Between a Cap and a Higher Price: Modeling the Price of Dairy Quotas under Price Ceiling Legislation

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Abstract

This paper considers various policy alternatives to price ceiling legislation in the market for production quotas in the dairy farming sector in Quebec. I develop a model of farmers’ demand for quotas and estimate a structural parameter that is required for the counterfactual experiments. Using my econometric results and the modeled equilibrium price, I estimate the price of dairy quotas over the period 1993-2011. The counterfactual experiments indicate that the price of quotas could be reduced to the ceiling price through a 4.16 percent expansion of the aggregate supply of quotas, or through moderate trade liberalization of Canadian dairy products.

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1 Introduction

After four decades, the Canadian dairy supply management system is burgeoning on crisis. The Trans-Pacific Partnership (TPP) negotiations and the Canada-European Union Comprehensive Economic and Trade Agreement (CETA) have increased pressure on Canada to reform its supply managed sectors of agriculture. As the industry faces trade liberalization, a recent OECD study highlights the poor economic performance of Canada’s dairy sector relative to the dairy sector in eight other OECD countries, (Kimura and Thi, 2013). While the sector already appears ill-equipped to compete in international markets, recent domestic policy changes in the supply management system are further weakening the sector’s competitive position.

To achieve the objective of providing a “fair” return to farmers,\(^1\) supply management relies on controlling output levels through the use of raw milk production quotas. The exchange of dairy quotas on provincial auctions encourages efficient allocation of dairy quotas across farmers. However, concern over the effect of rising quota prices on the cost of entry and expansion led Canada’s two largest dairy producing provinces, Quebec and Ontario, to implement a cap on the price of quotas in 2007 and 2009 respectively. In Quebec, dairy quotas have traded at the price ceiling (currently at $25,000 per unit) for over three years. With the cap in place, the demand for quotas has greatly exceeded supply, and the auction’s ability to allocate quotas to the most efficient farmers has been significantly compromised.

The extraordinary price of dairy quotas is indicative of the magnitude of the loss in consumer surplus that arises from supply management. The price of dairy quotas reflects the profitability of dairy farming, which is inflated under supply management. In 2011, the value of raw milk was approximately 67% higher in Canada than the United States.\(^2\) Higher farm prices are passed through the supply chain and result in higher consumer prices in Canada. For example, Larue (2012) estimates that average retail milk prices are 44% higher in Canada than in the United States. Higher retail prices result in a substantial reduction in consumer surplus as prior research indicates that consumers’ own-price elasticity of demand is relatively inelastic across most dairy products.\(^3\) Furthermore, Larue (1994) illustrates
that the system is regressive by noting that per capita consumption of dairy products is relatively constant across low and high income households. Therefore supply management imposes a disproportionate burden on the income of lower income households.

In this paper I develop a theoretical model of supply management and use it to analyze several counterfactual experiments that are currently being discussed in the context of policy reform. I begin by modeling farmers’ demand for dairy quotas and derive the equilibrium price contingent on the aggregate supply of quotas. The aggregate supply of quotas is endogenous to the model and is set by an administrator of the supply management system. The administrator has knowledge of farmers’ cost of production and the demand for raw milk, and sets the aggregate supply of quotas to achieve a target level of profits for the average producer. I develop an econometric model to estimate a structural parameter of the model that is required for the counterfactual experiments. This parameter is estimated using farm-level data from the Quebec Federation of Management Clubs’ Agritel database, and a quota price series from the Fédération des Producteurs de Lait du Québec (FPLQ).4

Using my econometric results and Statistics Canada data on the average profit per unit of quota in Quebec, I estimate the equilibrium price of dairy quotas in Quebec for the period 1993 to 2011. The modeled price fits the actual market exchange price well during the pre-price ceiling era. During the years following the introduction of the price ceiling in 2007, the modeled price remains well above the price ceiling. If the price cap were removed, I estimate that dairy quotas in Quebec would trade at a price of $29,923 per unit in 2011, which is 20% above the current ceiling price.

Cairns and Meilke (2012) argue that reducing the farm price of milk is a better means of reducing quota prices than price ceiling legislation. I estimate that lowering the valuation of quotas to $25,000 per unit in 2011 would have required a 9.97% reduction in the farm price of milk. The theoretical model predicts that a decrease in the farm price of milk encourages the exit of small dairy farmers from the industry. I predict that removing the price ceiling and reducing the farm price of milk by 9.97% would result in a 34.6% increase in the minimum viable scale of production.

I consider two policy experiments that could result in a farm price reduction of the magnitude required to reduce quota prices to $25,000 per unit.5 The first policy experi-
gment considers an expansion of the aggregate supply of quotas that is similar to the policy recommendations of Robson and Busby (2010). I predict that a 4.16% increase in production quotas would result in a 9.97% decline in the farm price and reduce the quota price to $25,000 per unit. The second policy experiment considers a specific trade liberalization scenario that is comparable to a moderate outcome to the prospective TPP and CETA agreements. By combining my results with those of Abbassi et al. (2008), I find that a similar drop in the price of dairy quotas in Quebec could be achieved through a 25% reduction in bound tariffs and 50% increase in the MAC, assuming that the aggregate supply of raw milk in Quebec is held constant following trade liberalization.

The ascent of quota prices over the past two decades has sparked a small literature on Canadian dairy quota prices. Examples include Barichello (1996), Chen and Meilke (1998), Turvey et al. (2003), Doyon et al. (2006), and Cairns and Meilke (2012). Of the aforementioned studies, only Cairns and Meilke (2012) address the issue of price ceiling legislation. Cairns and Meilke (2012) use a capital asset pricing model to analyze the recent rise in quota prices, and assess the welfare effects for dairy farmers arising from price ceiling legislation. Cairns and Meilke (2012) argue that the rapid rise in the price of quotas during the late 1990s was the result of two factors. The first factor was a drop in farmers’ perception of the risk of major reform to supply management following the conclusion of the Uruguay Round of multilateral trade negotiations in 1994. The second factor was an improvement in the borrowing conditions facing dairy farmers in the late 1990s. Based on 2007 data from the Ontario dairy quota exchange, Cairns and Meilke (2012) estimate that the deadweight loss from price ceiling legislation is $4.1 million.

There are a number of features that distinguish this paper from Cairns and Meilke (2012) and other research on this topic. My theoretical model captures the interaction between farmers’ optimal demand for quotas and the role of supply management in setting the aggregate supply of quotas. This feature enables counterfactual experiments that are not possible using the asset pricing model of Cairns and Meilke (2012), such as determining the price effect of expanding the aggregate supply of quotas. Another contribution of this paper are my empirical estimates of farmers’ perception of policy risk. Cairns and Meilke (2012) use a calibration exercise and aggregate data from Ontario to estimate policy risk,
whereas I estimate policy risk from farm-level data. My estimates of policy risk are similar to those of Cairns and Meilke (2012). By estimating policy risk from micro-level data, my results provide confirmation that the parameterization used in Cairns and Meilke (2012) is consistent with the behaviour of farms in my sample. Using a micro-founded model also allows me to complete farm-level analysis that is not possible using a capital asset pricing framework. In particular, I estimate the effect of a decrease in the farm price of milk on the exit decisions of small farmers. To the best of my knowledge, this paper is the first to establish linkages between the ceiling price of quotas, the farm price of milk, and trade liberalization. More generally, this model provides a new framework for evaluating future proposals to reform supply management, which is of particular relevance given the current policy environment. Finally, this paper contributes to the broader literature on price ceilings. The empirical studies in this literature focus mainly on cases where price ceilings have been applied to consumer goods and services. In contrast, this paper analyzes the effect regulating the price of an input that constrains the entry and expansion of producers.

The remainder of the paper is organized as follows: Section 2 explains how production quotas are used as part of the supply management system in the Canadian dairy sector. Section 3 presents a model of dairy farmers’ demand for production quotas. Section 4 presents the econometric model, empirical specification, and estimation results. Section 5 includes the counterfactual policy experiments, and Section 6 concludes.

2 Production Quotas, Supply Management, and the Canadian Dairy Sector

There are three main mechanisms used in the system of supply management in the Canadian dairy sector. These three mechanisms include administering the farm price of milk, restricting Canadian imports of dairy products, and setting milk production levels through the use of production quotas. The price Canadian dairy farmers receive for their milk is jointly administered by the Canadian Dairy Commission (CDC) and the provincial marketing boards. The CDC sets support prices for skim milk powder and butter. These support prices guide the provincial marketing boards in setting the prices that processors pay for
raw milk destined for industrial purposes (butter, cheese, yogurt, etc.). The provincial marketing boards also set the price that processors pay for “fluid” milk (table milk and cream). Farmers receive a “blended” price that reflects the various prices paid by processors for the different classes of fluid and industrial milk. Farm-level cost-of-production studies are used to guide the CDC and provincial marketing boards in setting prices at levels that provide a ‘fair’ return to farmers.

Production quotas are administered at the federal and provincial level, and are used to equate supply and demand at the administered price levels. The national marketing sharing quota (MSQ) determines production levels for industrial milk and is set at the federal level and then allocated to each province. In contrast, provincial production levels of fluid milk are determined by provincial marketing boards. Each provinces’ share of the MSQ, together with its provincial fluid milk production level, comprises its total production quota (TPQ). Dairy farmers buy and sell production quotas on provincial quota market exchanges, which are double auctions that operate on a monthly basis. Quotas are exchanged in units of one kilogram of butter fat per day and entitle a farmer to produce in perpetuity. While quotas are bought and sold in units, they are properly understood as shares of the provincial TPQ as individual quota holdings are periodically adjusted on a percentage basis in step with changes to the TPQ.

Figure 1 illustrates that quota prices in Quebec tripled in value between the early 1990s and mid-2000s. A similar ascent in quota prices occurred in Ontario over this same time period. The escalating cost of financing dairy farm entry and expansion led the provincial marketing boards in Quebec and Ontario to introduce a price cap on quotas in 2007 and 2009 respectively. With the price cap limiting the price of quotas, all farmers with a reservation bid above the ceiling price bid for quotas, and there is no market-based mechanism for allocating quotas to the most efficient farmers. As a result, the FPLQ has established rationing rules for distributing available quotas to all farmers that are willing to pay the ceiling price. During the price ceiling era, the demand for quotas has vastly exceeded the quantity of quotas supplied to the quota exchange. For example, on the 2012 monthly quota exchange the quantity of quotas demanded at the price cap was approximately 20 times the quantity supplied. The magnitude of this imbalance between supply and demand is
indicative of the inefficiency that has been created as a result of the price ceiling legislation.

**INSERT FIGURE 1 AROUND HERE**

3 A Model of Dairy Farmers’ Demand for Quotas

In this section I develop a model of dairy farmers’ demand for production quotas. Dairy farmers are assumed to be infinitely lived with preferences over a numeraire consumption good. Farmers face a budget constraint and must allocate resources between units of consumption and units of quota. Each unit of quota entitles the farmer to one share of the TPQ. The timing of the model is such that farmer $i$ enters period $t$ with a quota holding of $q_{i,t}$. The government then announces the aggregate growth rate, $g_t$, of the TPQ, and farmer $i$ is then entitled to produce $\tilde{q}_{i,t} \equiv (1 + g_t)q_{i,t}$ units in period $t$.

Each farmer produces milk using a technology that features constant returns to scale in production quotas. All farmers receive the government administered blended price for milk, $P_{t}^{m}$, but are heterogeneous with respect to their marginal cost of producing milk, $w_{i,t}$. For all farmers the random variable $w_{i,t}$ is assumed to be stationary with unconditional mean $\mu_w$. The profit function of farmer $i$ in period $t$ is:

$$\Pi_{i,t} = P_{t}^{m}q_{i,t}(1 + g_t) - w_{i,t}q_{i,t}(1 + g_t) = \pi_{i,t}q_{i,t}(1 + g_t)$$

Where $\pi_{i,t} \equiv P_{t}^{m} - w_{i,t}$ is farmer $i$’s marginal profit at time $t$. After producing and collecting profits, the farmer must allocate resources between current consumption, $c_{i,t}$, and investment in quotas, $q_{i,t+1}$. When making this allocation decision the financial resources available to farmer $i$ include earned income, $\pi_{i,t}q_{i,t}(1 + g_t)$, and asset wealth, $P_{t}q_{i,t}(1 + g_t)$; where $P_{t}$ is the price of production quotas at time $t$.

At the end of each period there is a risk of the government eliminating supply management, a policy change that results in the profits from quotas falling to zero under the assumption of free entry of new farmers. As demonstrated below, in the period following such a policy reform the equilibrium price of quotas, and therefore the sum total of financial resources available to farmers, also drops to zero. To assist farmers in the transition to the new policy environment, I assume that the government awards each farmer with an adjust-
ment payment that is dependent on the farmer’s quota holdings. Specifically, farmers are assumed to receive an adjustment payment equal to some fraction, $\eta$, of the market value of their quota holding. Following the policy reform, farmers earn an income $y$ in each period through working in another sector of the economy.

Farmer $i$’s dynamic optimization problem can be framed recursively as follows:

$$V(q_{i,t}, \pi_{i,t}, g_t, P_t) = \max_{c_{i,t}, q_{i,t+1}} \ln(c_{i,t}) + \frac{1-\lambda}{1+r} E_t V(q_{i,t+1}, \pi_{i,t+1}, g_{t+1}, P_{t+1}) + \frac{\lambda}{1+r} \left( \ln(\eta P_t q_{i,t+1}) + \frac{\ln(y)}{r} \right)$$

subject to:

$$P_t q_{i,t}(1 + g_t) + \pi_{i,t} q_{i,t}(1 + g_t) = c_{i,t} + P_t q_{i,t+1}$$

$V(q_{i,t}, \pi_{i,t}, g_t, P_t)$ is the value of a dairy farm with quota holding $q_{i,t}$ and marginal profit $\pi_{i,t}$, when the growth rate of quotas is $g_t$ and the price of quotas is $P_t$. The parameter $r$ is the discount rate, and $\lambda$ is farmers’ perception of the probability of policy reform. The left-hand side of the budget constraint represents the financial resources available to the farmer, and the right-hand side represents expenditures.

Define $c^*_{i,t}(q_{i,t}, \pi_{i,t}, g_t, P_t) \equiv c^*_{i,t}$ and $q^*_{i,t+1}(q_{i,t}, \pi_{i,t}, g_t, P_t) \equiv q^*_{i,t+1}$ as the policy functions for consumption and quotas respectively that solve (1). Under the specification of log utility from consumption, the policy functions $c^*_{i,t}$ and $q^*_{i,t+1}$ have the following closed form solutions:

$$c^*_{i,t} = \frac{r + \lambda}{1 + r + \lambda} (P_t + \pi_{i,t}) q_{i,t}(1 + g_t)$$

$$P_t q^*_{i,t+1} = \frac{1}{1 + r + \lambda} (P_t + \pi_{i,t}) q_{i,t}(1 + g_t)$$

The policy functions have an intuitive interpretation. Each period, farmer $i$ allocates a percentage, $(r + \lambda)/(1 + r + \lambda)$, of available resources to consumption, and a percentage, $1/(1 + r + \lambda)$, to quotas. If policy risk is high then farmers will purchase less quota since there is a lower probability of capturing future rents from quotas.

Dairy farmers are assumed to take the price of quotas, $P_t$, as given. Dividing equation (3) by $P_t$ and summing across all $n$ farmers yields the aggregate demand for quotas, $Q^d_{t+1}$. The aggregate supply of quotas, $\tilde{Q}_t = Q_t(1 + g_t)$, is the beginning of period TPQ adjusted by the aggregate growth rate $g_t$. Equating aggregate supply and demand, $Q^d_{t+1} = \tilde{Q}_t$, yields
a parsimonious pricing formula for quotas:

\[ Q_{d,t+1} = \sum_{i=1}^{n} q_{i,t+1} = \sum_{i=1}^{n} \left[ \left( \frac{1}{1 + r + \lambda} \right) q_{i,t}(1 + g_t) + \left( \frac{1}{1 + r + \lambda} \right) \frac{\pi_{i,t}}{P_t} q_{i,t}(1 + g_t) \right] = Q_t(1 + g_t) = \tilde{Q}_t \]

\[ \frac{1}{1 + r + \lambda} \sum_{i=1}^{n} q_{i,t}(1 + g_t) + \frac{1}{1 + r + \lambda} \frac{1}{P_t} \sum_{i=1}^{n} \pi_{i,t} q_{i,t}(1 + g_t) = Q_t(1 + g_t) \]

\[ P_t = \frac{1}{1 + r + \lambda} \left( 1 - \frac{1}{1 + r + \lambda} \right) \frac{\sum_{i=1}^{n} \Pi_{i,t}}{Q_t(1 + g_t)} = \frac{\tilde{\pi}_t}{r + \lambda}, \tag{4} \]

where \( \tilde{\pi}_t \equiv \sum_{i=1}^{n} \Pi_{i,t} / (Q_t(1 + g_t)) \) is the average profit per unit of quota at time \( t \). Note that when policy risk is zero, \( \lambda = 0 \), the price reduces to the familiar asset pricing formula \( P_t = \tilde{\pi}_t / r \). More generally, the price of quotas is decreasing in policy risk and the discount rate, and increasing in average profit per unit of quota. In the event of policy reform quota rents fall to zero, \( \pi_{i,t} = 0 \ \forall \ i \), and it follows immediately from (4) that the price of quotas falls to zero.

The role of supply management in determining the growth rate of the TPQ, \( g_t \), can be incorporated in this model in a manner that is consistent with the objectives of the system.\(^{10}\) At the beginning of each period an administrator of the system conducts a cost-of-production study after each farmer has observed their marginal cost of production for the period \( w_{i,t} \). The administrator also knows the quota holding of each producer, the beginning of period TPQ, and the aggregate demand for raw milk as a function of the farm price.\(^{11}\) Based on this information, the administrator chooses \( g_t \) so that the average profit per unit of quota remains constant at \( \tilde{\pi} \), which is exogenously chosen by the system in accord with its objective to provide ‘fair’ return to farmers. Therefore, the administrator’s objective is to choose \( g_t \) each period to satisfy the following constraint:

\[ \tilde{\pi} = \frac{\sum_{i=1}^{n} \Pi_{i,t}}{Q_t(1 + g_t)} = P_t^m(Q_t, g_t) - \frac{\sum_{i=1}^{n} w_{i,t} q_{i,t}}{Q_t} \tag{5} \]

There is a unique \( g_t \) that solves the administrator’s problem under the assumption that the demand for raw milk is strictly decreasing in the farm price. Note that in this modeled policy environment the price of quotas is constant, \( P = \tilde{\pi} / (r + \lambda) \). Variations in the modeled
price of quotas are the result of changes in the discount rate, the policy risk parameter, or changes in the targeted average profit per unit of quota.

I now consider the case of a deterministic equilibrium where each farmer’s marginal cost is fixed at the unconditional mean \( \mu_w \). In this equilibrium it is possible to characterize the size profile of farms that exit the dairy industry. Starting from equation (5) it follows that the deterministic steady state farm price is constant \( P_{ss}^m = \bar{\pi} + \mu_w \), and hence \( g_{ss} = 0 \). As \( g_{ss} = 0 \), the TPQ is held constant at a level \( Q_{ss} \) that supports the equilibrium farm price. \( g_{ss} \) and \( P \) can be substituted into equation (3) to solve for farmer i’s equilibrium quota holding:

\[
q_{i,ss} = \frac{1}{1 + r + \lambda} \left( 1 + \frac{\bar{\pi}}{P} \right) q_{i,ss} = q_{i,ss}
\]

Hence each farmer’s output level is constant in equilibrium and any distribution of quotas across farmers is an equilibrium provided that it satisfies the aggregation condition:

\[
\sum_{i=1}^{n} q_{i,ss} = Q_{ss}.
\]

The steady state value function of a farmer with quota holding \( q_{i,ss} \) is:

\[
V(q_{i,ss}) = \frac{\lambda}{r + \lambda} \left( \ln \left( \frac{\eta}{r + \lambda} \right) + \frac{1}{r} \ln (y) \right) + \frac{1 + r + \lambda}{r + \lambda} \ln (\bar{\pi} q_{i,ss})
\]

Farmers that choose to exit the dairy industry do so by selling their entire stock of quotas in the quota exchange after production occurs in the period. After exiting a farmer earns an income \( y \) in all future periods by working in another sector of the economy. The value of a farmer that exits with quota holding \( q_{i,ss} \) is therefore \( V^e(q_{i,ss}) = \ln ((P + \bar{\pi}) q_{i,ss}) + \ln (y)/r \). A farmer will exit the industry if \( V(q_{i,ss}) < V^e(q_{i,ss}) \). As \( \partial V(q_{i,ss})/\partial q_{i,ss} > \partial V^e(q_{i,ss})/\partial q_{i,ss} \), farmers with small quota holdings are more likely to exit the industry than are large farmers. By equating the two value functions it is possible to derive the unique quota level \( q_{ss}^* \) at which a farmer is indifferent between exiting and remaining in the industry.

\[
q_{ss}^* = \frac{y (1 + r + \lambda)^{(r+\lambda)}}{\bar{\pi} \eta^r (r + \lambda)^r}
\]

Since all farmer’s with quota holdings less than \( q_{ss}^* \) exit the industry, \( q_{ss}^* \) is the minimum viable scale of production in the dairy industry for the deterministic equilibrium. The mini-
minimum scale of production is decreasing in the average profit per unit of quota, $\pi$. Intuitively, when profits are high small farmers are less likely to exit. The minimum scale of production is also decreasing in $\eta$, which implies that small farmers are less likely to exit as the adjustment package becomes more generous. The effect of a marginal increase in the policy risk parameter, $\lambda$, on $q_{ss}^*$ is indeterminate of sign.

In the appendix I illustrate that it is possible to analyze the effects of price ceiling legislation on the minimum viable scale of production. Under price ceiling legislation, the minimum viable scale of production is:

$$ q_{ss}^* = y\eta^{-\lambda}(P + \bar{\pi})^{\frac{(1-\lambda)(1+2(r+\lambda))}{r+\lambda}} P^{\frac{1+r-2\lambda(r+\lambda)}{r+\lambda}} (r+\lambda)^{-\frac{(1+r)}{1+r}} (1+r+\lambda)^{\frac{(1+r)(r+\lambda)+\lambda(1-\lambda)(1+r+\lambda)}{r+\lambda}} $$

In the neighborhood of the equilibrium price of quotas, decreasing quota prices by price ceiling legislation may either decrease or increase the minimum viable scale of production, depending on the values of the discount rate, $r$, and the policy risk parameter, $\lambda$. In section 4.2 I estimate that farmers’ perception of policy risk was 4.63% in the period preceding the implementation of the price ceiling in 2007. In that section I follow Cairns and Meilke (2012) in assuming that farmers’ discount rate during this period was equal to the prime interest rate plus two percent, 7.262%. When evaluated at these estimates, decreasing the quota prices through price ceiling legislation reduces the minimum viable scale of production. This result suggests that the implementation of price ceiling legislation in 2007 effectively discouraged small farmers from exiting the industry in Quebec.

4 Empirical Application

4.1 Econometric Model and Variable Specification

In this section I develop an econometric model to estimate the structural parameter $1/(1+r+\lambda)$, which is required for the counterfactual policy experiments in section 5. Specifically, I divide both sides of equation (3) by financial resources, $P_t q_{i,t}(1 + g_t) + \pi_{i,t}q_{i,t}(1 + g_t)$, to isolate this parameter. Adding an error term to account for unobserved heterogeneity
results in the following empirical specification:

\[
P_{t+1}q_{i,t+1} = \theta_1 + u_{i,t}
\]

Under the assumption \( E(u_{i,t}) = 0 \), equation (9) implies that farmers’ mean percentage allocation of resources to quota purchases equals \( \theta_1 = 1/(1 + r + \lambda) \).

Previous research suggests that the discount rate \( r \) and policy risk \( \lambda \) were not constant over the period 1993-2011. In particular, Cairns and Meilke (2012) argue that policy risk declined following the conclusion of the Uruguay Round of multilateral trade negotiations in 1994. Cairns and Meilke (2012) also note that the borrowing conditions facing dairy farmers improved in the late 1990s. While I have not included a credit constraint in my model, a simple means of incorporating changes in the borrowing environment is to allow the interest rate, \( r \), to vary. Specification (9) can be easily modified to allow for structural breaks in the parameter \( 1/(1 + r + \lambda) \) by introducing break year indicator variables. In particular, I allow for up to two structural breaks in the years \( t_{b1} \) and \( t_{b2} \) as follows:

\[
\frac{P_{t+1}q_{i,t}}{(P_{t+1}q_{i,t}(1 + g_t) + \pi_{i,t}q_{i,t}(1 + g_t))} = \theta_1 + \theta_2 d_{1,t} + \theta_3 d_{2,t} + u_{i,t}
\]

Under this specification the value of \( 1/(1 + r + \lambda) \) is \( \theta_1 + \theta_2 \) between \( t_0 \) and \( t_{b1} \); equal to \( \theta_1 + \theta_3 \) between \( t_{b1} + 1 \) and \( t_{b2} \); and equal to \( \theta_1 \) in the years thereafter. The timing of the break years is determined by an econometric specification test described in the estimation results section of the paper.

The dependent variable in equation (10) includes both aggregate variables, \( P_t \) and \( g_t \), and farm-level variables, \( q_{i,t} \) and \( \pi_{i,t} \), that must be specified. The price of quotas, \( P_t \), is specified as the annual average price of quotas (dollars per hectolitre) on the monthly dairy quota exchange in Quebec.\(^{13} \) As a proxy for the growth of Quebec’s TPQ, \( g_t \), I use the percentage change in Quebec’s share of the national MSQ. Ideally I would use the percentage
change in Quebec’s TPQ, however prior to 2002 data on Quebec’s TPQ are only available for the years 1996, 1997, and 2003. Quebec’s share of the national MSQ is sourced from the Canadian Dairy Information Centre where it is reported as of August 1st of each year.

The farm-level variables are specified using the Agritel database, a farm-level panel data set that is collected annually by the Federation of Management Clubs in the province of Quebec. Under the specification of constant returns to scale in quotas, the marginal profit per unit of quota, $\pi_{i,t}$, is equal to the average profit per unit of quota. Therefore the net operating profit of a farmer (total revenue net of variable costs) divided by the farmer’s quota holding is an appropriate measure for marginal profits. Finding an accurate measure of the variable costs associated with dairy production poses difficulties given the data that are available. The challenge arises because many dairy farmers are engaged in joint production of various agricultural outputs. For example a dairy farmer may produce field crops and use a portion of the yield as feed for dairy cattle and then sell the remaining crops. Failing to account for the non-dairy costs in variable costs could result in measurement error and biased estimates. To address this problem I use a revenue threshold to eliminate farmers that are heavily involved in joint production of agricultural outputs. Specifically, I include only those farmers whose annual income from milk production and dairy subsidies account for at least 80% of total revenue. The use of revenue thresholds to address the problem of joint agricultural production is a common methodology in economic studies of the dairy sector. After applying the revenue threshold to filter the data, the marginal profit variable, $\pi_{i,t}$, is defined as total revenue net of variable costs divided by the farmer’s quota holding.

Specifying the quota holding variable requires careful consideration of differences between the latent specification of the model and the observed values in the data. Recall that the definition of $q_{i,t}$ is the beginning of period $t$ quota holding of farmer $i$. Also recall that $\bar{q}_{i,t} \equiv q_{i,t}(1 + g_t)$ is defined as the end of period $t$ quota holding of farmer $i$. In my empirical specification I proxy a farmer’s end of period quota holding with their annual milk production (in hectolitres). To accommodate for the fact that I proxy for farmer $i$’s end of period quota holding, specification (10) needs to be modified. Specifically, by multiplying the dependent variable by $(1 + g_{t+1})/(1 + g_{t+1})$ and using the definition of $\bar{q}_{i,t}$, equation (10) can be re-written:
Where \( d_{1,t} \) and \( d_{2,t} \) are defined as in equation (10). Note that the only difference between equation (10) and equation (11) is that \( \tilde{q}_{i,t} \) and \( g_{t+1} \) are substituted in place of \( q_{i,t} \) and \( g_t \) respectively.

Over the observation period 1993-2011 the Agritel database represents between 5.05% and 9.06% of the population of Quebec dairy farmers. Comparing the average revenue of dairy farmers in the database to the population of Quebec dairy farmers reveals that farms in the Agritel database tend to be larger than the average dairy farm in Quebec. Over the period 1993-2011, average revenue for farms in my sample are 42% higher than for the population of dairy farms in Quebec. As the Agritel database is not a representative sample, it is important to question how sampling bias might affect the estimation results.

With respect to the policy risk parameter, \( \lambda \), it is possible that large farmers might perceive a lower level of policy risk if greater resources provide these farmers with better information and the ability to influence policy. However, given that in 2011 even the largest farmer in the Agritel sample produced only 0.25% of the TPQ for Quebec, it is reasonable to assume that the degree of influence of any one farmer is relatively small and therefore this effect is unlikely to bias the estimate of the parameter \( \frac{1}{1 + r + \lambda} \).

Table 1 lists estimates of the average profit per unit of quota in Quebec for the years 1993-2011. The provincial profit estimates are calculated using the detailed revenues and costs data that are published in Statistics Canada’s Whole Farm Database (WFD). Statistics Canada’s WFD estimates revenues and costs at the provincial level using samples of individual farm tax records. An advantage of the WFD is that cross-tabulations are available by farm type. For example, a farm is classified as a dairy farm if “40% or more of agricultural sales are derived from the sale of dairy products and 10% or more from raising and selling dairy cattle” (p. 23, Statistics Canada, 2011). Revenue from dairy products and subsidies is included in the WFD and can be used to estimate dairy revenues. Certain categories of operating costs listed in the WFD are exclusive (or nearly exclusive) to dairy farming. However, other categories of operating costs are shared between dairy farming...
and other agricultural enterprises. For the latter category I introduce a weight to allocate a share of these costs to dairy farming. Specifically, for each year the fraction of joint operating costs allocated to dairy farming is set equal to the fraction of total operating revenues derived from dairy products and subsidies. For the years 1993-2011 the average value of this ratio is 0.78. The procedure used to estimate the average profit per unit of quota in Quebec in each year is summarized in the following formula:

\[
\frac{\Pi_t}{\hat{Q}_t} = \frac{R_t - C_{1,t} - \nu_t C_{2,t}}{\hat{Q}_t} = \frac{R_t - C_t}{\hat{Q}_t}
\]  

Equation (12)

The variables in equation (12) are defined as follows: \( R_t \) is dairy product and subsidy revenue in year \( t \); \( C_{1,t} \) are operating costs that are specific to dairy farming in year \( t \) (feed, supplement, straw, and bedding expenses; veterinary fees, medicine and breeding fees; other livestock expenses; marketing expenses); \( C_{2,t} \) are operating costs that are jointly shared between dairy and other agricultural enterprises in year \( t \) (crop expenses; farm share of fuel, machinery, truck, and automobile expenses; land rental expenses; custom work and machine rental expenses); \( \nu_t \) is the period \( t \) weight introduced to account for joint agricultural production, \( \nu_t = R_t/TR_t \), where \( TR_t \) is total operating revenues in year \( t \); \( C_t \) are operating costs in year \( t \), \( C_t = C_{1,t} + \nu_t C_{2,t} \); and \( \hat{Q}_t \) is total annual milk production in year \( t \) (in hectolitres).\(^{17}\)

**INSERT TABLE 1 AROUND HERE**

Table 1 presents data on the Agritel sample and the Quebec and New York Dairy farming industries. The data from New York are presented to contrast trends that are industry specific from those that are specific to the Quebec dairy sector and supply management.\(^{18}\) Over the period 1993-2011 the number of dairy farms declined by 51.5% in Quebec and 53.18% in New York. The similarity of this trend across the two jurisdictions suggests that net exit is a feature of the dairy industry and is being driven by factors other than supply management. During the late 1990s there was a decline in the rate of net exit of Quebec dairy farmers. In particular from 1999 to 2000 the number of farms actually increased, and this coincides with the year of highest growth in the average profit per unit of quota (11.15%). This suggests the rising profit levels may have discouraged dairy farmers in
Quebec from exiting during this period. The monotonic increase in the average revenue per farm in Quebec from 1993-2011 can be explained by the steady decline in the number of farms and rise of aggregate revenue over this period. A final observation from Table 1 concerns the average profit per unit of quota in Quebec, which grew at an annual average rate of 2.25% over the period 1993-2011. This suggests that the rapid increase in the price of quotas over the past two decades can be partially explained by a growth in profitability of dairy farming in Quebec.

4.2 Estimation Results

Model (11) is estimated over the pre-price ceiling era 1993-2005 with an unbalanced panel of 6,890 observations. To determine the preferred specification of the break years, model (11) is estimated by fixed effects using ninety-one different specifications. Seventy-eight of the specifications allow for two structural breaks in the parameter $1/(1 + r + \lambda)$ in every possible combination of years between 1993 and 2005. Twelve of the specifications allow for a single structural break in this parameter for each respective year between 1993 and 2004. The final specification estimates the model without any structural breaks. I then use the Akaike information criterion (AIC) and Bayesian information criterion (BIC) as the basis for model selection across the ninety-one different specifications. Both AIC and BIC select the model with structural breaks in the years 1995 and 1998.

Table 2 presents the fixed effects and random effects estimates of model (11) under the specification of heteroskedastic robust standard errors. A test of overidentifying restrictions following the approach suggested by Arellano (1993) is used to choose between the random effects and fixed effects estimates. The fixed effects estimates are selected as preferred to the random effects estimates based on the results of this test.

INSERT TABLE 2 AROUND HERE

For the purposes of modeling the price of quotas, the parameter of interest is $1/(1+r+\lambda)$. For the years 1993-1995 this parameter is estimated by $\theta_1 + \theta_2$, for 1996-1998 it is estimated by $\theta_1 + \theta_3$, and finally for 1999-2005 the parameter is estimated by $\theta_1$. Under the preferred specification, $1/(1 + r + \lambda) = 0.821$ for 1993-1995, $1/(1 + r + \lambda) = 0.865$ for 1996-1998, and $1/(1 + r + \lambda) = 0.894$ for 1999-2005. The timing of the first increase in the parameter of
interest coincides with the conclusion of the Uruguay Round of negotiations at the end of 1994. This suggests that this increase may have been the result of a decline in dairy farmers’ perception of the risk of major policy reform to supply management. The second structural break in the parameter of interest occurred in 1998. The timing and direction of this break is consistent with the theory that improved borrowing conditions in the mid-to-late 1990s led to increased demand and higher prices in Canadian dairy quota markets. However, as I have not explicitly modeled the credit constraint facing farmers, it is not possible to interpret the magnitude of this shift in relation to the borrowing and lending practices of dairy farmers.

The parameters $r$ and $\lambda$ are not individually identified through estimating equation (11). However, it is possible to estimate the change in perceived policy risk by assuming that farmers’ discount rate was equal to the average prime interest rate plus two percent over the three sub-periods, $r_{93-95} = 0.09153$, $r_{96-98} = 0.07875$, and $r_{99-05} = 0.07262$. Substituting these interest rates into the parameter of interest yields estimates of policy risk of $\lambda_{93-95} = 12.69\%$, $\lambda_{96-98} = 7.71\%$, and $\lambda_{99-05} = 4.63\%$ in the three sub-periods respectively. My estimates of policy risk are close to those of Cairns and Meilke (2012), who estimate that policy risk fell from 10.7\% in 1995 to 5.2\% in 2006.

In sum, the econometric results provide evidence in support of the theory that reduced policy risk and improved borrowing conditions in the 1990s put upward pressure on the price of dairy quotas in Quebec. However, as noted in the previous sub-section, quota prices may have also risen due to increases in the average profit per unit of quota over the past twenty years. In the next section I combine these two factors by modeling price of dairy quotas over the period 1993-2011.

5 Counterfactual Policy Experiments

5.1 The Price of Dairy Quotas in the Absence of Price Ceiling Legislation

In this section I model the price of quotas over the period 1993-2011 using the formula for the equilibrium price of quotas from the model, $P = [1/(1 + r + \lambda)]/[1 - 1/(1 + r + \lambda)] \bar{\pi}_t$. There are two factors in the modeled quota price. The first term involves only the parameter
$1/(1 + r + \lambda)$, and the second term is the average profit per unit of quota in each period. Average profit per unit of quota is estimated from Statistics Canada under the specification defined in equation (12). The parameter $1/(1 + r + \lambda)$ is specified over four sub-periods using the preferred estimates from Table 2. For the sub-periods 1993-1995, 1996-1998, and 1999-2005 I use the Table 2 estimates for each respective sub-period. For the final sub-period, 2006-2011, I use the estimate of $1/(1 + r + \lambda)$ for the period 1999-2005 ($\theta_1 = 0.894$).

Implicit in this specification is the assumption that policy risk, $\lambda$, and the interest rate, $r$, did not change from their values during the period 1999-2005. This is clearly not the case as interest rates have fallen, while policy risk has likely risen as the TPP and CETA trade negotiations have increased the probability of supply management being reformed. Note that while lower interest rates increase the parameter $1/(1 + r + \lambda)$, higher policy risk decreases this parameter. I proceed under the assumption that the increase in $\lambda$ has offset the decrease in $r$, and therefore the estimate of the parameter $1/(1 + r + \lambda)$ for the period 1999-2005 provides a reasonable estimate for the period 2006-2011.

A second assumption implicit in my methodology concerns the effect of the price ceiling on the average profit per unit of quota. It is likely that average production costs would be lower if the price ceiling were removed. I assume that the decrease in average production costs would be offset by a reduction in the administered farm price of milk so as to hold the average profit per unit of quota constant. This assumption is reasonable given that supply management employs cost-of-production pricing to target a profit level that is set by the administrators of the system. Therefore, under the theoretical assumptions of the system and my model, changes in the average cost of production arising from the price ceiling affects the farm price but not price of quotas.

**INSERT FIGURE 2 AROUND HERE**

The modeled price series is presented in Figure 2, along with the actual price series, and the price ceiling. As Figure 2 illustrates, the modeled price series fits the actual price series relatively well throughout the pre-price ceiling era 1993-2005. In particular, the modeled price series closely matches the abrupt increase in the price of dairy quotas during the 1990s. The success of the model in this regard can be attributed to the econometric estimates of the timing and magnitude of the structural breaks in the parameter $1/(1 + r + \lambda)$. While the
two upward shifts in this parameter partially explain the rising trajectory of the modeled price, growth in the average profit per unit of quota is a second factor influencing this trend. The fact that the modeled price closely follows the actual prices series suggests that these two factors are important determinants of quota price dynamics during this era. In the period following the introduction of the price ceiling the modeled price of quotas remains well above the price cap. In 2011, I estimate that dairy quotas in Quebec would have traded at a price of $29,923 per unit, which is 20% above the price ceiling of $25,000.

5.2 Reducing Quota Prices by Lowering the Farm Price of Milk

In this section I estimate the magnitude of the decrease in the farm price of milk required to reduce the valuation of Quebec dairy quotas to the current ceiling price of $25,000 per unit. Re-arranging equation (4) and using the definition of average farmer profits \( \pi_t = P_m^t - \sum_{i=1}^{n} w_{i,t} q_{i,t}/Q_t \) from equation (5) yields:

\[
P_m^t = \left[ \frac{1 - \frac{1}{1+r+\lambda}}{1+r+\lambda} \right] P_t + \frac{\sum_{i=1}^{n} w_{i,t} q_{i,t}}{Q_t} \tag{13}
\]

Define \( P^* \) as the target price of quotas and \( P^*_m \) as the farm price of milk that supports this target. It is possible to solve for the value of \( P^*_m \) that supports a target quota price of $25,000 per unit given estimates of average operating costs \( C_t/Q_t = \sum_{i=1}^{n} w_{i,t} q_{i,t}/Q_t \), and the parameter \( 1/(1+r+\lambda) \). The estimated values of \( Q_t \) and \( C_t \) are defined in equation (12), and \( 1/(1+r+\lambda) \) is set equal to its econometrically estimated value for the period 1999-2005. An important caveat to this methodology is the point raised in section 5.1 regarding the effect of the price ceiling on the farm price of milk. As argued in that section, if the price ceiling were removed the average cost of production would fall, as would the farm price, assuming that the administrators of supply management remain committed to a target profit level. In light of this point, the estimate in this section should be viewed as a lower bound on the actual farm price reduction required to lower the price of quotas to $25,000 per unit.

Following the methodology proposed above, I find that in 2011 a quota price of $25,000 per unit in Quebec would be supported by a farm price of $66.00 per hectolitre. In 2011,
Quebec dairy farmers received an average price of $73.31 per hectolitre for farm milk, and thus lowering the price to $66.00 would represent a 9.97% reduction in the farm price. Figure 3 applies the same methodology and plots the target price of quotas as a function of the farm price of milk. The graph illustrates that any targeted quota price could be attained through adjusting the farm price of milk.

**INSERT FIGURE 3 AROUND HERE**

The impact of a 9.97% farm price reduction can be contextualized by considering the effect on Quebec dairy farmers’ profit margin. Statistics Canada’s Whole Farm Database is used to estimate the profit margin for Quebec dairy farmers, Canadian dairy farmers excluding Quebec dairy farmers, and all other animal product farmers excluding dairy farmers (this last category includes beef cattle, hog, poultry, and egg farmers). Figure 4 illustrates that dairy farming is the most profitable animal product industry in Canada. Over the period 1993-2011, the average profit margin of Canadian dairy farmers is over 11 percentage points higher than the average profit margin of other Canadian animal product farmers. Figure 4 also highlights that dairy farming in Quebec is more profitable than in the rest of Canada.

**INSERT FIGURE 4 AROUND HERE**

Holding constant the aggregate quota holding of each producer, a 9.97% reduction in the farm price results in a 9.97% reduction in farmers’ revenue from dairy production. In 2011, a 9.97% reduction in revenue from dairy products and subsidies would have reduced Quebec dairy farmers’ profit margin from 16.81% to 9.72%. Despite the magnitude of this decline, the profit margin of Quebec dairy farmers would remain 7.34 percentage points higher than the 2011 profit margin of other Canadian animal product farmers. However after the reduction, the profit margin of Quebec dairy farmers would be 3.28 percentage points lower than the 2011 average profit margin of dairy farmers in the rest of Canada.

The model developed in section 3 can be used to estimate the effects on the minimum viable scale of production that result from removing the price ceiling and lowering the farm price of milk. I begin by estimating the minimum viable scale in 2011 under price ceiling legislation by calibrating equation (8). To simulate the effect of removing the price ceiling, I impose market clearing for dairy quotas by evaluating equation (8) at the equilibrium...
price \( P = \bar{\pi}/(r + \lambda) \) (this is equivalent to estimating the minimum viable scale by equation (7)). Finally, to estimate the effect of removing the price cap and lowering the farm price by 9.97%, I reduce \( \bar{\pi} \) to account for the farm price reduction and re-evaluate the minimum scale using equation (7).

The minimum viable scale is estimated for 2011 using the following calibration: \( P \) is set equal to the 2011 ceiling price (converted to dollars per hectolitre), \( y \) is set to the Statistics Canada median household income for Quebec in 2011; \( r \) is set to the prime interest rate plus two percent for 2011; the policy risk parameter \( \lambda \) is set equal to its econometrically estimated value for the period 1999-2005; \( \eta \) is set equal to 2/3; finally \( \bar{\pi} \) is set to its 2011 value as defined by equation (12). In 2011, the minimum scale of production is estimated to be 20.16 units of quotas, which roughly equates to a dairy herd of 20 cows. To simulate the effect of removing the price cap, I re-evaluate the minimum scale of production using equation (7) at the same calibration values and find that the minimum viable scale increases to 22.18 units of quotas. Therefore the price ceiling is estimated to have reduced the minimum viable scale of production by approximately 10%. Finally, the combined effect of removing the price ceiling and lowering the farm price by 9.97% is estimated by lowering the implicit farm price of milk, \( R/\bar{Q} \), by 9.97%, which by equation (12) results in a decrease in \( \bar{\pi} \). Under this policy, the minimum scale of production is estimated to be 27.13 units of quotas, which represents a 34.6% increase as compared with the estimated minimum scale of production under price ceiling legislation in 2011.

**INSERT FIGURE 5 AROUND HERE**

Estimates of the minimum scale of production can also be used to interpret the pattern of net exit of Quebec dairy farms during the past two decades. Figure 5 plots the rate of net exit of dairy farms and the minimum viable scale of production during the period 1994-2011. The rate of net exit is calculated using the data on the population of Quebec farmers that is presented in Table 1. The minimum viable scale is estimated for the price ceiling period (2007-2011) using equation (8), and equation (7) for the period 1994-2006. The calibration values used in each respective year correspond with the specification described in the previous paragraph for the year 2011. The average annual rate of net exit for Quebec dairy farms during the period 1994-2011 was 3.92%. As noted in my discussion of
Table 1, the long run trend of net exit is also observed in the United States and is unlikely to be attributable to supply management. However, Figure 5 illustrates that the fluctuations around the trend of net exit appear to be positively correlated with the minimum viable scale, especially during the period 2003-2011. The correlation coefficients between the two time series for the periods 1994-2011 and 2003-2011 are 0.21 and 0.65 respectively. Changes in the minimum viable scale result from variation in factors that are exogenous to the sector (e.g. interest rate changes) and from policy changes that are determined within the supply management system. The positive correlation between the two series in Figure 5 suggests that farmers’ exit decisions are responsive to supply management policy changes. For example, both the minimum viable scale of production and the net rate of exit declined following the introduction of the price ceiling in 2007. This suggests that the price ceiling has discouraged small farmers from exiting, thereby reducing the rate of decline in the number of dairy farmers in Quebec.

5.3 Policy Options for Reducing the Farm Price of Milk and Quota Prices

In this section I consider two policy experiments that could generate a farm price reduction of the magnitude required to reduce quota prices to $25,000 per unit. The first policy considers reducing the farm price through increasing the TPQ. In this policy experiment I assume that the demand for raw milk exhibits constant own-price elasticity of demand. The functional form of the demand equation is $\tilde{Q}_t = a(P_{tm}^{m})^{-\epsilon}$, where $-\epsilon$ is the own-price elasticity of demand for raw milk. Define $g_t^*$ as the growth in the TPQ that yields a targeted farm price of $P_t^{m*}$. Given $\epsilon$ and a reference price $P_{t-1}^{m}$, it is possible to determine $g_t^*$ from the demand equation:

$$P_t^{m*} = \left(\frac{a}{\tilde{Q}_t}\right)^{\frac{1}{\epsilon}} = \left(\frac{a}{Q_t(1 + g_t^*)}\right)^{\frac{1}{\epsilon}} = \left(\frac{a}{Q_t}\right)^{\frac{1}{\epsilon}} \frac{1}{(1 + g_t^*)^{\frac{1}{\epsilon}}} = P_{t-1}^{m} \frac{1}{(1 + g_t^*)^{\frac{1}{\epsilon}}}$$

(14)

Where the final equality uses the definition of $\tilde{Q}_{t-1} = Q_{t-1}(1 + g_{t-1}) = Q_t$. I specify $\epsilon = 0.72\epsilon_I + 0.28\epsilon_F$, where $\epsilon_I$ and $\epsilon_F$ are the own-price elasticities of industrial and fluid milk respectively. The weights of 0.72 and 0.28 are set equal to the fraction of Quebec’s TPQ that comes from industrial and fluid milk respectively. The values of $\epsilon_I$ and $\epsilon_F$ are set
to 0.5 and 0.1 following Meilke et al. (1998). Using this parameterization and the FPLQ’s 2011 reference price of 73.31, I find that the farm price of milk could be lowered to $66.00 through a 4.16% expansion in the TPQ.

The final counterfactual experiment in this section considers the effect of trade liberalization on the farm price of milk and the price of dairy quotas. Abbassi et al. (2008) simulate the impacts of various trade liberalization scenarios in the Canadian dairy industry using data from 2003-04. Abbassi et al. (2008) assume that the aggregate supply of raw milk remains constant in their moderate short-run trade liberalization scenario. This scenario involves a 25% reduction in bound tariffs, and a 50% increase in the minimum access commitment (MAC). The CETA agreement-in-principle provides the European Union with 16,000 tonnes of new access for cheese in the Canadian market, (Canada, 2013). This represents a 78% increase in the MAC for cheese, however CETA entails no additional European market access for other dairy products (milk, yogurt, butter, ice cream, etc.). The TPP may result in further increases in MAC levels, however as Gifford (2012) has commented, the TPP will likely require adjustment rather than elimination of supply management in Canada. Therefore, the trade liberalization scenario considered by Abbassi et al. (2008) appears to be comparable to a moderate outcome to the prospective TPP and CETA agreements. Abbassi et al.’s (2008) simulation of the above scenario results in a 10.3% reduction in the farm price of milk in the province of Quebec. Under this same scenario Abbassi et al. (2008) estimate that the welfare of Canadian dairy farmers is reduced by 25.2%, while total Canadian welfare increases by 0.4%.

Drawing on Abbassi et al.’s (2008) results and using the methodology presented above in equation (13), I estimate that a 10.3% reduction in the farm price of milk would result in a farm price of $65.76 and reduce the 2011 price of dairy quotas in Quebec to $24,820 per unit. Thus, it is likely that the price of dairy quotas in Quebec would drop to a level roughly equivalent to the current ceiling price following a 25% reduction in bound tariffs and 50% increase in the MAC, assuming that the aggregate supply of raw milk in Quebec is held constant following trade liberalization.
6 Conclusions

The price of dairy quotas has risen dramatically over the past two decades. The empirical results in this paper provide evidence in support of the theory that reduced policy risk and improved borrowing conditions in the 1990s put upward pressure on the price of dairy quotas. However, the results also indicate that quota prices may have risen due to increases in the average profit per unit of quota over the past twenty years.

I estimate that dairy quotas in Quebec in 2011 would have traded at a price of $29,923 per unit in the absence of the price ceiling. My results indicate that lowering the market valuation of quotas to $25,000 per unit would have required a 9.97% reduction in the farm price of milk. In 2011, a 9.97% reduction in operating revenue would have reduced Quebec dairy farmers’ profit margin to 9.72%. While this is the lowest level in recent history, the margin would remain 7.34 percentage points higher than the 2011 profit margin of other Canadian animal product farmers.

The recent implementation of quota price ceilings in Canada’s two largest dairy producing provinces have introduced a new source of inefficiency in the Canadian dairy sector. From the perspective of economic theory, lowering the farm price of milk is preferred to a price cap as a method for lowering the price of quotas. Consumers also stand to benefit from a reduction in the farm price of milk, as the profitability of dairy farming under supply management is reflected in higher retail prices for Canadian dairy products. While I have not estimated the welfare effects of a 9.97% decrease in the farm price of milk, the inelasticity of consumer demand for dairy products suggests that there would be large gains in consumer surplus from the counterfactual policy experiments considered in this paper. The counterfactual experiments in section 5 indicate that the price of quotas could be reduced to the ceiling price level through a 4.16% expansion of the TPQ, or through a trade liberalization scenario involving a 25% reduction in bound tariffs and 50% increase in the MAC. The farm price reduction resulting from these policies would improve the competitive position of the Canadian dairy sector, which is imperative given that recent research suggests that the sector is not prepared to compete in international markets, (Kimura and Thi, 2013). The results of this paper highlight the complementarity between policy reform and improved
efficiency in the Canadian dairy sector.
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Notes

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1 The Canadian Dairy Commission Act states that an objective of the Canadian Dairy Commission (CDC) is “to provide efficient producers of milk and cream with the opportunity of obtaining a fair return for their labour and investment...” (Canada, Department of Justice, 1985, s.8).

2 Author’s own calculation using data sourced from the Canadian Dairy Information Centre and United States Department of Agriculture, Economic Research Service. Pounds of milk are converted to hectolitres using a conversion ratio of 2.273 lbs/litre. US dollars are converted to Canadian using the Bank of Canada’s annual average exchange rate.

3 For example, Moschini and Moro (1993) find that the own-price elasticities of milk, butter, cheese and other dairy products are -0.34, -0.92, -0.4, and -1.02 respectively.

4 The FPLQ is the provincial dairy marketing board in Quebec.

5 More generally, as Barichello et al. (2009) point out, there are several additional policy options in the broader context of reform of the supply management system.

6 Cairns and Meilke (2012) also analyze the welfare effects of the progressive transfer assessment policy that was introduced on the Ontario dairy quota exchange in 2006.

7 Recent examples in this literature include Knittel and Stango (2003) and Sen et al.
The annual production entitlement of one unit of quota is roughly equivalent to the milk produced by a single cow in one year.

See the appendix for a detailed derivation of the policy functions $c^*_t,i$ and $q^*_t,i,t+1$.

I am grateful to an anonymous referee who recommended that I explicitly model the role of supply management and the linkage between the growth rate of quotas, $g_t$, the farm price of milk, $P^m_t$.

Recall that the aggregate supply of raw milk is simply $\tilde{Q}_t = Q_t(1 + g_t)$.

See appendix for the derivation of the value function, $V(q_i,ss)$.

To convert the price of dairy quotas to dollars per hectolitre, I use milk composition annual average test data for the province of Quebec sourced from the Canadian Dairy Information Centre.

Alvarez et al. (2006), Godah et al. (1990), and Boots et al. (1997) use revenue thresholds of 90, 70, and 50 percent respectively.

As an additional measure of safety against measurement error I also omit suspected outliers. In each period $t$, suspected outliers for the variable $\pi_{i,t}$ are indentified using the standard 1.5 interquartile range (IQR) rule. Specifically, I identify suspected outliers as those values of $\pi_{i,t}$ that fall a distance of more than 1.5xIQR below the first quartile in period $t$, or 1.5xIQR above the third quartile in period $t$.

This is a reasonable proxy given that the FPLQ enforces strict financial penalties against dairy farmers producing under or over the amount permitted by their quota holding.

The variable $\tilde{Q}_t$ is sourced from Statistics Canada CANSIM series v382194.

In 2011, New York State was the 4th largest dairy producing state in the United States. As a large dairy producing state in a similar physical environment, the New York dairy farming industry provides a natural benchmark for comparison.
Anecdotal evidence suggests that there are few dairy farmers entering the dairy industry relative to the number exiting. For example, in an effort to stimulate entry the marketing boards in several provinces (including Quebec and Ontario) have implemented ‘new entrant programs’ that subsidize the quota purchases of new farmers.

Aggregate revenue from dairy products and subsidies grew at an annual average rate of 3.09% per year over the period 1993-2011.

The fixed effects estimates are calculated using the fixed effects (within) regression estimator. Fixed effects specified at the farm level. The random effects estimates are calculated using the generalized least squares random effects estimator.

The p-value of the test is 0.04.

The changes in policy risk in 1996 and 1998 are statistically significant at the 1% level.

Milk production output is converted from hectolitres per year to kilograms of butter-fat per day using a province specific conversion factor sourced from the Canadian Dairy Information Centre.

As discussed in section 2, during the price ceiling era the FPLQ has implemented a rationing rule to allocate the available quotas to all farmers bidding at least the price cap. As a result, average production costs are higher under the price ceiling because there are fewer quotas in the hands of the most efficient producers than under the market allocation.

Annual average calculated from FPLQ monthly reference price.

It is important to recognize that there are considerable differences in capital costs across the animal product industries and therefore a straight comparison of the ratio of net operating income to operating revenue would be misleading. To address this issue I define the profit margin as the ratio of net operating income adjusted for capital cost allowance to total operating revenue. Note that a more general definition of operating revenue and net operating income is used in this section of the paper as compared with the specification in equation (12). To facilitate comparison of the profit margin across different animal prod-
uct industries total operating revenue and total operating costs are used (i.e. operating revenues and costs are inclusive of all farm enterprises).

28 Median household income data for Quebec is sourced from Statistics Canada CANSIM series v41950213.

29 This parameterization reflects the precedent set by the United States’ tobacco (2004) and peanut (2002) production quota buyout programs. Based on the evidence presented in Womach (2003), these programs paid farmers an amount ranging from approximately 60% to 74% of the asset value of their quotas.

30 The minimum viable scale is calculated in hectolitres per year and then converted to units of quotas (kilograms of butterfat per day) using a province specific conversion factor sourced from the Canadian Dairy Information Centre.

31 The parameter $\lambda$ is calibrated to the econometric estimates 0.1269, 0.0771, and 0.0463 for the periods 1994-1995, 1996-1998, and 1999-2011 respectively.

32 I am grateful to an anonymous referee who recommended extending the model to address the issue of farmer exit.

33 Trade of Canadian dairy products is regulated by tariff rate quotas (TRQs). TRQs involve a MAC and two tariff rates, an in-quota and over-quota tariff. The in-quota tariff is applied to imports not exceeding the MAC, while the over-quota tariff is applied to imports exceeding the MAC.

34 The 25% reduction in bound tariffs considered by Abbassi et al. (2008) appears to be less likely in the context of the TPP and CETA agreements. However, the authors note that the effect of the over-quota tariff decrease is negligible in this trade liberalization scenario, as the magnitude of the decrease is not large enough to trigger imports above the MAC.
7 Appendix

7.1 Derivation of the policy functions $c_{i,t}^*$ and $q_{i,t+1}^*$

Starting from (1) and substituting the budget constraint into the period objective function yields:

$$
V(q_{i,t}, \pi_{i,t}, g_t, P_t) = \max_{q_{i,t+1}} \ln ((P_t + \pi_{i,t})q_{i,t}(1 + g_t) - P_tq_{i,t+1})
+ \frac{\alpha}{1+r} \mathbb{E}_t V(q_{i,t+1}, \pi_{i,t+1}, g_{t+1}P_{t+1}) + \frac{\lambda}{1+r} \left( \ln (\eta P_q q_{i,t+1}) + \frac{\ln(y)}{r} \right)
$$

The first order condition with respect to $q_{i,t+1}$ is:

$$
\frac{P_t}{(P_t + \pi_{i,t})q_{i,t}(1 + g_t) - P_tq_{i,t+1}} = 1 - \frac{\lambda}{1+r} \mathbb{E}_t V'(q_{i,t+1}, \pi_{i,t+1}, g_{t+1}, P_{t+1}) + \frac{\lambda}{1+r} \frac{1}{q_{i,t+1}}
$$

(15)

Under mild regularity conditions (see Stokey et al. (1989), chapter 4), one can apply the envelope theorem:

$$
V'(q_{i,t}, \pi_{i,t}, g_t, P_t) = \frac{(P_t + \pi_{i,t})(1 + g_t)}{(P_t + \pi_{i,t})q_{i,t}(1 + g_t) - P_tq_{i,t+1}}
= \frac{(P_{t+1} + \pi_{i,t+1})(1 + g_{t+1})}{(P_{t+1} + \pi_{i,t+1})q_{i,t+1}(1 + g_{t+1}) - P_{t+1}q_{i,t+2}}
$$

(16)

Substituting (16) into (15) and using the definitions of $c_{i,t}$ and $c_{i,t+1}$ yields the Euler equation:

$$
P_t = 1 - \frac{\lambda}{1+r} \mathbb{E}_t \left[ \frac{P_{t+1} + \pi_{i,t+1}}{c_{i,t+1}} (1 + g_{t+1}) \right] + \frac{\lambda}{1+r} \frac{1}{q_{i,t+1}}
$$

Next I use the guess and verify method for solving for the optimal policy functions $c_{i,t}^*$ and $q_{i,t+1}^*$. My guess is as follows:

$$
c_{i,t}^* = \alpha (P_t + \pi_{i,t})q_{i,t}(1 + g_t)
$$

$$
P_tq_{i,t+1}^* = (1 - \alpha)(P_t + \pi_{i,t})q_{i,t}(1 + g_t)
$$

Where my guess is that $\alpha$ is a constant. Using the Euler equation and my guess of $c_{i,t}^*$:

$$
\frac{P_t}{\alpha(P_t + \pi_{i,t})q_{i,t}(1 + g_t)} = 1 - \frac{\lambda}{1+r} \mathbb{E}_t \left[ \frac{(P_{t+1} + \pi_{i,t+1})(1 + g_{t+1})}{(P_{t+1} + \pi_{i,t+1})q_{i,t+1}(1 + g_{t+1})} \right] + \frac{\lambda}{1+r} \frac{1}{q_{i,t+1}}
$$

$$
\Rightarrow \frac{P_tq_{i,t+1}^*}{(P_t + \pi_{i,t})q_{i,t}(1 + g_t)} = 1 - \frac{\lambda}{1+r} + \frac{\lambda}{1+r} \alpha
$$

Finally, implementing my guess of $P_tq_{i,t+1}^*$:

$$
1 - \alpha = \frac{1 - \lambda}{1+r} + \frac{\lambda}{1+r} \alpha \Rightarrow 1 - \alpha = \frac{1}{1+r + \lambda}; \quad \alpha = \frac{r + \lambda}{1 + r + \lambda}
$$

Thus verifying my guess that $\alpha$ is a constant. The optimal policy functions $c_{i,t}^*$ and $q_{i,t+1}^*$
are therefore:
\[
c_{i,t}^* = \frac{r + \lambda}{1 + r + \lambda} (P_t + \pi_{i,t}) q_{i,t} (1 + g_t) ; \quad P_t q_{i,t+1}^* = \frac{1}{1 + r + \lambda} (P_t + \pi_{i,t}) q_{i,t} (1 + g_t) \]

### 7.2 Derivation of $V(q_{i,ss})$ and $q_{ss}$ in the deterministic equilibrium

In order to analyze the effects of a price ceiling on the exit decisions of farmers, it is convenient to first derive the value function $V(q_{i,ss})$ and minimum viable scale of production $q_{ss}$ as a function of $P$ prior to substituting in the equilibrium value $P = \bar{\pi}/(r + \lambda)$. Under the conjecture that the value function is of the form $V(q_{i,ss}) = A + B ln(q_{i,ss})$ and using the equilibrium values $q_{i,ss} = (1 + \bar{\pi}/P) q_{i,ss}/(1 + r + \lambda)$ and $c_{i,ss} = (P + \bar{\pi}) q_{i,ss} (r + \lambda)/(1 + r + \lambda)$, equation (1) can be written:

\[
A + B ln(q_{i,ss}) = ln \left( \frac{r + \lambda}{1 + r + \lambda} (P + \bar{\pi}) q_{i,ss} \right) + \frac{1 - \lambda}{1 + r} \left\{ A + B ln \left( \frac{1}{1 + r + \lambda} (1 + \frac{\bar{\pi}}{P}) q_{i,ss} \right) \right\} + \frac{\lambda}{1 + r} \left( ln (\eta P_{i,ss}) + \frac{ln(y)}{r} \right) 
\]

The conjecture is verified by solving for $A$ and $B$ from the above equation, where $B = (1 + r + \lambda)/(r + \lambda)$ and

\[
A = \frac{(1+r)(r+\lambda)+(1-\lambda)(1+r+\lambda)}{(r+\lambda)^2} ln \left( \frac{P + \bar{\pi}}{1 + r + \lambda} \right) - \frac{1 - 2\lambda(r + \lambda)}{(r + \lambda)^2} ln(P) + \frac{\lambda}{r + \lambda} \left( ln(\eta) + \frac{ln(y)}{r} \right) + \frac{1 + r}{r + \lambda} ln(r + \lambda). 
\]

The representation of $V(q_{i,ss})$ in equation (6) can be derived by substituting $P = \bar{\pi}/(r + \lambda)$ into the above expression for $A$.

As discussed in section 3, $q_{ss}$ is defined by the equality $V(q_{i,ss}) = V^e(q_{i,ss})$. Solving this equality for $q_{ss}$ yields:

\[
q_{ss} = y \eta^{-\lambda} (P + \bar{\pi}) \frac{(1-\lambda)(1+2(r+\lambda))}{r+\lambda} P^{\frac{1+r-2\lambda(r+\lambda)}{r+\lambda}} (r + \lambda)^{-\lambda} (1+r + \lambda)^{\frac{(1+r)(r+\lambda)+(1-\lambda)(1+r+\lambda)}{r+\lambda}} 
\]

(17)

The representation of $q_{ss}$ in equation (7) can be derived by substituting $P = \bar{\pi}/(r + \lambda)$ into equation (17). Equation (17) is a convenient representation of $q_{ss}$ as it can be used to analyze the effect a marginal change in the $P$, holding constant $\bar{\pi}$, as is the case with price ceiling legislation. Evaluating the partial derivative of $q_{ss}$ with respect to $P$ at the equilibrium price $P = \bar{\pi}/(r + \lambda)$ yields:

\[
\frac{\partial q_{ss}}{\partial P} \bigg|_{P = \frac{\bar{\pi}}{r + \lambda}} = y (r + \lambda)^{1-r} = \frac{\bar{\pi}^2 \eta^\lambda (1 + r + \lambda)^{1-r-\lambda} (r - 2\lambda(r + \lambda))}{\bar{\pi}^2 \eta^\lambda (1 + r + \lambda)^{1-r-\lambda} (r - 2\lambda(r + \lambda))} 
\]

(18)

This derivative is indeterminate of sign as the final term may be positive or negative depending on the values of $r$ and $\lambda$. In section 4.2 I estimated that farmers’ perception of policy risk was 4.63% between 1999-2005. In that section I assumed that farmers’ discount rate during this period was equal to the prime interest rate plus two percent, 7.262%. The
partial derivative in (18) is positive when evaluated at these values.
### Table 1: Summary Statistics for Agritel Database, Quebec, and New York Dairy Farming

<table>
<thead>
<tr>
<th>Year</th>
<th>Agritel Sample Size</th>
<th>Agritel Revenue</th>
<th>Quebec Population</th>
<th>Quebec Revenue</th>
<th>Quebec Π_t/Qt</th>
<th>New York Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>606</td>
<td>$154,188</td>
<td>11,990</td>
<td>$101,814</td>
<td>$26.97</td>
<td>11,000</td>
</tr>
<tr>
<td>1994</td>
<td>649</td>
<td>$167,803</td>
<td>11,490</td>
<td>$112,902</td>
<td>$27.83</td>
<td>10,700</td>
</tr>
<tr>
<td>1995</td>
<td>696</td>
<td>$175,660</td>
<td>11,240</td>
<td>$125,596</td>
<td>$29.23</td>
<td>10,000</td>
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<tr>
<td>1996</td>
<td>624</td>
<td>$177,949</td>
<td>10,200</td>
<td>$131,192</td>
<td>$27.35</td>
<td>9,200</td>
</tr>
<tr>
<td>1997</td>
<td>555</td>
<td>$189,972</td>
<td>9,590</td>
<td>$138,791</td>
<td>$26.03</td>
<td>9,000</td>
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<tr>
<td>1998</td>
<td>531</td>
<td>$199,417</td>
<td>9,385</td>
<td>$146,395</td>
<td>$27.51</td>
<td>8,700</td>
</tr>
<tr>
<td>1999</td>
<td>485</td>
<td>$209,428</td>
<td>8,840</td>
<td>$158,355</td>
<td>$28.60</td>
<td>8,200</td>
</tr>
<tr>
<td>2000</td>
<td>459</td>
<td>$242,518</td>
<td>8,660</td>
<td>$173,633</td>
<td>$31.79</td>
<td>8,000</td>
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<tr>
<td>2001</td>
<td>458</td>
<td>$262,323</td>
<td>8,650</td>
<td>$185,067</td>
<td>$31.94</td>
<td>7,300</td>
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<tr>
<td>2002</td>
<td>462</td>
<td>$275,490</td>
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<td>$193,412</td>
<td>$32.51</td>
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<tr>
<td>2003</td>
<td>453</td>
<td>$308,745</td>
<td>7,710</td>
<td>$216,117</td>
<td>$33.19</td>
<td>7,100</td>
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<td>2004</td>
<td>420</td>
<td>$341,000</td>
<td>7,375</td>
<td>$231,020</td>
<td>$33.18</td>
<td>6,900</td>
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<tr>
<td>2005</td>
<td>492</td>
<td>$359,763</td>
<td>7,165</td>
<td>$255,051</td>
<td>$36.75</td>
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<tr>
<td>2006</td>
<td>484</td>
<td>$385,434</td>
<td>6,850</td>
<td>$269,088</td>
<td>$37.62</td>
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<td>2007</td>
<td>453</td>
<td>$415,681</td>
<td>6,550</td>
<td>$292,017</td>
<td>$38.70</td>
<td>5,700</td>
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<tr>
<td>2008</td>
<td>465</td>
<td>$429,115</td>
<td>6,300</td>
<td>$311,945</td>
<td>$39.17</td>
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<tr>
<td>2009</td>
<td>542</td>
<td>$476,373</td>
<td>6,190</td>
<td>$324,565</td>
<td>$37.44</td>
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<tr>
<td>2010</td>
<td>527</td>
<td>$495,613</td>
<td>6,005</td>
<td>$342,534</td>
<td>$39.50</td>
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<tr>
<td>2011</td>
<td>527</td>
<td>$525,319</td>
<td>5,815</td>
<td>$359,004</td>
<td>$39.55</td>
<td>5,150</td>
</tr>
</tbody>
</table>

Data sources: Sample size and revenue - Agritel database. Population of dairy farmers, revenue, and Π_t/Qt for Quebec: Statistics Canada’s Whole Farm Database and CANSIM series v382194 and v31191101. Population of farms for New York: United States Department of Agriculture, Economic Research Service. Revenue is defined as mean revenue from dairy products and subsidies. Π_t/Qt is defined as the average profit per hectolitre.
Table 2: Fixed Effects and Random Effects Estimation Results

<table>
<thead>
<tr>
<th>Coefficients</th>
<th>Random Effects</th>
<th>Fixed Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_1 )</td>
<td>0.895***</td>
<td>0.894***</td>
</tr>
<tr>
<td></td>
<td>(0.00123)</td>
<td>(0.00103)</td>
</tr>
<tr>
<td>( \theta_2 )</td>
<td>-0.0771***</td>
<td>-0.0730***</td>
</tr>
<tr>
<td></td>
<td>(0.00180)</td>
<td>(0.00227)</td>
</tr>
<tr>
<td>( \theta_3 )</td>
<td>-0.0309***</td>
<td>-0.0286***</td>
</tr>
<tr>
<td></td>
<td>(0.00193)</td>
<td>(0.00220)</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.122</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>6,890</td>
<td>6,890</td>
</tr>
<tr>
<td>Number of producers</td>
<td>1,616</td>
<td>1,616</td>
</tr>
</tbody>
</table>

Preferred specification in bold; Robust standard errors in parentheses; *** p<0.01
Figure 1: Quebec Dairy Production Quota Prices - 1993-2013  (Source: FPLQ)
Figure 2: Quebec Dairy Quota Prices: Exchange, Ceiling, and Modeled
Figure 3: Target Dairy Quota Price as a Function of the Farm Price of Milk
Figure 4: Profit Margins in Canadian Animal Product Farming (Source: CANSIM table 20048)
Figure 5: The Minimum Viable Scale of Production and Rate of Net Exit of Quebec Dairy Farms