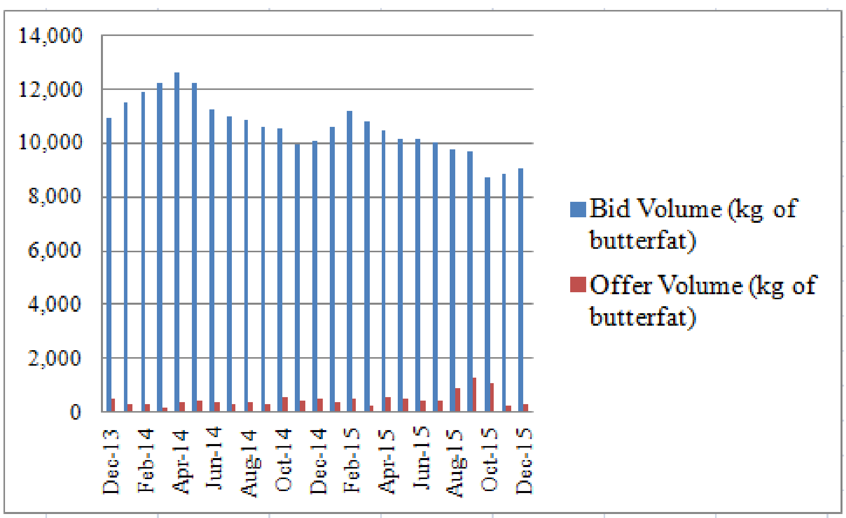
Since 2003, quota values in the western provinces have generally increased. However, in 2014 and 2015, quota values in Alberta, Saskatchewan, and Manitoba declined from past years.

[3] Alberta quota values for market sharing quota are included in Figure 3.1 through 2008. From 2009 onward, total production quota values are presented.

Quota values have historically been highest in British Columbia over the sample time period for the western provinces. Quota values in the eastern provinces fluctuated similarly over the sample time period. In 2009, the price cap policy was implemented first for Ontario and Quebec, and then was implemented in the maritime provinces shortly thereafter. Since the inception of the price cap policy on monthly quota exchanges, quota values have generally remained at $25,000 per kg of butterfat per day. However, quota values were slightly below the cap level in Ontario, New Brunswick, and Prince Edward Island in 2015.

Two quota exchanges, the Dairy Farmers of Ontario Quota Exchange and the Alberta Milk Quota Exchange, provide data on bid and offer volumes for recent monthly exchanges. Figure 3.3 shows the bid and offer volume submitted by Ontario dairy producers from December 2013 through December 2015.

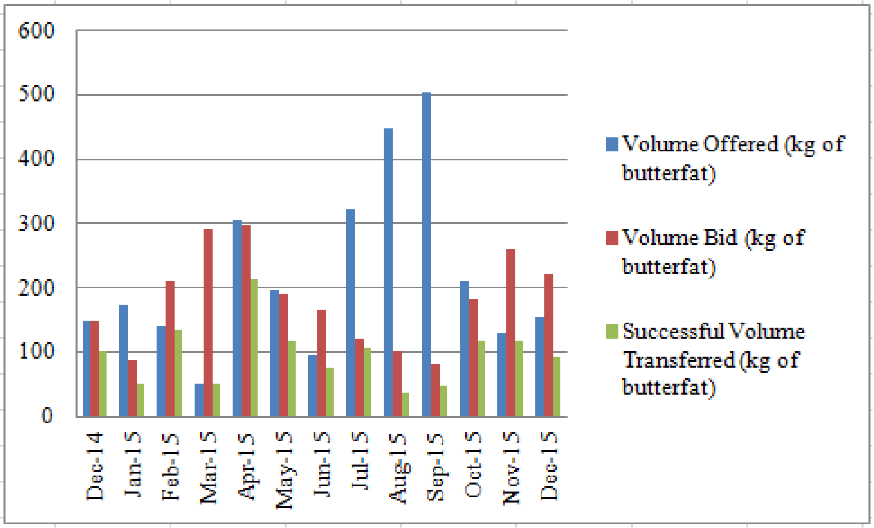
Figure 3.3 Bid and Offer Volume by Ontario Dairy Producers



Dairy Farmers of Ontario. 2015. "Quota Exchange Results." https://www.milk.org/Qex/QexResults.aspx. (Accessed December 13, 2015).

Bid volume far exceeded offer volume over the sample period, which indicates that demand for quota exceeded supply on Ontario exchanges. Figure 3.4 shows bid volume, offered volume, and successful volume transferred by Alberta dairy producers from December 2014 through December 2015.

Figure 3.4 Bid, Offer, and Exchanged Volume in Alberta



Alberta Milk. 2015b. "Quota Exchange Results". https://secure.albertamilk.com/secure/abm/quotainfo/quotaprices.aspx. (accessed December 13, 2015).

Bid and offer volumes were comparable over the sample period, with exception for July, August, and September 2015, where offer volume far exceed demand volume of Alberta dairy producers.

The following section concludes this chapter with a discussion of potential determinants of quota value on provincial quota exchanges.

3.5 Potential Determinants of Quota Value

A bid price submitted by a dairy producer to a quota exchange represents the amount they are willing to pay for a unit of quota. Similarly, an offer price represents the amount a potential seller is willing to accept in exchange for a unit of quota. These bid and offer prices are generated by underlying explanatory variables that dairy producers assign values to. Potential determinants of bid and offer prices, and hence, quota values, that have been discussed in past literature include: the expected margin between the producer blend price and marginal cost; the discount rate; the expected margin growth; and policy risk (Barichello 1996; Nogueira et al 2011). The expected margin between the producer blend price and marginal cost is an expected return, and the discount rate is the expected rate of return. The expected margin growth and policy risk measure the expected change in returns and the risk of a dairy supply management policy change respectively. One potential explanatory variable that has not been as prominent in the dairy quota value literature is income volatility risk. Dairy producer behaviour on quota exchanges may be influenced by the degree of return variability, or the risk inherent in their returns. The objective of the empirical analysis of this thesis is to determine whether quota values are impacted by income volatility risk. Technological change is also another potential determinant of quota value that is examined in the empirical section of this thesis.

Chapter 4: Agricultural Risk Analysis

4.1 Introduction

Agricultural producers often make production and marketing decisions under risk, which can take many forms, including income volatility risk, output price risk, production risk, production quality uncertainty, weather uncertainty, and the possibility of disease or pests affecting a crop or animal herd. These examples of risk, and the many others that exist, can influence agricultural producer decisions, and changing risk conditions may result in changes in producer behaviour. Agricultural risk analysis develops economic models that include risk variables to analyze the relationships between these risk measures and the behaviour of the specified economic agents (for example, producers, consumers, processors, and government agencies). This chapter provides a background to agricultural risk analysis, and then applies the topics discussed to the Canadian dairy industry. First, a description of agricultural risk and risky events is provided. Second, selected risk measures are outlined. Third, risk preferences are defined. Agricultural producers have subjective risk preferences that determine how their decisions are influenced by risk. Fourth, the concept of a risk premium is introduced, which is a measure of the additional compensation required by a risk averse producer that faces a risky scenario (Robison and Barry 1987). Fifth, potential producer responses to risk are considered. The chapter concludes by applying these risk topics to the analysis of Canadian dairy producer behaviour on quota exchanges. Dairy producers operate under a supply management system that attempts to reduce their income volatility risk, which may have implications on their behaviour on quota exchanges. The application of a risk premium to measure the responsiveness of dairy producers to changing risk conditions on quota exchanges is considered.

4.2 Background on Agricultural Risk

Risk is present in agriculture in many different forms: Commodity prices are cyclical, and often times volatile, leading to unpredictable prices and incomes; Production is variable because it depends on environmental conditions. Extreme weather, disease, or pests can adversely impact output; Large swings in supply can contribute to volatile commodity prices and producer incomes; Many inputs used by agricultural producers are commodities that are subject to changing supply and demand conditions that may cause periods of volatile production and prices. Oil, fertilizer, feed, and seed are common inputs used in agricultural production with prices that can unexpectedly rise, increase production costs, and diminish producer returns; Agricultural industries that benefit from government programs and policies face policy risk, the probability of the policy benefits being reduced or completely removed (Barichello 1996); and fluctuating exchange rates impact the quantity of sales, commodity prices, and revenues for products sold to export markets. These examples of agricultural risks all create producer uncertainty about future outcomes. If agricultural producers are risk averse, then the examples previously described can be classified as risky events, as they are likely to affect producer decisions and their well-being (measured as either utility or income) (Robison and Barry 1987). Risk is characterized by random variables and their associated probability distributions (Robison and Barry 1987; Chavas 2004), where the probability distribution includes all possible values the random variable can take, and their associated probabilities.

Agricultural producers are uncertain about what future values the relevant random variable will take, and must form expectations based on their knowledge of the potential outcomes and their associated probabilities of occurrence (Robison and Barry 1987). When analyzing producer behaviour under risk, producers are assumed to evaluate the probability distribution of a random variable to form their expectations and to determine the amount of risk they face. Risk can be measured in different ways, depending on the source of the risk and how individuals view the risk. The following section reviews measures of income volatility risk, and focuses on the measure that will be applied to the empirical section of this thesis.

4.3 Measuring Risk

Future incomes of agricultural producers are generally unknown when production decisions are made, and producers must form expectations of their future incomes, and reference these expectations, when making their production decisions. If producers are risk averse, income volatility risk may be a factor in their decision making process. When analyzing the effect of income volatility risk on risk averse agricultural producer decisions, an appropriate measure of risk must be chosen. This section reviews common income risk measures, including variance, standard deviation, beta, skewness, and kurtosis.

Income volatility is a form of risk faced by agricultural producers, and can be measured as the variance of a producer's income using a probability distribution or historical data approach.

If the probabilities of all possible future income values are known (or estimates are available), then the variance of a producer's income can be measured as the weighted average of the sum of squared deviations of all potential income values from the producer's expected income:

[1] Variance of Income – Probability Distribution Approach: $\sum_{i=1}^{n} P_i\{x_i - E(x)\}^2$

where x_i represents the income level for period i, $E(x)$ is the expected income, and P_i is the probability of income i occurring. If the probability distribution of income is unavailable, the historical data approach can be used to calculate the variance of producer income when a dataset of past observations of income is available. The variance of producer income can be calculated using the historical data approach as the average of the sum of squared deviations of observed income values from the mean of the dataset:

[2] Variance of Income – Historical Data Approach: $\frac{\sum_{i=1}^{n}\{x_i - E(x)\}^2}{n}$

where x_i represents the observed income level for period i, $E(x)$ is expected income, and n is the number of observations in the income dataset. A key difference between the probability distribution and historical data approaches of the measurement of risk is that the variance in [1] is measured as a weighted average and [2] is measured as an arithmetic mean. For both approaches, a larger variance implies greater income volatility risk faced by the producer.

Another variance approach that can be used to measure income volatility risk is to assume producers consider historical deviations of realized income values from expected values, and that the most recent observations have a greater impact on their evaluation of risk. A sum of squared deviations approach is used, where more weight is given to the most recent observations of squared deviations. Coyle (1992) used this approach to calculate price variance by assigning weights of 0.5, 0.33, and 0.17 to the last three sum of squares prediction errors. This approach, if applied to the variance of income, would be calculated as:

[3] $Var\,(x_i) = 0.5\,(x_{i-1} - E_{i-2} \cdot x_{i-1})^2 + 0.33\,(x_{i-2} - E_{i-3} \cdot x_{i-2})^2 + 0.17\,(x_{i-3} - E_{i-4} \cdot x_{i-3})^2$

x_i is the producer's income in current period i and expected income, $E_{i-1} \cdot x_i$, is formed in the previous period. The variance of the current period's income, $Var\,(x_i)$, is the weighted average of the squared deviations of past income values from the previous period's expected income. This method of assigning chosen weights to past observations, and selecting the amount of past observations for the calculation, allows for a less restrictive approach for measuring income volatility risk, as these parameters can be chosen to reflect how producers evaluate income volatility risk. This method is used as the measure of income volatility risk in the empirical section of this thesis. Dairy producers are assumed to measure the risk they face by examining more recent deviation observations. The recent observations are more representative of the current risk conditions. It is unlikely that a dairy producer would look back at an entire range of historical deviations, and consider each observation equally, to calculate a risk measure. Older observations are likely less relevant to the current risk conditions. The ability to choose parameter values as weights accounts for the dairy producer's consideration for recent observations of deviations when evaluating their risk.

Standard deviation is a measure of income volatility risk that equals the square root of the variance of income. Like the variance, standard deviation is an average of deviations from expected income, but its unit of measure is the same as the unit of measure for income. Standard deviation can be measured using the three approaches described above by calculating the variance, and taking the square root.

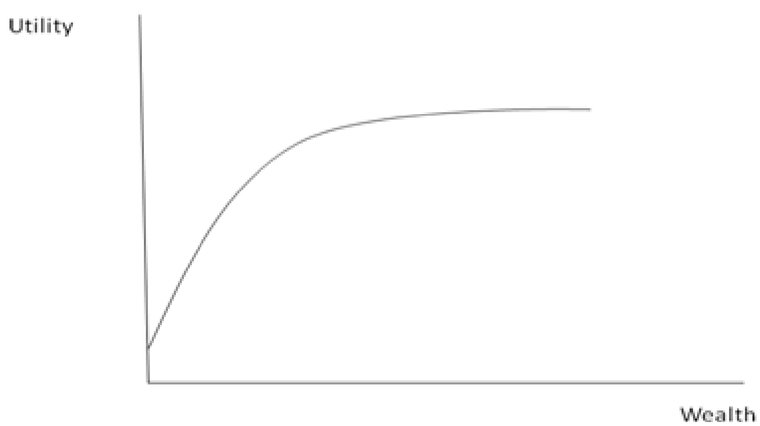
In financial portfolio theory, risk is commonly measured by a parameter called beta, which represents the relationship between an asset's value and the value of a relevant market as a whole. For example, beta could be estimated to measure how a stock price would be expected to respond to a change in value to the overall stock market. This measure of income risk can be applied to an individual's portfolio of assets and any selected asset contained in the portfolio to measure how that asset's value would respond to a change in value of the portfolio of assets. Beta measures how the value of an asset changes when the value of a collection of assets changes. It does not account specifically for producer responses to changes in income volatility risk. Beta can be estimated using an econometric approach that uses sample data and an econometric model to estimate the relationship between the relevant asset and market.

The final two income risk measures to be reviewed are skewness and kurtosis. These two risk measures require knowledge of the shape of the probability distribution for producer income. Analyzing a probability distribution of income for left-tail skewness indicates the probability for relatively low income or possible losses. A normal distribution, used as a measurement benchmark, has a skewness value of zero. A probability distribution with skewness to the left has a negative value, and the smaller the value (the more negative the value is) the greater the skewness. Kurtosis is a measure that considers both tails of a probability distribution and summarizes the relative likelihood of high or low outcomes occurring compared to a normal distribution. This would include both large profits and losses for the probability distribution of income. The probability of achieving profits is not generally considered to be a risky prospect, and therefore skewness may be considered the more appropriate risk measure of the two.

4.4 Risk Preferences

Producer risk preferences are characterized by their unique utility functions defined over wealth outcomes (Robison and Barry 1987). Risk preferences can be inferred from the utility function of wealth by evaluating several risky events, and the utility they yield, that have the same expected value (Robison and Barry 1987). A risk neutral individual will equally prefer any risky event that yields the same expected value. This risk preference is represented by a linear utility function; a risk averse individual prefers risky events that have a lower variance of outcomes. Risk aversion is represented by a concave utility function; a risk seeking individual prefers risky events that have a higher variance of outcomes. This risk seeking preference is represented by a convex utility function (Robison and Barry 1987). Agricultural producers are generally assumed to be risk averse in agricultural risk analyses. Risk aversion is a preference for choices with certain outcomes over risky alternatives that have outcomes with expected values of equal value to the certain outcomes. Nicholson and Lipnowski (2008) defined risk aversion as the unwillingness of individuals to accept fair gambles. Given a choice between a risky alternative and a certain alternative, where the expected value of the outcome to the risky alternative is equal to the outcome of the certain alternative, the risk averse individual will choose the certain alternative.

Figure 4.1 Utility Function of Wealth for a Risk-Averse Individual



Source: Nicholson and Lipnowski 2008

Figure 4.1 illustrates diminishing marginal utility of wealth, where each additional unit of wealth provides less utility to the risk averse individual. Therefore, at any particular point on the utility curve of wealth, the utility gained from a marginal increase in wealth is less than the utility lost from a marginal decrease in wealth of equal magnitude. A risk averse individual's well-being in terms of utility is affected more by losses in wealth than gains in wealth.

Risk aversion can be measured by coefficients of risk aversion, which measure the degree of risk aversion of an individual at some point on their utility function of wealth. Risk aversion may adjust with the level of wealth of the individual. That is, an individual's degree of risk aversion may depend on their wealth level. Two measures of risk aversion include the coefficient of relative risk aversion and the coefficient of absolute risk aversion. The former is evaluated at a particular level of wealth, and is measured as an elasticity (Newberry and Stiglitz 1981). The latter does not include a specific level of wealth in its calculation, and has a unit of measure (Newberry and Stiglitz 1981). The coefficient of relative risk aversion, R(Y), and the coefficient of absolute risk aversion, A(Y), are calculated as (Newberry and Stiglitz 1981):

[4] $$R(Y) = \frac{-YU''(Y)}{U'(Y)}$$

[5] $$R(A) = \frac{-U''(Y)}{U'(Y)}$$

Both R(Y) and A(Y) are functions of the individual's wealth (Y). U'(Y) and U''(Y) are the first and second derivatives of the individual's utility curve respectively.

The propensity and magnitude of these coefficients to change with wealth depends on the individual's risk preferences. Constant relative risk aversion (CRRA) and constant absolute risk aversion (CARA) coefficients remain the same across all levels of wealth. Decreasing relative risk aversion (DRRA) and decreasing absolute risk aversion (DARA) decrease as wealth increases. Individuals with these risk preferences have decreasing risk aversion as their wealth increases. Increasing relative risk aversion (IRRA) and increasing absolute risk aversion (IARA) coefficients increase as wealth increases. Individuals with these risk preferences become more risk averse as wealth increases.

Estimates of these risk aversion measures can be applied to empirical risk analyses. Anderson and Dillon (1992) classify degrees of risk aversion by assigning values to CRRA coefficients, and these CRRA values can be used to calculate CARA coefficients. To derive CARA coefficients, estimated values of CRRA, provided by the CRRA classification of Anderson and Dillon (1992), can be divided by the producer's current level of wealth (Hardaker et al. 2004):

[6] CARA = CRRA / Producer Wealth

Estimates of producer risk preferences, along with an appropriate risk measure, are the necessary components to estimate the risk effects on producer behaviour in empirical risk analyses. Risk premiums utilize these two measures to capture the relationship between risk and producer behaviour.

4.5 Risk Premium

A risk premium represents the additional costs to individuals provided by the risk they face. It is the additional compensation in excess of the risk-free return that risk averse individuals require to take on the additional risk (Robison and Barry 1987). The relationship between the expected return of a risky scenario, its certainty equivalent return, and the risk premium, is represented as follows (Robison and Barry 1987):

[7] Expected Return = Certainty Equivalent + Risk Premium

If the risk averse individual were to accept the risky scenario, they would require the risk premium as compensation for this risk. By rearranging [6], the risk premium is equal to:

[8] Risk Premium = Expected Return – Certainty Equivalent

Risk premium calculations depend on an individual's utility function of wealth. The appropriate method used must coincide with the specified utility function and how risk aversion changes across different levels of wealth. Assuming absolute risk aversion, Pratt (1964) approximated a risk premium calculation as:

[9] $\pi = \frac{1}{2} \cdot A[E(Y)] \cdot \sigma^2$

where $A[E(Y)]$ is the measure of absolute risk aversion at the expected wealth, and σ^2 is the variance of the risky event. Under this approach, the risk premium is one-half the product of the absolute risk aversion coefficient and the variance of the risky event. With estimates of absolute risk aversion coefficients and the variance from either the probability distribution or historical data, the risk premium can be calculated and applied to an empirical risk analysis of producer behaviour.

4.6 Potential Responses to Risk

Pratt's risk premium approximation in [9] is an appropriate estimation of the relationship between risk and producer responses because it incorporates a risk preference measure and variance, which is a type of risk measure often used in empirical risk analyses. If the source of risk faced by the risk averse producer is income volatility risk, this risk premium would equal one-half the product of the absolute risk aversion coefficient and the variance of income. Potential producer responses to income volatility risk changes can be estimated empirically using an econometric approach that includes the risk premium as an explanatory variable in the model. The estimated parameter associated with the risk premium measures the effect of a change in income volatility risk, risk preference, or both, on the dependent variable under analysis.

Applying this methodology to the Canadian dairy industry, and specifically to the behaviour of dairy producers on quota exchanges, an econometric approach can be used to estimate the relationship between income volatility risk and quota value. This approach specifies quota value as the dependent variable, and the risk premium as an explanatory variable. The estimated parameter associated with the risk premium measures the effect of a change in income volatility risk, risk preference, or both, on quota value. This estimated parameter could be utilized to predict responses in quota value to potential changes in the level of risk that dairy producers face, if the estimated parameter is determined to be statistically significant.

Chapter 5: Literature Review

5.1 Introduction

One objective of supply management is to reduce income volatility risk faced by producers. If this risk is reduced, and dairy producers are risk averse, quota values may be impacted by this risk reduction. Also, if the supply management policy changes such that the level of risk faced by producers changes, quota values may adjust according to a risk response by producers on quota exchanges. The empirical section of this thesis analyzes this potential risk response, and in preparation for this analysis, a literature review is conducted to assess past risk analyses of Canadian supply managed markets, and past studies that have utilized discounted cash flow models to analyze quota values in agricultural markets. The objective of this literature review is to understand past models and techniques used to measure the impact of risk on producer behaviour under Canadian supply management systems, and to determine the explanatory variables specified in production quota valuation models.

5.2 Risk Analyses of Canadian Supply Managed Markets

Theoretical and empirical analyses of risk in Canadian supply managed industries have examined the impact of changing risk conditions on producer behaviour. Past theoretical studies have suggested that price variability may contribute to quota value if producers are risk averse and responsive in their production decisions to reduced uncertainty. Schmitz (1983) considered the potential impact of reduced uncertainty on dairy producer behaviour, where the source of uncertainty was price volatility. He suggested that risk averse dairy producers could respond to reduced uncertainty through price stabilization. This theory suggested that quota value could be affected by the degree of risk faced by producers. Moschini (1984) derived a utility function to determine the effect of reduced price uncertainty on dairy quota value. He defined expected utility to be a function of producer profit, and the producer was assumed to produce the level of milk to maximize expected utility. He concluded that quota value may be partially explained by reduced price uncertainty.

Empirical risk analyses of supply managed markets have focused on the impact of world price uncertainty on producer behaviour and economic welfare. Specifically, these studies analyzed the economic impacts of potential tariff liberalization scenarios resulting from World Trade Organization (WTO) negotiations and agreements. Rude and Gervais (2006) compared the welfare impacts of liberalizing TRQs applied to the Canadian chicken industry by lowering over-quota tariffs (tariff-rate liberalization) and increasing minimum access commitments associated with in-quota tariffs (import quantity liberalization). They accounted for the potential impact of world price uncertainty by running stochastic simulations of world chicken prices when over-quota tariffs were reduced. They constructed an inverse supply function from 2001 base data from the Canadian chicken industry that accounted for output price risk by including a risk premium. The risk premium was defined as the product of a CARA coefficient, producer price variance, and output quantity. A CRRA coefficient value of 4 was selected to represent chicken producer risk preferences, and was converted to the CARA coefficient by dividing the CRRA by producer profits. Historical U.S. chicken prices were used to fit a probability distribution for the simulation, which included 1,000 draws of U.S. prices. The simulation results indicated that producer surplus declined and consumer surplus increased under tariff-rate liberalization and import quantity liberalization. Producer surplus decreased more under the import quantity liberalization scenario, as domestic chicken production decreased from the base scenario as chicken imports expanded. Total welfare decreased under import quantity liberalization and expected welfare increased under tariff-rate liberalization. A distribution of economic welfare impacts was constructed under the tariff-rate liberalization scenario by simulating the stochastic world price for chicken. Given that U.S. chicken prices are stochastic, the impacts of tariff-rate liberalization were reported as expected values, along with the 5th and 95th percentile values from the probability distribution. The impact of world price uncertainty on the chicken producer's behaviour was captured by the risk premium which shifted the supply function according to the risk preference parameter, price risk variance, and output quantity. Rude and An (2013) analyzed potential tariff liberalization scenarios under the Trans-Pacific Partnership to determine the impact of world price uncertainty on economic welfare and quota rents. A simulation model was constructed to compare key economic variable values under the current Canadian dairy market structure to two potential TRQ reductions. The economic variables measured in the simulation included supply, demand, price, net imports or exports, and economic welfare. Measures of economic welfare included producer and consumer surplus, and quota rental value. TRQs were reduced in the simulation by 40% in the first scenario and by 70% in the second scenario. The simulation results indicated that producer surplus and quota rental values would decrease, and consumer surplus and net welfare would increase, for both TRQ reductions. The simulation model also accounted for world price risk, and measured a risk premium that accounted for the additional reduction in producer surplus resulting from the TRQ reductions due to the higher price volatility faced by dairy producers. Under the 40% tariff reduction, expected producer surplus decreased by $231.4 million, of which $2.4 million was accounted for by the risk premium resulting from the increased price volatility risk. Hacault (2011) conducted a simulation of potential policy changes in the Canadian dairy industry under the WTO Doha Development Agenda, using a partial-equilibrium framework that accounted for stochastic world prices. A risk premium was included in the supply function of the selected dairy products to account for stochastic prices when over-quota tariffs were reduced. The risk premium was calculated as the product of a CARA coefficient, price variance, and output, and was applied to the supply functions of the dairy products when over-quota tariffs were reduced by 70% and 46% respectively. When these potential policy changes reduced the landed world prices below domestic prices, producers were faced with world price risk that impacted the economic welfare of Canadian dairy industry participants. The risk premium shifted the supply curves of these dairy products to the left, and the stochastic prices resulted in a distribution of welfare impacts for each product. Under the over-quota tariff reduction scenarios, producer surplus was expected to decrease and consumer surplus was expected to increase. These three empirical analyses of risk in the Canadian supply managed industries all included a risk premium to account for producer risk-responsiveness to world price uncertainty, and the associated economic welfare implications.

5.3 Studies of Quota Valuation using Discounted Cash Flow Models

Past quota valuation studies that have focused on agricultural production quotas created by government policy have utilized capital asset pricing models to determine the impact of specified economic variables on producer bids and offers on quota exchanges, and subsequently, quota values. These models discounted an expected future cash flow by a discount rate to determine a present value for quota. Barichello (1996) defined a quota pricing model to estimate the discount rate, or the expected rate of return. The model discounted expected returns by an interest rate, adjusted by policy risk and expected growth rate parameters. The policy risk parameter was defined as the probability of the rents received by dairy producers being removed completely or reduced, and the expected growth rate parameter represented producer expectations of future quota returns growth (Barichello 1996). Nogueira et al. (2011) incorporated a policy risk parameter into a quota pricing model to determine the effect of policy risk on the magnitude of discount rates and its influence on quota values in Canadian supply managed industries. Lermer and Stanbury (1985) specified a capital asset pricing model to demonstrate that the discount rate consisted of a risk-free rate and a risk premium. They argued that Canadian poultry producers incur risk associated with holding quota and consequently require a risk premium that ultimately affects quota value and increases the social cost of supply management regulation. Sumner and Wilson (2005) recognized the high rates of return to California dairy quota, and analyzed the effect of portfolio risk on quota value. Their findings suggest portfolio risk was not a significant factor contributing to California dairy quota rates of return, but rather policy risk was likely a large contributor to the high rates of return.

Past policies have been enacted by either government agencies or quota exchanges that potentially affected the trade of production quotas, and several studies have utilized capital asset pricing models to estimate the economic impact of these policies. Turvey, Weersink, and Martin (2002) discussed the impact of the Commercial Export Milk program on dairy quota values. This program gave producers the option of marketing milk to the domestic market under supply management or to the export market. They showed that under such a program, the cash flow benefit of quota equaled the difference between the domestic milk price and the export milk price, instead of the marginal cost. A mean-variance portfolio model was used to explain the decisions of producers between the domestic and export market and to analyze how the export price risk influenced decisions. Price volatility was measured in both markets, and the paper concluded that it was unlikely farmers would increase their use of export contracts due to the greater export price risk. Cairns and Meilke (2012) applied an infinite time horizon asset pricing model to Ontario dairy quota to determine the effect of quota price ceiling policies on the economic welfare of buyers and sellers of quota on the Ontario quota exchange. The model was also utilized to explain why dairy quota values in Ontario increased rapidly from 1994 through 2009. Results indicated the rise in quota prices over this time period were caused by economic factors, not speculation, and the price ceiling policies created economic welfare losses in the Ontario quota exchange. They concluded that the rise in quota values over this time period likely resulted from declining interest rates, declining policy risk, and the adjustment of quota values to their intrinsic value after the reduction in credit restrictions.

This thesis develops a discounted cash flow model to explain how Canadian dairy producers value production quotas. Specifically, the quota valuation model defines the potential relationship between income volatility risk and quota value. The model builds on the work mentioned above by considering the impact of risk, measured by income volatility, on quota values. The quota valuation model is used to examine how the level of risk affects producer behaviour on quota exchanges, and potentially to determine how dairy producers could respond to changing risk conditions if the supply management policy were amended.

Chapter 6: Methodology

6.1 Introduction

The purpose of this chapter is to construct a framework to model dairy producer behaviour on monthly quota exchanges with consideration for income volatility risk. This framework consists of three central components: a mean-variance utility model that assumes dairy producers consider expected returns and the variance of returns when making decisions on the quota exchange (i.e. submitting bids or offers); the risk premium that is derived from the utility model; and the quota valuation model which discounts utility by an interest rate adjusted for expected returns growth and policy risk. This framework establishes the theoretical relationship between quota value and income volatility risk that will be used for the empirical analysis that follows in Chapter seven.

6.2 Mean-Variance Utility Model

Assume that the returns received by dairy producers from quota are equal to price less marginal cost, and that returns are stochastic, such that future returns are uncertain:

[10] Returns = R = P – MC

Also assume that returns are normally distributed, and dairy producers have CARA risk preferences. Under these conditions, a dairy producer's utility function is characterized by the mean and variance of the random variable, R (Chavas 2004). The utility function is (Chavas 2004):

[11] EU(R) = $E(R) - \frac{r}{2} \cdot Var(R)$

Where: r = -U''/U' = Arrow-Pratt CARA coefficient

Expected returns and the variance of returns are measured in the empirical analysis using a weighted average approach where historical observations are assigned weights that decrease going back in time. That is, older observations are assigned smaller weights. Expected returns and the variance of returns are measured as follows:

[12] $E(R) = 0.5 \cdot (R_{i-1}) + 0.33 \cdot \left(R_{i-2)}\right) + 0.17 \cdot (R_{i-3})$

[13] $Var(R) = 0.5 \cdot (R_{i-1} - E_{i-2} \cdot R_{i-1})^2 + 0.33 \cdot (R_{i-2} - E_{i-3} \cdot R_{i-2})^2 + 0.17 \cdot (R_{i-3} - E_{i-4} \cdot R_{i-3})^2$

Expected returns are measured by assigning weights to the past three realized return observations and calculating the sum-product. Similarly, the variance of returns is measured by assigning weights to the last three sum of squares prediction errors, and calculating the sum-product (Coyle 1992).

6.3 Quota Risk Premium

The second term in the utility model, $\frac{r}{2} \cdot Var(R)$, is the risk premium. It can be interpreted as an implicit cost to a dairy producer that is deducted from their expected return. The magnitude of the risk premium depends on dairy producer risk preferences, measured by the CARA coefficient (r), and the variance of returns. A positive r-value implies risk aversion, and that income volatility risk would decrease utility. A larger CARA coefficient and/or variance would result in lower utility.

6.4 Quota Valuation Model

Barichello (1996) developed a discounted cash flow model to examine quota values in the Canadian dairy industry. The margin between the producer price and marginal cost was assumed to be a perpetual cash flow, discounted by an interest rate adjusted for expected return growth and policy risk. The quota valuation model takes a similar form, but discounts dairy producer utility as defined in [2] instead of expected returns. This approach accounts for the potential effect of income volatility risk on quota value through the risk premium. The quota valuation model is:

[14] $QV = \frac{E(R) - RP}{dr - g - j}$

where: QV = Quota value

E(R) = P - MC

RP = $\frac{r}{2} \cdot Var(R)$

dr = Discount rate

g = Expected return growth

j = Policy risk

Utility is treated as a perpetual cash flow to be received for an infinite time horizon, and is discounted by an interest rate adjusted for expected return growth and policy risk. The quota valuation model guides the construction of the econometric models for the empirical analysis.

Chapter 7: Empirical Analysis

7.1 Introduction

The quota valuation model establishes the theoretical relationship between quota value and its potential determinants, including income volatility risk through the risk premium. The purpose of this chapter is to develop econometric models, with reference to the established theoretical framework, for estimation using a chosen estimation approach and dataset. Several econometric models that differ by their specified explanatory variables are estimated under the OLS and GLS approaches. A dataset of the Ontario dairy industry is applied to the econometric models to determine the relationship between quota value and income volatility risk. The results of the regressions are compared to determine which specification best explains quota valuation of dairy producers. The first regression takes the simplest form by regressing quota value by the discounted flows of expected returns and risk premiums. The second regression adds a policy risk dummy variable to the model, where the variable takes a value of zero when policy risk is not present, and one when it is present, and dairy producers may believe that future policy changes could reduce their future returns. An upward time trend is also added to the model as an explanatory variable to account for technological change, and to mitigate the potential of spurious regression results. Although an expected return growth rate variable is included in the quota valuation model, it is not included in the econometric models for estimation. The net returns data collected for this analysis does not display any significant upward trend over the time series. Therefore, it is unlikely that Ontario dairy producers would expect a long term growth in net returns after observing their past realized returns. The third regression replaces the discounted flows of expected returns and risk premiums with the non-discounted values of these variables. Non-discounted variables are included in the third regression to compare against the results of the first two regressions that used discounted values.

Linear econometric models are constructed to estimate the economic relationships between quota value and the potential determinants using a historical dataset from the Ontario dairy industry. Ontario was selected for the empirical analysis because of its data availability pertaining to dairy producer returns, relative to other Canadian dairy producing provinces, and the volume of quota that has traded on past Ontario quota exchanges. Selecting Ontario for the empirical analysis allows for a larger dataset for estimation. The parameters of the econometric models are first estimated using the OLS approach. First, the econometric models are developed and the models' assumptions are listed. Second, the dataset is described. Each variable is described in detail, including how the variables are measured, and the source used to collect data on each variable. Third, prior to estimation, the dataset is tested for nonstationarity. Quota value, the discounted flows of expected returns and risk premiums, non-discounted expected returns, and the non-discounted risk premium variables are each tested for nonstationarity prior to estimating the econometric models to ensure reliable regression results. Once tests for nonstationarity are conducted, the parameters are estimated using the OLS approach, which uses the OLS estimators to minimize the sum of squares of the disturbance terms. Initial results are discussed, including the significance of the estimated coefficients in each regression, and adjusted R-squared values are reported and compared. After conducting the OLS regressions, tests for autocorrelation and heteroskedasticity are carried out to determine if these econometric problems are present in the models. Breusch-Godfrey tests are conducted to determine whether first-order autocorrelation is present in the models. Breusch-Pagan tests and White tests are conducted for each model to determine whether heteroskedasticity is present. Endogeneity, or the collinearity between explanatory variables and the error term, is another potential econometric problem that can result in inconsistent estimators. It is not tested for in this empirical analysis because it is unlikely that the explanatory variables' values are determined jointly with the dependent variable, quota value. Expected returns and the risk premium values are determined based on historical return and income variability observations respectively, whereas quota value is determined in the current period. Policy risk is specified as a dummy variable and technological change is an upward time trend, both of which are assigned values that are independent of quota values. The econometric models are re-estimated using the GLS estimation approach, as these estimators have the lowest variances of all linear unbiased estimators when autocorrelation is present. The GLS regression results are evaluated in detail. Hypothesis tests are conducted to determine the statistical significance of the estimated parameters associated with each explanatory variable. Finally, inferences about the true relationships between quota value and the explanatory variables are drawn from the estimated relationships obtained from the econometric models. The estimated relationship between quota value and income volatility risk is evaluated in detail. The results of this empirical analysis may provide information about what factors influence quota values in the Canadian dairy industry, the magnitude of quota value responses to changes in the explanatory variable values, whether income volatility risk is a determinant of quota value, and how quota values would respond to changing risk conditions.

7.2 Econometric Models

The econometric models are specified as multiple linear regression models, where quota value is the dependent variable. The first econometric model is based on a simple version of [14] in the theoretical model and includes the discounted flows of expected returns and risk premiums as explanatory variables:

[15] $$QV_t = \beta_1 + \beta_2 \cdot x_{2t} + \beta_3 \cdot x_{3t} + e_t$$

where: x_2 = Discounted expected returns

x_3 = Discounted risk premiums

e_t = Disturbance term

The second econometric model builds on [15] by adding the policy risk and technological change variables:

[16] $$QV_t = \beta_1 + \beta_2 \cdot x_{2t} + \beta_3 \cdot x_{3t} + \beta_4 \cdot x_{4t} + \beta_5 \cdot x_{5t} + e_t$$

where: x_4 = Policy risk

x_5 = Technological change

The third econometric model replaces the discounted flows of expected returns and risk premiums with the non-discounted values of these variables:

[17] $$QV_t = \beta_1 + \beta_6 \cdot x_{6t} + \beta_7 \cdot x_{7t} + \beta_4 \cdot x_{4t} + \beta_5 \cdot x_{5t} + e_t$$

where: x_6 = Non-discounted expected returns

x_7 = Non-discounted risk premiums

The betas (β_k) associated with the explanatory variables are the true parameters that represent the economic relationships between quota value and each explanatory variable. These true parameter values are unknown, and are estimated using the OLS and GLS econometric approaches, and the data series from the Ontario dairy industry. The econometric models include assumptions about the disturbance term, which include normality, zero covariance between any two disturbance term observations, a constant disturbance term variance, and an expected disturbance value of zero (Hill et al. 2001).

This empirical analysis separates the expected return, as defined in the quota valuation model, into two variables: the difference between price and marginal cost, and the risk premium. This allows for an explicit measurement of the estimated effect of income volatility risk on quota value with the least squares estimate of the coefficient associated with the risk premium.

7.3 Data

The data used for the empirical analysis was gathered from the Ontario dairy industry as monthly observations for the period October 1990 to July 2009 (226 observations). Ontario implemented the quota price cap policy on its quota exchange in August 2009, therefore quota values were not determined purely by market forces beyond this date. Ontario quota value observations were collected from the Dairy Farmers of Ontario – Dairy Statistical Handbooks, and are applied to the econometric models to represent the dependent variable. Quota values were measured in the dairy statistical handbooks in dollars per kilogram ($/kg), and were converted to dollars per hectolitre ($/hl) for the data series in the empirical analysis.

Data for the expected returns were collected from the Dairy Farmers of Ontario – Dairy Statistical Handbooks and the Ontario Dairy Farm Accounting Projects (ODFAP). Revenues ($/hl) were collected from the dairy statistical handbooks, which are defined as gross revenues less transportation costs, administration costs, promotion costs, and Ontario Dairy Heard

Improvement Corporation (ODHIC) fees[4]. Cost data were collected from the ODFAP reports and used as an estimate for marginal costs. This proxy for marginal cost was computed as the sum of total direct expense, total crop expense, total indirect and overhead expenses, and total dairy livestock purchases, all measured in dollars per hectolitre ($/hl). The marginal cost estimate was deducted from revenue to calculate returns that are used as a proxy of the margin between producer price and marginal cost. Revenues from the Ontario statistical handbooks were used in place of P5 blend prices because of its larger dataset. The return data series was used to derive an expected return data series for the empirical analysis. Ontario dairy producers are assumed to form their expectations based on a weighted average approach by observing the past three return observations, and assigning weights to each. The weights are chosen to be 0.5, 0.33, and 0.17 to represent a declining impact on the return average for observations further in the past (Coyle 1992). The weighted average calculation determines the current period expected return.

The risk premium is calculated as the product of one-half the risk preference parameter and variance of returns. The risk premium includes two measures: the dairy producer risk preference parameter and a measure of income volatility risk. A CARA coefficient is selected to represent dairy producer risk preferences. Following Rude and An (2013), a CRRA coefficient of 4 is chosen, and is divided by dairy producer returns to convert the risk preference parameter to a CARA coefficient. Income volatility risk is measured for dairy producer returns using a variance approach that assigns weights to the past three prediction errors of expected returns. The weights that are assigned to the last three prediction errors are 0.5, 0.33, and 0.17 respectively (Coyle 1992). This declining weight methodology represents the dairy producer's stronger consideration for more recent observations of income volatility risk.

[4] Ontario dairy statistical handbooks use the term returns (gross and net), but these are treated as revenues for this analysis as production costs were not deducted from these figures.

The interest rate chosen for the empirical analysis is the chartered bank prime business rate (CANSIM 2016), which is used to represent the discount rate in the quota valuation model. The Bank of Canada describes the prime business rate as “the interest rate charged to the most credit-worthy borrowers” (Bank of Canada 2016). This interest rate series was chosen because it is a reasonable representative measure of a dairy producer’s borrowing cost to purchase quota.

Policy risk is represented as a dummy variable that takes a value of one when policy risk is present, and zero when it is not present. The Uruguay Round of negotiations was ongoing from the start of the data series until April 1994, when the agreements were signed. However, the first draft of the “Final Act”, completed by Arthur Dunkel (Director-General of GATT from 1980-1993), was made public in December of 1991 (WTO 2016). This draft was an accurate indication of the policy changes to be made to the Canadian dairy industry. Therefore, policy risk likely diminished with the release of this draft. Policy risk is determined to be present from October 1990 through October 1991, leading up to the completion of the Final Act, and the monthly observations for the policy risk variable are assigned values of one over this time period.

Finally, technological change is measured as an upward time trend over the data series. As discussed in chapter two, Canadian dairy operations have increased in size, and milk output per cow has increased over time. The increasing time trend is included in the empirical analysis for two purposes: to capture the consolidation of dairy farms into larger operations that produce more milk per cow; and to mitigate the potential for spurious results due to nonstationary processeses in the variables. Before tests for potential econometric problems are conducted and estimating the econometric models, summary statistics of key economic variables included in the empirical analysis are presented in figure 7.1:

Figue 7.1 Summary Statistics of Key Variables

Variable	Mean	Standard Deviation	Min	Max
Quota Value ($/hl)	196.18	58.59	58.29	297.96
Discounted Expected Returns ($/hl)	259.63	85.76	116.91	674.455
Discounted Risk Premiums	168.95	193.41	0.7868	1215.50
Non-discounted Expected Returns ($/hl)	14.79	3.25	8.32	22.84
Non-discounted Risk Premiums	9.20	10.29	0.077	82.04

7.4 Tests for Nonstationarity

Prior to estimating the econometric models in [15], [16], and [17], it is necessary to test for nonstationarity of certain time series variables included in the models. Estimating the models with nonstationary variables can lead to spurious regression results (Hill et al. 2001). Five variables are tested for nonstationarity: Quota value (QV), discounted expected returns (x_2), discounted risk premiums (x_3), non-discounted expected returns (x_6), and non-discounted risk premiums (x_7) . Augmented Dickey-Fuller tests, with constant and trend, are conducted for each of these variables to determine whether unit roots are present. One-period autoregressive models (AR(1) models), with constant and trend, are specified for these five variables to represent the relationship between the current and last period observations. The AR(1) models for each variable are presented below:

[18] $\Delta QV_t = \alpha_0 + \alpha_1 t + \gamma QV_{t-1} + v_t$

[19] $\Delta x_{2t} = \alpha_2 + \alpha_3 t + \theta x_{2t-1} + u_t$

[20] $\Delta x_{3t} = \alpha_4 + \alpha_5 t + \delta x_{3t-1} + w_t$

[21] $\Delta x_{6t} = \alpha_6 + \alpha_7 t + \varepsilon x_{6t-1} + y_t$

[22] $\Delta x_{7t} = \alpha_8 + \alpha_9 t + \pi x_{7t-1} + z_t$

where:

[23] $\gamma = \rho_1 - 1$

[24] $\theta = \rho_2 - 1$

[25] $\delta = \rho_3 - 1$

[26] $\varepsilon = \rho_6 - 1$

[27] $\pi = \rho_7 - 1$

ρ_i represents the correlation between the current and last period observations. The dependent variables of the AR(1) models are the first differences of quota value, discounted expected returns, the discounted risk premium, non-discounted expected returns, and the non-discounted risk premiums respectively. The AR(1) models each include a constant, a time-trend variable, a one-period lagged variable, and a disturbance term with zero mean and constant variance. The hypothesis tests for unit roots, or nonstationarity, are:

[28] $H_0: \gamma = 0$ vs $H_1: \gamma < 0$

[29] $H_0: \theta = 0$ vs $H_1 : \theta < 0$

[30] $H_0 : \delta = 0$ vs $H_1: \delta < 0$

[31] $H_0 : \varepsilon = 0$ vs $H_1: \varepsilon < 0$

[32] $H_0 : \pi = 0$ vs $H_1: \pi < 0$

Equations [28], [29], [30], [31], and [32] are estimated using the OLS approach to obtain tau-statistics (τ), which are compared to τ-critical values at 5% and 10% significance levels. Rejection of a null hypothesis suggests that the variable time series is stationary. Failure to reject a null hypothesis suggests the variable time series is nonstationary, and a unit root is present. The results of the Augmented Dickey-Fuller tests, with constant and trend, are presented in figure 7.2:

Figure 7.2 Results of Augmented Dickey-Fuller Tests, with Constant and Trend

Variable	Tau-Statistic	Tau Critical Value – 5% Significance Value	Tau Critical Value – 10% Significance Value	Test Result
Quota Value (QV)	-17.460	-2.882	-2.572	Reject H_0
Discounted Expected Returns (X_2)	-12.627	-2.882	-2.572	Reject H_0
Discounted Risk Premiums (X_3)	-14.506	-2.882	-2.572	Reject H_0
Non-Discounted Expected Returns (X_6)	-11.120	-2.882	-2.572	Reject H_0
Non-Discounted Risk Premiums (X_7)	-14.442	-2.882	-2.572	Reject H_0

The Augmented Dickey-Fuller tests, with constant and trend, for all five variables result in rejection of the null hypothesis, which implies that the variables follow a stationary process, and do not contain unit roots. Therefore, these variables can be included in the econometric models for estimation without taking first-differences.

The econometric models in [15], [16], and [17] are first estimated using the OLS approach. An initial analysis of the OLS regression results is conducted through hypothesis tests to determine the statistical significance of the OLS parameter estimates. After this initial analysis, the residuals are obtained to test for first-order autocorrelation and heteroskedasticity. Two assumptions of the econometric models are that the covariance of any two error terms is zero, and that each error term has the same variance. These assumptions are violated if autocorrelation and heteroskedasticity are present in the models. Autocorrelation and heteroskedasticity can be represented by the following equations:

[33] Autocorrelation: $\mathrm{cov}(e_t, e_s) \neq 0$

[34] Heteroskedasticity: $\mathrm{var}(e_t) = \sigma_t^2$

Autocorrelation and heteroskedasticity lead to least squares estimators with larger variances that are not the best linear unbiased estimators (Hill et al. 2001). Also, the standard errors for the least squares estimators will be incorrect, leading to inaccurate confidence intervals and hypothesis tests (Hill et al. 2001).

7.5 Ordinary Least Squares Estimation Results

The econometric models are first estimated using the OLS approach. Equation [15] is estimated first, and includes the discounted flows of expected returns and risk premiums as explanatory variables. The regression results are reported in figure 7.3:

Figure 7.3 OLS Regression Results - 1

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value	t-critical value (5%) significance level
Discounted Expected Returns (X_2)	0.0939	0.0440	0.0377	2.49	0.013	±1.97
Discounted Risk Premiums (X_3)	0.0836	0.0195	0.0208	4.02	0.000	±1.97

The discounted flows of expected returns and risk premiums are statistically significant at the 5% significance level, however, the discounted risk premiums have a positive value, which is an unexpected sign based on economic theory. An inverse relationship, represented by a negative coefficient, would be expected, as risk averse producers would potentially decrease their bid values or increase the quantity of quota to be sold on quota exchanges in response to an increase in income volatility risk.

Equation [16] expands on [15] by adding the policy risk and technological change variables. The estimation results are reported in figure 7.4:

Figure 7.4 OLS Regression Results - 2

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value	t-critical value (5%) significance level
Discounted Expected Returns (X_2)	-0.0951	0.0187	0.0136	-7.02	0.000	±1.97
Discounted Risk Premiums (X_3)	0.0059	0.0082	0.0083	0.71	0.480	±1.97
Policy Risk (X_5)	-21.45	7.1082	7.8502	-2.73	0.007	±1.97
Technological Change (X_6)	0.8256	0.0265	0.0283	29.18	0.000	±1.97

Discounted expected returns, policy risk, and technological change are statistically significant at the 5% significance level, but discounted risk premiums are found to be statistically insignificant. Also, the estimated coefficient associated with discounted expected returns has a negative value, which does not coincide with the theoretical relationship between expected returns and quota value. As expected returns increase, it is expected that dairy producers would respond on quota exchanges by increasing their bid values to buy quota and/or decrease the supply of quota available on the quota exchange.

The third regression estimates equation [17], and replaces the discounted flows of expected returns and risk premiums with the non-discounted values of these variables. Policy risk and technological change remain as explanatory variables for this regression. The estimation results are reported in figure 7.5:

Figure 7.5 OLS Regression Results - 3

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value	t-critical value (5%) significance level
Non-Discounted Expected Returns (X_7)	-3.62	0.5092	0.4818	-7.50	0.000	±1.97
Non-Discounted Risk Premiums (X_8)	-0.0429	0.1395	0.1309	-0.33	0.7433	±1.97
Policy Risk (X_5)	-18.60	6.71	7.05	-2.64	0.009	±1.97
Technological Change (X_6)	0.7024	0.0278	0.0328	21.44	0.000	±1.97

Non-discounted expected returns, policy risk, and technological change are statistically significant at the 5% significance level. The non-discounted risk premium is statistically insignificant, and non-discounted expected returns has an unexpected sign that does not coincide with the theoretical positive relationship.

Adjusted R-squared is a measure of variation in the dependent variable about its sample mean that is explained by the regression, relative to the total variation in the dependent variable about its sample mean (Hill et al. 2001). It is an indication of how well the regression model explains the variability in the dependent variable about its mean. An increasingly large R-squared figure indicates that the variability of the dependent variable about its mean is attributed more by the regression model rather than the random components of the residuals. Figure 7.6 reports the adjusted R-squared figures for the three OLS regressions.

Figure 7.6 OLS Adjusted R-Squared Results

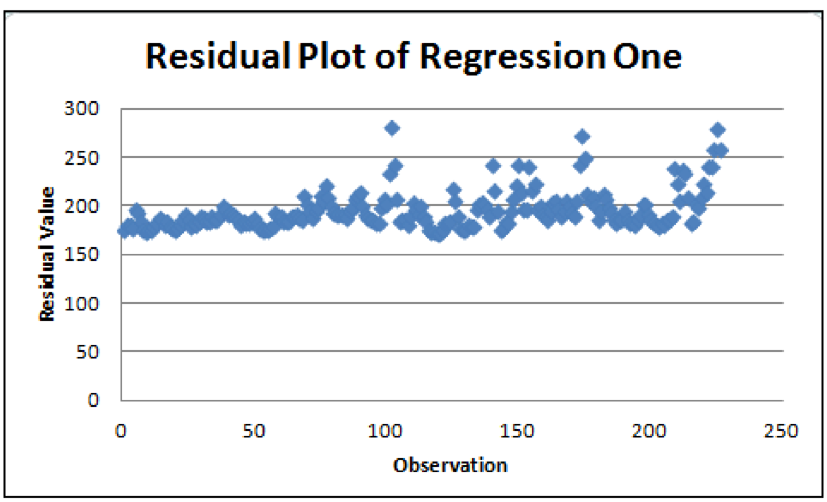
OLS Regression Model	Adjusted R-Squared
1	0.1020
2	0.8580
3	0.8790

The adjusted R-squared results increased substantially for OLS regressions two and three relative to OLS regression one, as the policy risk and technological change variables were added as explanatory variables. The OLS regression three has the highest R-squared value, which suggests that it has the highest relative explanatory ability of the variability in quota value about its mean. It means that 87.9% of the variability in quota value around its mean can be explained by the variation in the explanatory variables of OLS regression three.

7.6 Tests for Potential Econometric Problems and GLS Estimation

Prior to evaluating the regression results further, the residuals are obtained from the regressions to test for autocorrelation and heteroskedasticity. It can be helpful to analyze a residual plot before tests are conducted to visually identify the potential presence of autocorrelation and heteroskedasticity. Figure 7.7 is a plot of the residuals from OLS regression one.

Figure 7.7 Residual Plot



The residual plot shows the residuals generally take on consistent values, and are not randomly scattered. A notable trend in the residuals may indicate the presence of autocorrelation. This plot shows that subsequent residuals generally take on values similar to their previous observations, which may be due to correlated residuals. Therefore, the presence of autocorrelation cannot be ruled out by this plot, and formal tests are conducted to determine whether autocorrelation is present in each regression model. Furthermore, the residuals are more spread out for the most recent observations, which may indicate the presence of heteroskedasticity. Therefore, formal tests are also conducted to determine whether heteroskedasticity is present in each regression model.

The Breusch-Godfrey test for first-order autocorrelation is conducted to determine if current period error terms are correlated with the one-period lagged error terms. The test statistic is compared to the appropriate chi-square critical value to determine whether to reject or fail to reject the null hypothesis of no first-order autocorrelation. The null and alternative hypotheses for the test are:

[35] $H_0: \rho = 0$ vs $H_1: \rho \neq 0$

Failure to reject the null hypothesis would lead to the inference that first-order autocorrelation is not present in the model. The results of the Breusch-Godfrey tests, at a 5% significance level, for each of the three models are provided in Figure 7.8:

Figure 7.8 Breusch-Godfrey Test Results for Autocorrelation

Model	Chi-Square Test Statistic	Degrees of Freedom	Chi-Square Critical Value	Test Conclusion
[15]	194.537	1	3.841	Reject H_0
[16]	127.942	1	3.841	Reject H_0
[17]	118.807	1	3.841	Reject H_0

The test conclusions for autocorrelation in each of the three models is to reject the null hypothesis, and conclude that first-order autocorrelation is present. OLS estimation is not an appropriate estimation method in the presence of autocorrelation, as the OLS estimators are no longer best (they do not have minimum variances), and the standard errors are incorrect (Hill et al. 2001). Alternatively, the econometric models are re-estimated using the GLS approach, which estimates the models with transformed explanatory variables. Estimation using the GLS approach provides for least squares estimators that have minimum variances for large sample sizes.

Two tests are conducted to determine if heteroskedasticity is inherent in the models: the Breusch-Pagan test and White test. The Breusch-Pagan test is conducted for each econometric model in [15], [16], and [17] to determine if heteroskedasticity is present in the models with the form (Johnston and DiNardo 1997):

[36] $\sigma_t^2 = Ee_t^2 = h(Z_t\ \alpha)$

Z_t is a vector of chosen variables for the test, and α is the vector of their associated coefficients (Johnston and DiNardo 1997). Z_t includes all the explanatory variables of the econometric model for which the test is being conducted. The null and alternative hypotheses are:

[37] H_0: $\sigma_t^2 = \alpha_1$ = constant vs $H_{1:}$ $\sigma_t^2 \neq \alpha_1$

Acceptance of the null hypothesis implies that the error variance is a constant, and the model has homoskedastic errors. If the null hypothesis is rejected, the error variance is not constant because it varies with the explanatory variables contained in $Z_{t,}$, and the model's errors are determined to be heteroskedastic. The results of the Breusch-Pagan tests are contained in figure 7.9:

Figure 7.9 Breusch-Pagan Test Results for Heteroskedasticity

Model	Chi-Square Test Statistic	Degrees of Freedom	Critical Value (5% significance)	Result	Conclusion
[15]	2.98	2	5.991	Fail to reject H_0	Heteroskedasticity is not present in the model.
[16]	19.96	4	9.488	Reject H_0	Heteroskedasticity is present in the model.
[17]	14.86	4	9.488	Reject H_0	Heteroskedasticity is present in the model.

The Breusch-Pagan test results suggest that heteroskedasticity in the form specified in [36] is present in econometric models [16] and [17]. The estimated standard errors of these models will not be best under OLS regression. Therefore, robust standard errors are reported in the regression results for these models.

The White test also consists of an auxiliary regression that specifies the squared errors as the dependent variable, and the explanatory variables , their squares, and cross products as the regressors (Johnston and DiNardo 1997). The null and alternative hypotheses for the White test are as follows:

[38] $H_0: \sigma_t^2 = \sigma^2$ vs $H_1: \sigma_t^2 \neq \sigma^2$

The null and alternative hypotheses represent homoskedasticity and heteroskedasticity respectively. The results of the White test for heteroskedasticity for models [15], [16], and [17] are reported in figure 7.10:

Figure 7.10 White Test Results for Heteroskedasticity

Model	Chi-Square Test Statistic	Degrees of Freedom	Critical Value	Result	Conclusion
[15]	7.79	5	11.07	Fail to reject H_0	Heteroskedasticity is not present in the model.
[16]	26.72	13	22.36	Reject H_0	Heteroskedasticity is present in the model.
[17]	33.94	13	22.36	Reject H_0	Heteroskedasticity is present in the model.

The White test results suggest that heteroskedasticity is present in models [16] and [17], which is consistent with the Breausch-Pagan test results. These test results confirm that robust standard errors should be reported in the regression results for models [16] and [17], and used for hypothesis testing.

Given that autocorrelation is inherent in econometric models [15], [16], and [17], the models are re-estimated using GLS, which provides more accurate hypothesis testing, including tests for coefficient significance, because the GLS estimators have the smallest variances and standard errors of all linear, unbiased estimators. The GLS estimation results for econometric models [15], [16] and [17] are provided in figures 7.11, 7.12, and 7.13 respectively:

Figure 7.11 GLS Regression Results - 1

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value
Discounted Expected Returns (X_2)	0.0032	0.0373	0.0351	0.09	0.932
Discounted Risk Premium (X_3)	-0.0027	0.0066	0.0052	-0.41	0.683

Figure 7.12 GLS Regression Results - 2

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value
Discounted Expected Returns (X_2)	-0.0452	0.0306	0.0276	-1.48	0.142
Discounted Risk Premium (X_3)	-0.0043	0.0066	0.0051	-0.65	0.514
Policy Risk (X_4)	-6.2354	12.1067	16.4857	-0.52	0.607
Technological Change (X_5)	0.8427	0.0668	0.0663	12.62	0.000

Figure 7.13 GLS Regression Results - 3

Explanatory Variable	Estimated Coefficient	Standard Error	Robust Standard Error	t-statistic	P-value
Non-Discounted Expected Returns (X_6)	-1.4604	0.8370	0.7471	-1.74	0.082
Non-Discounted Risk Premium (X_7)	-0.1107	0.1224	0.1070	-0.90	0.367
Policy Risk (X_4)	-6.6501	11.8947	15.6106	-0.56	0.577
Technological Change (X_5)	0.7765	0.06589	0.0675	11.79	0.00

The adjusted R-squared for each of the three GLS regressions are reported in figure 7.14 to compare each regression's ability to explain the variability of quota value about its mean.

Figure 7.14 GLS Adjusted R-Squared Results

GLS Regression Model	Adjusted R-Squared
1	-
2	0.3863
3	0.4216

The adjusted R-squared figures for the three GLS regressions are relatively low as compared to the previous OLS adjusted R-squared results. A measure was not reported by the GLS regression one analysis of variance results, and the GLS regression two and three figures do not indicate high explanatory ability of the variation in quota value about its mean by these regressions. Only 38.63% and 42.16% of the variation of quota value is explained by the variability of the explanatory variables contained in these models.

7.7 Evaluation of Estimation Results

Significance tests are conducted for each explanatory variable in the regressions to determine whether statistically significant relationships exist with quota value. The general hypothesis test that is applied for each explanatory variable's parameter is:

[39] H_0: $\beta_k = 0$ vs. H_1: $\beta_k \neq 0$

The null hypothesis (H_0) postulates that the true parameter value is zero, whereas the alternative hypothesis (H_1) suggests that the true parameter value does not equal zero. If H_0 is accepted, the test concludes that a statistically significant relationship does not exist between quota value and the explanatory variable (x_i). Alternatively, if H_0 is rejected and H_1 is accepted, the test concludes that a statistically significant relationship exists, and the estimated parameter may be used to draw inferences about the true relationship between quota value and the particular explanatory variable.

The t-statistics and t-critical values are obtained from the t-distribution for n-k degrees of freedom at a 5% significance level, where n is the number of sample observations and k is the number of parameters in the econometric model associated with explanatory variables to be estimated. Two tailed tests are conducted by comparing the t-statistic for each variable to the positive and negative values of the t-critical value. The hypothesis test results for regressions one through three are presented in figures 7.15, 7.16, and 7.17 respectively.

Figure 7.15 Hypothesis Test Results – Regression 1

Explanatory Variable	t-statistic	t-critical value	Test Conclusion
Discounted Expected Returns (X_2)	0.09	±1.97	Fail to reject H_0
Discounted Risk Premiums (X_3)	-0.41	±1.97	Fail to reject H_0

Figure 7.16 Hypothesis Test Results – Regression 2

Explanatory Variable	t-statistic	t-critical value	Test Conclusion
Discounted Expected Returns (X_2)	-1.48	±1.97	Fail to reject H_0
Discounted Risk Premiums (X_3)	-0.65	±1.97	Fail to reject H_0
Policy Risk (X_4)	-0.52	±1.97	Fail to reject H_0
Technological Change (X_5)	12.62	±1.97	Reject H_0

Figure 7.17 Hypothesis Test Results – Regression 3

Explanatory Variable	t-statistic	t-critical value	Test Conclusion
Non-Discounted Expected Returns (X_6)	-1.74	±1.97	Fail to reject H_0
Non-Discounted Risk Premiums (X_7)	-0.90	±1.97	Fail to reject H_0
Policy Risk (X_4)	-0.56	±1.97	Fail to reject H_0
Technological Change (X_5)	11.79	±1.97	Reject H_0

The discounted flows of expected returns and risk premiums were found to be statistically insignificant at the 5% significance level in regressions one and two. The non-discounted values of these variables were also determined to be statistically insignificant at the 5% level in regression three. Policy risk was statistically insignificant in regressions two and three, and technological change was found to be statistically significant in regressions two and three.

These results indicate that, given the specified econometric model, dataset, and GLS estimation procedure, expected returns (discounted and non-discounted), risk premiums (discounted and non-discounted), and policy risk do not explain quota values on the Ontario dairy quota exchange from October 1990 through July 2009. Since these estimated coefficients are statistically insignificant, their values are not interpreted to explain their estimated relationship with quota value. The risk premium significance test results suggest that, under the econometric methods and dataset used in the empirical analysis, there is no statistical evidence that income volatility risk impacted quota values on the Ontario dairy quota exchange throughout this time period. This conclusion is dependent on the specification of the econometric models, the data collected, the measurement of risk and expected returns, and the estimation procedure.

Chapter 8: Conclusion

The objective of this thesis was to determine the effect of income volatility risk on dairy quota values. A quota valuation model was used to represent the relationship between quota value and several explanatory variables. The risk premium was included in the quota valuation model as an explanatory variable to describe the relationship between quota value and income volatility risk. It was specified to account for dairy producer risk preferences and a measure of income volatility risk. An econometric approach was employed to estimate the relationship between quota value and the selected explanatory variables, including expected returns and risk premium cash flows (both discounted and non-discounted versions), policy risk, and technological change. The empirical analysis was applied to the Ontario dairy industry, where monthly data was collected for the period October 1990 through July 2009. Three linear regressions were estimated using the OLS approach, the initial results were examined, and the residuals were collected to test for autocorrelation and heteroskedasticity. Econometric model [15] regressed quota value on the discounted flows of expected returns and risk premiums. Econometric model [16] built on [15] by including a policy risk dummy variable and a time-trend variable representing technological change. Econometric model [17] adjusted [16] by replacing the discounted flows of expected returns and risk premiums with their non-discounted values. The purpose of estimating three different econometric models was to compare the estimated results to determine which specification best explained quota valuation on monthly Ontario quota exchanges. In OLS regression one, the estimated coefficients of the discounted flows of expected returns and risk premiums were found to be statistically significant at the 5% significance level. The statistical significance of the latter estimated coefficient is evidence of a potential relationship between quota value and income volatility risk. However, the sign of the coefficient suggests a positive relationship between quota value and income volatility risk, which does not coincide with the theoretical relationship established in the quota valuation model. It is expected that an increase in income volatility risk would cause quota values to decrease, and vice versa. In OLS regressions two and three, the discounted and non-discounted quota risk premium was statistically insignificant, respectively. Discounted and non-discounted expected returns were statistically significant, but had unexpected negative signs. Policy risk and technological change were statistically significant for regressions two and three. Adjusted R-squared values were obtained from each OLS regression to determine how each regression explains the variation in quota value about its mean. OLS regression three reported the largest R-squared value, which suggests that this model best explains the variation in quota value about its mean. Also, the R-squared increased significantly when the policy risk and technological change variables were added.

A Breusch-Godfrey test was conducted for each model to determine whether first-order autocorrelation was present. These tests concluded that first-order autocorrelation was present in each model. Breusch-Pagan tests and White tests were conducted to determine whether heteroskedasticity was present in the model. These tests concluded that heteroskedasticity was present in econometric models [16] and [17], and robust standard errors were reported for hypothesis testing. Given the presence of autocorrelation in econometric models [15], [16], and [17], all were re-estimated under the GLS approach which utilized GLS estimators that have minimum variances and standard errors of all linear unbiased estimators. Hypothesis tests were conducted to determine the statistical significance of each explanatory variable and their associated estimated parameters. All three regressions under GLS concluded that expected returns and risk premium flows (discounted and non-discounted), and policy risk were statistically insignificant at the 5% significance level. Technological change was the only explanatory variable found to be statistically significant under the GLS estimation approach. These empirical results do not coincide with the theoretical framework presented in chapter six. Economic theory suggests that quota value would be driven by dairy producers' expected future returns, and potentially risks associated with these expected returns, including income volatility risk and policy risk. However, the estimation techniques and chosen dataset utilized in this thesis do not provide empirical evidence of these theoretical relationships. The adjusted R-squared values collected from the GLS regressions included a null value for GLS regression one, and relatively low values for GLS regression values two and three. These regressions did not explain the variation in quota value about its mean well.

A secondary objective of this thesis was to use the estimated coefficients of the econometric models to predict quota value responses to changes in income volatility risk under hypothetical scenarios involving U.S. and EU farm-level milk prices, where U.S and EU prices would present different risk levels for Canadian dairy producers. Since the relationship between quota value and income volatility risk was found to be insignificant or had unexpected signs, predictions under these scenarios were omitted from the empirical results.

This thesis estimated econometric models using the OLS and GLS approaches and Ontario dairy industry data. Different approaches may have led to alternative results. First, the functional form assumed in econometric models [15], [16], and [17] may not represent the true functional form of quota value and its explanatory variables. Different model specifications may produce different results. Second, data from the Ontario dairy industry was used to estimate the econometric models. Ontario provides the most data observations on quota values and dairy producer returns compared to all other Canadian provinces, but only data prior to the implementation of the quota price cap policy was useful for the empirical analysis. An empirical analysis of quota values and income volatility risk using a more recent dataset may reach different conclusions. Third, income volatility risk and expected returns were calculated using a weighted-average approach of past observations to estimate how dairy producers calculate these measures. This approach is thought to be a reasonable approximation of how dairy producers form their expectations and risk measures. However, dairy producers may formulate their risks and expected returns using a different approach, and alternative measures of income volatility risk and expected returns could generate alternative results.

The theoretical framework developed in this thesis, and the empirical results, attempted to provide information about the factors that influence Canadian dairy quota values, and the contribution of risk to quota values established on quota exchanges. These methods could be used in future research of quota values and/or risk analyses. The quota valuation and econometric models can be expanded or replaced with other potential explanatory variables of quota value. Finally, the risk premium may be applied to other empirical models to capture potential effects of risk on producer behaviour in other agricultural markets.

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Appendix

An additional econometric model was estimated to determine the effect of seasonality on quota value. Winter, spring, and summer dummy variables were included in the model to represent particular seasons. The winter dummy variable was assigned a value of one for December, January, and February, and zero for all other months. The spring dummy variable was assigned a value of one for March, April, and May, and zero otherwise. Finally, the summer dummy variable was assigned a value of one for June, July and August, and zero for all other months. These dummy variables and their associated estimated coefficients were compared to the fall season variable, which was omitted to avoid exact collinearity between the seasonal dummies. This model also used an alternative method to calculate expected returns, which were defined to be the last period's realized return. The risk premium calculation also incorporated this alternative expected return method. An upward time trend variable was included to account for technological change and to mitigate potential spurious results. The econometric model was defined as:

$$QV_t = \beta_1 + \beta_2 \cdot x_{2t} + \beta_3 \cdot x_{3t} + \beta_4 \cdot x_{4t} + \beta_5 \cdot x_{5t} + \beta_6 \cdot x_{6t} + \beta_7 \cdot x_{7t} + e_t$$

where: x_{2t} = Expected returns

x_{3t} = Risk Premium

x_{4t} = Winter dummy variable

x_{5t} = Spring dummy variable

x_{6t} = Summer dummy variable

x_{7t} = Technological change

This model was estimated using the OLS approach, and the regression results are provided in the table below:

Appendix OLS Regression Results:

Explanatory Variable	Estimated Coefficient	Standard Error	t-statistic	t-critical value (5%) significance level
Discounted Expected Returns (X_2)	-3.27	0.50	-6.51	±1.97
Discounted Risk Premiums (X_3)	-0.07	0.11	-0.64	±1.97
Winter dummy variable (X_4)	4.42	4.05	1.09	±1.97
Spring dummy variable (X_5)	9.40	4.16	2.26	±1.97
Summer dummy variable (X_6)	-0.875	4.16	-0.21	±1.97
Technological change (X_7)	0.74	0.03	28.82	±1.97

Significance tests of the estimated coefficients followed the general null and alternative hypotheses:

H_0: $\beta_k = 0$ vs. H_1: $\beta_k \neq 0$

The estimated results suggest that the discounted risk premiums are statistically insignificant at the 5% significance level. Discounted expected returns were statistically significant, but the estimated coefficient was negative, which suggests an inverse relationship between quota value and expected returns. This is inconsistent with economic theory, which suggests that quota value is expected to increase in response to an increase in expected returns, and vice versa. The spring variable was the only dummy variable that was tested to be statistically significant. The positive estimated coefficient suggests that quota values are, on average, higher during the spring months relative to the fall months, all else being equal. Finally, the technological change variable was determined to be statistically significant.