AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

CATPRN

Canadian Agricultural Trade Policy And Competitiveness Research Network

BETWEEN A CAP AND A HIGHER PRICE: THE DAIRY QUOTA TRILEMMA

CATPRN Working Paper 2013-01
February 2013

Alex W. Chernoff
Ph.D. Student
Queen's University
Kingston, Ontario

http://www.catrade.org

Funding for this project was provided by the Canadian Agricultural Trade Policy and Competitiveness Research Network (CATPRN) which in turn is funded by Agriculture and Agri-Food Canada. The views in this paper are those of the authors and should not be attributed to the funding agencies.

Abstract

The system of supply management in the Canadian dairy sector requires that farmers acquire quota to produce milk. In Canada's largest dairy producing province, Quebec, a ceiling on the price of quotas has been in effect since 2007. Previous research established that the use of quota price ceilings create a new source of inefficiency in the Canadian dairy sector. An alternative method for lowering quota prices is to lower the rent from quotas through lowering the farm price of milk. I determine the magnitude of the decrease in the farm price of milk that would be required to reduce the valuation of Quebec dairy quotas to the current price ceiling of $25,000 per unit. Accomplishing this task requires modeling the implicit valuation of quotas during the price ceiling era. Starting from a dynamic model of the demand for quotas, I develop an econometric model to estimate producers' discount factor. Using my econometric results and the modeled equilibrium price, I estimate the price of dairy quotas over the period 1993-2010. In 2010, I estimate that dairy quotas in Quebec would have traded at a price of $31,955 in the absence of the price ceiling. My results indicate that lowering the valuation of quotas to $25,000 per unit would have required an 11.83% reduction in the farm price of milk.

1. Introduction

After four decades, the Canadian dairy supply management system is caught in a trilemma. To achieve the objective of providing a "fair" return to farmers, the system relies on controlling production levels through the use of raw milk production quota. The exchange of dairy quotas on provincial auctions encourages efficient allocation of dairy quotas across producers. However, rising quota prices and the increasing cost of financing 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. With the cap in place, the demand for quotas has greatly exceeded supply, and the auctions ability to allocate quotas to the most efficient producers has been significantly compromised. An alternative means of lowering quota prices is to reduce the quota rent by lowering the farm price of milk. However this strategy may conflict with the system's objective of providing a "fair" return for producers.

In the face of escalating quota prices, three policy options define the dairy quota trilemma. The provincial marketing boards can retain the existing cap on the price of quotas at the expense of limiting the auction's ability to allocate quotas to the most efficient producers. Second, is the option of removing the price ceiling and letting the auctions determine the price of quotas. However, at the higher price of quotas, increases in financing costs will limit the entry and expansion of dairy producers. The third option is to reduce the price of quotas by lowering the farm price of milk.[1] This option overcomes the shortcomings of the first two options. The auction can continue to allocate quotas to the most efficient producers, and a lower price of quotas is maintained thereby reducing financing costs. Whether or not there is a conflict between this option and the objective of providing a "fair" return for producers depends on the magnitude of the reduction in the farm price of milk, and the effect on farmers' profit levels. The objective of this paper is to complete two counterfactual policy experiments to empirically estimate the implications of the second and third options.

The first counterfactual experiment involves estimating the implicit market valuation of quotas during the price ceiling era. I begin by developing a theoretical model of the market for dairy quotas in Quebec. Working from this economic model I develop an econometric model that is used to estimate producers' discount factor. The model 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)[2]. Using my estimate of producers' discount factor and the modeled equilibrium price, I estimate the price of dairy quotas in Quebec for the period 1993 to 2010. 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. In 2010, I estimate that dairy quotas in Quebec would trade at a price of $31,955.

[1] As Barichello, Cranfield and Meilke (2009) point out there are more than three policy options in the broader context of reform of the supply management system.

[2] The FPLQ is the provincial dairy marketing board in Quebec.

In my second counterfactual experiment 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 level of $25,000 per unit. My results indicate that lowering the valuation of quotas to $25,000 per unit in 2010 would have required an 11.83% reduction in the farm price of milk. How would an 11.83% reduction in the farm price of milk affect the profitability of dairy farming in Quebec? I answer this question by using Statistics Canada data to compare the profit margin of Quebec dairy farmers with dairy farmers in the rest of Canada, and other Canadian animal product producers. In 2010, an 11.83% reduction in the operating revenue of Quebec Dairy farmers would have reduced Quebec dairy farmers' profit margin to 4.46%. While this is the lowest level in recent history, the margin would remain 2.56 percentage points higher than the 2010 profit margin in other Canadian animal product industries.

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 an economic model of dairy producers' demand for production quotas. In section 4, I present the econometric model 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. In setting prices and production levels, the system makes a distinction between farm milk that is destined for industrial use (butter, cheese, yogurt, etc.), and milk that is used to produce fluid milk (table milk and cream). 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 decided on by the 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 1 kg of butter fat per day and entitle a farmer to produce in perpetuity.[3] While quotas are bought and sold in units, they are properly understood as shares of the provincial TPQ since 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. Cairns and Meilke (2012) argue that the rapid rise in the price of quotas during the late 1990s was the result of several factors, notably including a drop in producers' perception of the risk of major reform to supply management following the conclusion of the Uruguay Round of

[3] The annual production entitlement of one unit of quota is roughly equivalent to the milk produced by a single cow in one year.

multilateral trade negotiations in 1994. With the system of supply management politically entrenched, producers discounted future profits at a lower rate resulting in large increases in quota prices. However as quota prices rose, so too did the cost of financing dairy farming. Concerns over the escalating cost of financing led the provincial marketing boards in Quebec and Ontario to introduce a price cap on quotas in 2007 and 2009 respectively. In Quebec, dairy quotas have traded at the price cap (currently at $25,000) for over three years. With the price cap limiting the price of quotas, all producers with a reservation bid above the ceiling price bid

Figure 1: Quebec Dairy Producer Quota Prices - 1993-2012

(Source: FPLQ)

for quotas, and there is no market based mechanism for allocating quotas to the most efficient producers. As a result, the FPLQ has established rationing rules for distributing available quotas to all producers 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.

3. An Economic Model of Dairy Producers' Demand for Quotas

In this section I develop a model of dairy producers' demand for production quotas. Dairy producers are assumed to be profit maximizing infinitely lived firms, with logarithmic preference over consumption. Producers face a budget constraint and must allocate resources between units of consumption and units of quotas. Each unit of quota entitles the producer 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 P_t^m for milk, but are heterogeneous with respect to their marginal cost of producing milk $w_{i,t}$. Therefore, 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 producer i's marginal profit at time t. After producing and collecting profits, the producer 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 the ith farmer 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 producers. 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 producers in the transition to the new policy environment the government awards all farmers with an adjustment package that is independent of producers' quota holding and production history.[4] Farmers' lifetime valuation of the adjustment package is equal to $\bar{V}$.

Using Bellman's principle, the producer's dynamic optimization problem can be framed recursively as follows:

$$V(q_{i,t}, \pi_{i,t}, g_t, P_t) = \max_{c_{i,t}, q_{i,t+1}} \; ln(c_{i,t}) + \frac{1-\lambda}{1+r} E_t V(q_{i,t+1}, \pi_{i,t+1}, g_{t+1}, P_{t+1}) + \frac{\lambda}{1+r}\bar{V} \qquad (1)$$
$$subject\ \ to: \quad P_t q_{i,t}(1+g_t) + \pi_{i,t}q_{i,t}(1+g_t) = c_{i,t} + P_t q_{i,t+1}$$

Where V is the value function; r is the discount rate; and λ is the probability of policy reform. Define $\frac{1-\lambda}{1+r}$ as the effective discount factor. The left-hand side of the budget constraint represents the financial resources available to the producer, and the right-hand side

[4] I acknowledge that it is more likely that any such government adjustment package *would* depend on producers' quota holding and/or production history. However it is reasonable to assume that when Canadian dairy farmers decide on their quota holdings, they are not actively considering the effect of their quota holding on a prospective adjustment package that would be paid out in the event of policy change. Assuming that the adjustment package is independent of production history and quotas is a simple means of incorporating this assumption into the model.

represents expenditures (consumption plus quotas).

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 problem (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:[5]

$$c_{i,t}^* = (1 - \tfrac{1-\lambda}{1+r})(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{2}$$

$$P_t q_{i,t+1}^* = \tfrac{1-\lambda}{1+r}(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{3}$$

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

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

$$Q_{t+1}^d = \sum_{i=1}^n q_{i,t+1}^* = \sum_{i=1}^n \left[\tfrac{1-\lambda}{1+r} q_{i,t}(1+g_t) + \tfrac{1-\lambda}{1+r}\tfrac{\pi_{i,t}}{P_t} q_{i,t}(1+g_t)\right] = Q_t(1+g) = Q_{t+1}^s \tag{4}$$

$$\tfrac{1-\lambda}{1+r}\sum_{i=1}^n q_{i,t}(1+g_t) + \tfrac{1-\lambda}{1+r}\tfrac{1}{P_t}\sum_{i=1}^n \pi_{i,t} q_{i,t}(1+g_t) = Q_t(1+g_t) \tag{5}$$

$$P_t = \frac{\frac{1-\lambda}{1+r}}{(1-\frac{1-\lambda}{1+r})} \frac{\sum_{i=1}^n \Pi_{i,t}}{Q_t(1+g_t)} \tag{6}$$

Define $\frac{\sum_{i=1}^n \Pi_{i,t}}{Q_t(1+g_t)}$ as 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 $P_t = \frac{1}{r}\frac{\sum_{i=1}^n \Pi_{i,t}}{Q_t(1+g_t)}$. More generally, the price of quota 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 ($\pi_{i,t} = 0 \quad \forall\ i$), and it follows immediately from (6) that the price of quotas falls to zero.

[5] See the appendix for a detailed derivation of the policy functions $c_{i,t}^*$ and $q_{i,t+1}^*$.

4. Empirical Application

4.1 Econometric Model and Variable Specification

In this section I work directly from the policy function for quotas to develop an econometric model that is used to estimate the value of producers' effective discount factor. Specifically, I divide both sides of equation in (3) by $(P_t + \pi_{i,t})q_{i,t}(1 + g_t)$ in order to isolate the effective discount factor. Adding an error term to account for unobserved heterogeneity results in the following empirical specification:

$$\frac{P_t q_{i,t+1}}{(P_t+\pi_{i,t})q_{i,t}(1+g_t)} = \theta_1 + u_{i,t} \qquad (7)$$

Under the assumption $E(u_{i,t}) = 0$, equation (7) implies that producers' mean percentage allocation of resources to quota purchases equals the effective discount factor $\theta_1 = \frac{1-\lambda}{1+r}$.

Previous research suggests that the effective discount factor was not constant over the observation period 1993-2010. In particular, Cairns and Meilke (2012) argue that policy risk declined following the conclusion of the Uruguay Round of multilateral trade negotiations in 1994. In my model, a reduction in policy risk ($\partial\lambda < 0$) is reflected as an increase in producers' effective discount factor. Specification (7) can be easily modified to allow for a structural break in the value of the effective discount factor at time t_{break} by simply introducing a break year indicator variable as follows:

$$\frac{P_t q_{i,t+1}}{(P_t+\pi_{i,t})q_{i,t}(1+g_t)} = \theta_1 + \theta_2 d_t + u_{i,t} \qquad (8)$$

$$Where \qquad d_t = 1 \;\; if \;\; t \leq t_{break} \; ; \;\; and \;\; = 0 \;\; if \;\; t > t_{break}$$

Under this specification the value of the effective discount factor up to t_{break} is equal to $\theta_1 + \theta_2$, and equal to θ_1 in the years thereafter. The timing of the break year is determined by an econometric specification test described in the estimation results section.

The dependent variable in equation (8) includes both aggregate variables (g_t and P_t) and farm-level variables ($q_{i,t}$ and $\pi_{i,t}$) that must be specified. As a proxy for the growth of the 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 is 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.[6] This coincides with the beginning of the "dairy year" which begins on August 1st and ends on July 31st. The price of quotas (P_t) is specified as the annual average price of quotas on the monthly Quebec dairy quota exchange. To maintain consistency with the variable g_t

[6] For example, I define $g_{1993} = (Quebec_{MSQ1993} - Quebec_{MSQ1992})/Quebec_{MSQ1992}$; where $Quebec_{MSQ1993}$ is Quebec's share of the national MSQ as of August 1st, 1993.

the average is taken over the dairy year.[7]

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.[8] 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 ($\pi_{i,t} = \frac{\pi_{i,t} q_{i,t}(1+g_t)}{q_{i,t}(1+g_t)}$). Therefore the net operating profit of a producer (total revenue net of variable costs) divided by the producer'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 is 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. Unfortunately, my dataset does not separate the variable costs associated with dairy production from those associated with other activities. 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 agricultural producers that are heavily involved in joint production of agricultural outputs. Specifically, I include only those producers 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 producers is a common methodology in economic studies of the dairy sector.[9] 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 producer's quota holding.[10]

Specifying the quota holding variable ($q_{i,t}$) requires careful consideration of how the variable is defined in the Agritel database. Recall that the definition of $q_{i,t}$ is the beginning of period t quota holding of producer i. Define $\tilde{q}_{i,t} \equiv q_{i,t}(1+g_t)$ as the end of period t quota holding of producer i. If quota values are recorded in the data as of the beginning of each year then equation (8) is the correct specification. However, if quota values are recorded at the end of each year in the data then equation (8) needs to be modified. Specifically, by multiplying the dependent variable by $\frac{(1+g_{t+1})}{(1+g_{t+1})}$ and using the definition of $\tilde{q}_{i,t}$, equation (8) can be re-written:

---

[7] For example, P_{1993} is defined as the average monthly quota exchange price over the 12 month period spanning August 1992 to July 1993.

[8] The time of the year when the management clubs record producer data varies by producer. The majority of farmers report either at the end of the dairy year, or at the end of the calendar year. Unfortunately, the time of the year when a producer reports is not specified in my dataset. To maintain consistency with the aggregate variables, I specify all farm-level variables as if all producers are reporting as of the end of the dairy year.

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

[10] 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.

$$\frac{P_t \tilde{q}_{i,t+1}}{(P_t + \pi_{i,t})\tilde{q}_{i,t}(1+g_{t+1})} = \theta_1 + \theta_2 d_t + u_{i,t} \qquad (9)$$

$$Where \quad d_t = 1 \ if \ t \leq t_{break} \ ; \ and \ = 0 \ if \ t > t_{break}$$

Note that the only difference between equation (8) and equation (9) is that $\tilde{q}_{i,t}$ and g_{t+1} are substituted in place of $q_{i,t}$ and g_t respectively. Unfortunately, the Agritel database reports the *average* quota holding of each producer in each year, which is an imperfect proxy of both $q_{i,t}$ and $\tilde{q}_{i,t}$.[11] In my empirical application I use producers' annual average quota holding as a proxy for their end of year quota holding, and therefore equation (9) is the empirical specification.[12]

Table 1 presents summary statistics for the Quebec dairy farming industry and for my sample of dairy farmers from the Agritel database. The real price of quotas roughly doubled between the early 1990s and mid-2000s, while the quota rent remained relative constant over this period. This suggests that the increase in quota prices was driven by changes in farmers' discount factor. The average quota holding per farm approximately doubled between 1993 and 2010, a trend that is characteristic of the dairy sector in Quebec and the rest of Canada during this period. The final two collumns illustrate that my sample represents between 4.65% and 8.25% of the population of Quebec dairy farmers.

4.2 Estimation Results

Model (9) is estimated over the pre-price ceiling era 1993-2005 with an unbalanced panel of 7097 observations.[13] To determine the preferred specification of the break year, model (9) is estimated by fixed effects using twelve different specifications. The twelve models specify a structural break in the effective discount factor for each respective year between 1993 and 2004. The specification of the break year that yielded the highest within group R^2 was chosen as the preferred specification. The highest R^2 occurs when the break year is 1995, one year after the conclusion of the Uruguay round of multilateral trade negotiations.

[11] The end of period quota holding is reported in the data, but only for a small subset of producers and only of years 1999 and later.

[12] As part of my sensitivity analysis I estimated the model under specification (8), using producers' annual average quota holding as a proxy for their beginning of year quota holding. The qualitative conclusions drawn from this alternative specification are consistent with my preferred specification, while the quantitative results vary only slightly. These results are available upon request.

[13] The final year of the pre price ceiling era is chosen to be 2005 based on the fact that the price cap was implemented by the FPLQ in July of 2007. Since the dependent variable includes a forward lag of quota holdings, 2005 is the last year during which the dependent variable reflects the pre price ceiling era.

Table 1: Summary Statistics for Quebec Dairy Farming and Agritel Data

Year	Quota Price ($/unit)	Quota Rent ($/unit)	Mean Quotas (units)	Sample Size	Sample/Population
1993	$15,238	$3,843	31	611	5.15%
1994	$14,664	$3,902	33	720	6.11%
1995	$16,436	$3,998	34	792	6.94%
1996	$16,571	$3,641	34	695	6.33%
1997	$16,816	$3,728	36	636	5.99%
1998	$19,392	$3,967	38	581	5.66%
1999	$24,258	$3,993	40	498	5.10%
2000	$27,017	$3,914	43	430	4.65%
2001	$24,791	$3,873	46	448	5.04%
2002	$28,125	$3,722	47	409	4.81%
2003	$27,801	$3,942	49	430	5.34%
2004	$25,977	$3,564	53	407	5.25%
2005	$27,161	$4,164	55	440	5.86%
2006	$28,507	$3,993	57	492	6.87%
2007	$24,250	$4,066	57	405	5.90%
2008	$23,533	$3,941	58	407	6.11%
2009	$21,644	$3,849	64	526	8.10%
2010	$21,777	$4,003	66	526	8.25%

All of the dollar values in this table are real 2002 dollars deflated using the all-items CPI for Quebec.

Sources: Quota Price: FPLQ. Quota rent, mean quotas per farmer, and sample size: Agritel data. Population of dairy farmers in Quebec: Canadian Dairy Information Centre.

Table 2 presents the fixed effects and random effects estimates of model (9). The Hausman test is used to choose between the random effects and fixed effects estimates. The null hypothesis that random effects estimates are consistent is rejected at the 1% level of significance.[14] The fixed effects estimates are therefore determined to be preferred to the random effects estimates.

The first coefficient (θ_1) is the estimate of producers' effective discount factor in the period following the break year (1996-2005). For the period up to and including the break year (1993-1995), producers' effective discount factor is estimated by $\theta_1 + \theta_2$. Recall from equation (1) the definition of the effective discount factor $\left(\frac{1-\lambda}{1+r}\right)$. The effective discount factor captures the two types of discounting. r is the conventional discount rate, and λ is farmers' perception of the probability of policy reform. The effective discount factor is a measure of the weight that farmers place on future consumption relative to current consumption. Under the preferred specification, producers' effective discount factor increases from 0.8144 in the early 1990s to 0.8748 following the break year in 1995. Therefore, my results suggest that the rapid escalation in dairy quota prices during the late 1990s was driven by increases in producers' effective discount factor.

[14] The p-values for both Hausman tests are equal to 0.0000. Here and elsewhere in the paper p-values are rounded to 4 decimal places.

Table 2: Fixed Effects and Random Effects Estimation Results

Coefficients	**Fixed Effects**	Random Effects
θ_1	**0.875*** **	0.878***
	(0.00104)	(0.00118)
θ_2	**-0.0604*** **	-0.0707***
	(0.00221)	(0.00185)
Break year	**1995**	1995
R-squared	**0.120**	
Observations	**7,097**	7,097
Number of farmers	**1,584**	1,584

$\theta_1 + \theta_2 \equiv$ Discount Factor 93-95; $\theta_1 \equiv$ Discount Factor 96-05

*** p<0.01, ** p<0.05, * p<0.1

Preferred specification in bold; Standard errors in parentheses

The timing of the increase in the effective discount factor coincides with the conclusion of the Uruguay Round of negotiations at the end of 1994. This suggests that the increase in the effective discount factor in the mid 1990s was the result of a decline in dairy farmers' perception of the risk of major policy reform to supply management. Given discount rates for the two sub-periods (r_{93-95} and r_{96-05}), it is possible to calculate the change in policy risk. Following Cairns and Meilke (2012), I approximate dairy farmers discount rate using the average prime interest rate plus 2% over the two sub-periods ($r_{93-95} = 0.091042$ and $r_{96-05} = 0.075792$). Substituting these interest rates into the formula for the effective discount factor yields estimates of policy risk of $\lambda_{93-95} = 11.15\%$ and $\lambda_{96-05} = 5.89\%$ in the two sub-periods respectively. The 5.26 percentage point drop in policy risk over the two sub-periods is statistically significant at the 1% level. My estimates of policy risk are very close to those of Cairns and Meilke (2012), who use a CAPM framework and aggregated data from Ontario dairy producers to estimate that policy risk fell from 10.7% in 1995 to 5.2% in 2006.

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 1993-2010 using the formula for the equilibrium price of quotas which is re-written below for convenience:

$$P_t = \frac{\frac{1-\lambda}{1+r}}{(1-\frac{1-\lambda}{1+r})} \frac{\sum_{i=1}^{n} \Pi_{i,t}}{Q_t(1+g_t)} \tag{10}$$

The effective discount factor is specified over the two sub periods using the preferred estimates from Table 2. Specifically, when modeling the price of quotas for the period 1993-1995, I use the 1993-1995 estimated effective discount factor. For the 1996-2010 period I use the 1996-2005 estimated discount factor. Recall that the second term in the equilibrium

price is the average profit per unit of quota at time t ($\frac{\sum_{i=1}^{n}\Pi_{i,t}}{Q_t(1+g_t)}$). The numerator of this term is specified as the aggregate profit as summed across the producers in my sample at time t.

Figure 2: Quebec Dairy Quota Prices: Exchange, Ceiling, and Modeled

Recall that $Q_t(1+g_t)$ is the end of period sum of quota holdings across all producers. Following specification (9), I assume that the quota holdings reported in the Agritel database provide a reasonable proxy to the end of year quotas of a producer. It follows that the appropriate specification of $Q_t(1+g_t)$ is the sum of quotas across the producers in my sample at time t.

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, with the exception of the four year period between 1996-1999. The reason why the modeled price series fits poorly during this era is because the structural break in the effective discount factor is modeled as an abrupt change that occurred at the end of 1995. In actuality the factors that led to the increase in the effective discount factor are more likely to have materialized gradually over the course of the mid to late 1990s. After the conclusion of the Uruguay Round, rather than an abrupt change in farmers

perception of policy risk, it is more plausible that producers' confidence in the stability of the supply management system grew over time. This is reflected in the more gradual increase in the quota exchange price over the late 1990s as compared with the modeled price series. In the period following the introduction of the price ceiling the modeled price of quotas remains well above the price cap. In 2010, I estimate that dairy quotas in Quebec would have traded at a price of $31,955 in the absence of the price ceiling.

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 level of $25,000 per unit. I begin by noting that the equilibrium price of quotas (equation (6)) can be written as a function of the effective discount factor, *average* producer profits, and the *average* quota holding of producers:

$$P_t = \frac{\frac{1-\lambda}{1+r}}{(1-\frac{1-\lambda}{1+r})}\left[\frac{\frac{\sum_{i=1}^{n}\Pi_{i,t}}{n}}{\frac{Q_t(1+g_t)}{n}}\right] \tag{11}$$

Re-arranging equation (11) and using the definition of producer profits ($\Pi_{i,t} = P_t^m q_{i,t}(1+g_t) - w_{i,t}q_{i,t}(1+g_t)$) yields:

$$\frac{P_t^m Q_t(1+g_t)}{n} = \left[\frac{(1-\frac{1-\lambda}{1+r})}{\frac{1-\lambda}{1+r}}\right]\frac{Q_t(1+g_t)}{n}P_t + \frac{\sum_{i=1}^{n} w_{i,t}q_{i,t}(1+g_t)}{n} \tag{12}$$

Define the left hand side of (12) as average producer revenue at time t ($\bar{R}_t$). Define P^* as the target price of quotas and $\bar{R}_t^*$ as the level of average producer revenue that is required to support the target price at time t. Using (12) and holding constant the effective discount factor, average quota holdings, and average variable costs ($\frac{\sum_{i=1}^{n} w_{i,t}q_{i,t}(1+g_t)}{n}$), it is possible to define $\bar{R}_t^*$ as a function of these variables and the target price:

$$\bar{R}_t^* \equiv \left[\frac{(1-\frac{1-\lambda}{1+r})}{\frac{1-\lambda}{1+r}}\right]\frac{Q_t(1+g_t)}{n}P^* + \frac{\sum_{i=1}^{n} w_{i,t}q_{i,t}(1+g_t)}{n} \tag{13}$$

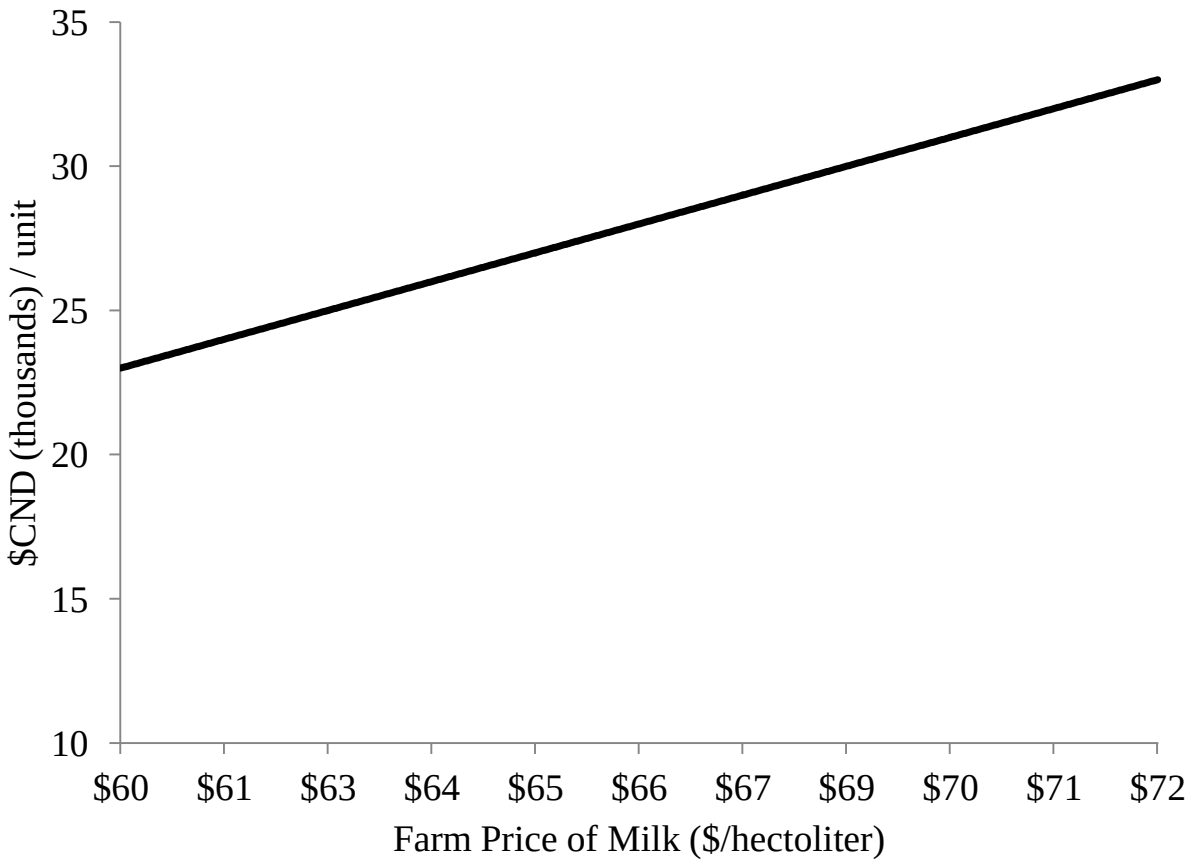
$\bar{R}_t^*$ is estimated for 2010 using the estimated effective discount factor for 1996-2005, and the sample values of average quota holdings, and average variable costs in 2010. Average producer revenue for 2010 ($\bar{R}_{2010}$) is estimated using the average producer revenue in my sample for 2010. Having defined $\bar{R}_{2010}^*$ and $\bar{R}_{2010}$, it is possible to determine the magnitude of the required reduction in average producer revenues that is necessary to reduce the price of quotas to $25,000 per unit. Applying this methodology I find that an 11.83% decrease in the average revenue of dairy farmers is required to lower the valuation of dairy quotas to $25,000 in Quebec.

Define P_t^{m*} as the farm price of milk that supports the target price of quotas. Holding constant the average quota holding of producers, the percentage change in the farm price of milk equals the percentage change in total revenues:

$$\frac{P_t^{m*}-P_t^m}{P_t^m} = \frac{P_t^{m*}Q_t(1+g_t)-P_t^m Q_t(1+g_t)}{P_t^m Q_t(1+g_t)} = \frac{\bar{R}_t^*-\bar{R}_t}{\bar{R}_t} \tag{14}$$

Therefore, in 2010 the price of dairy quotas in Quebec could have been lowered to $25,000 per unit via an 11.83% reduction in the farm price of milk. During the 2009-2010 dairy year, Quebec dairy farmers received an average price of $70.95 per hectoliter for farm milk.[15] Thus an 11.83% reduction would result in a $8.39 reduction in the farm price of milk, lowering the price to $62.56. Figure 3 applies the same methodlogy 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. For example, a quota price of $27,500 could be supported by reducing the farm price of milk to $65.57 per hectoliter.

Figure 3: Target Quota Price as a Fuction of the Farm Price of Milk

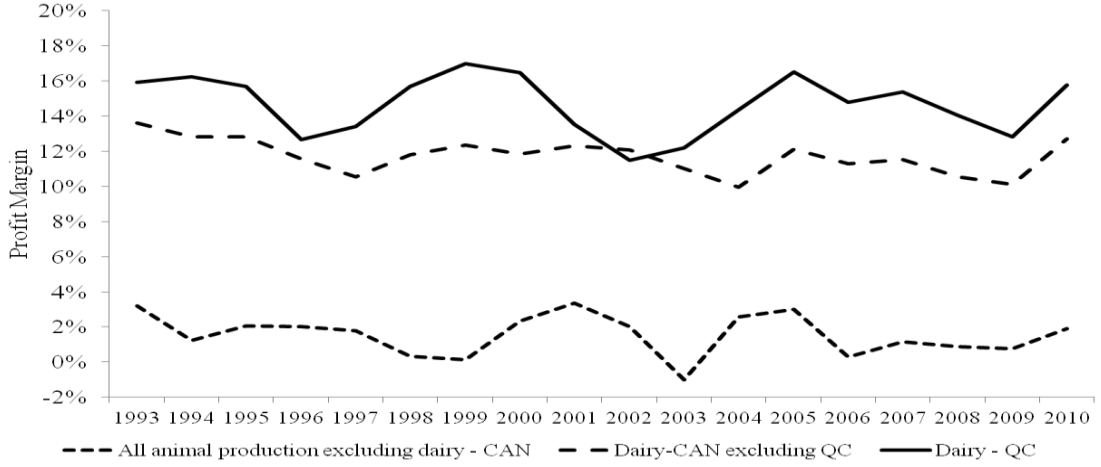


[15] Annual average calculated from FPLQ monthly reference price.

How would an 11.83% reduction in the farm price of milk affect the profitability of farming in Quebec? One method to address this question is to compare the profit margin of Quebec dairy producers to dairy producers in other parts of Canada. A more general approach is to draw comparison to the profit margins of other animal product producers (such as beef cattle, hog, poultry, and egg farming). 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. Figure 4 plots the average profit margin for Quebec dairy farmers, Canadian dairy farmers excluding Quebec dairy farmers, and all other animal product producers excluding dairy farmers. The data in Figure 4 are sourced from Statistics Canada's CANSIM Table 20048. Figure 4 illustrates that dairy farming is the most profitable animal product industry in Canada. Over the period 1993-2010, the average profit margin of Canadian dairy farmers is over 11 percentage points higher than the average profit margin of other Canadian animal product producers. Figure 4 also highlights that dairy farming in Quebec is more profitable than in the rest Canada. Over 1993-2010, the average profit margin of Quebec dairy farmers is 14.66%, 2.94 percentage points higher than the average profit margin of dairy farmers in other parts of Canada.

In 2010, an 11.83% reduction in the operating revenue of Quebec dairy producers would have reduced Quebec dairy farmers' profit margin to 4.46%. Despite the magnitude of this decline, the profit margin of Quebec dairy farmers would remain 2.56 percentage points higher than the 2010 profit margin of other Canadian animal product producers. However after the reduction, the profit margin of Quebec dairy farmers would be 8.24 percentage points lower than the 2010 average profit margin of dairy farmers in the rest of Canada. Figure 4 illustrates that the profit margin of Quebec dairy producers has never dropped below 11% since 1993. Therefore, lowering the price of quotas to $25,000 per unit by reducing the farm price of milk would result in the lowest profit margins in recent history for Quebec dairy farmers.

Figure 4: Profit Margins in Canadian Animal Product Production



(Source: CANSIM table 20048)

6. Conclusion

The price of dairy quotas has risen dramatically over the past two decades. The ascent of quota prices can be explained as the result of a decline in dairy farmers' perception of the risk of major policy reform to supply management following the conclusion of the Uruguay Round in 1994. My empirical results indicate that dairy producers' perception of policy risk dropped by 5.26 percentage points at the end of the twentieth century.

Escalating quota prices led the provincial marketing boards in Quebec and Ontario to implement price ceilings on quotas in 2007 and 2009 respectively. With the cap limiting the price of quotas, the auctions ability to allocate quotas to the most efficient producers has been significantly compromised. 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. However, this strategy is potentially in conflict with the legislated objectives of the supply management system if the required reduction in producer profits prevents dairy farmers from earning a "fair" return.

In 2010, I estimate that dairy quotas in Quebec would have traded at a price of $31,955 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 an 11.83% reduction in the farm price of milk. In 2010, an 11.83% reduction in operating revenue would have reduced Quebec dairy farmers' profit margin to 4.46%. While this is the lowest level in recent history, the margin would remain 2.56 percentage points higher than the 2010 profit margin in other Canadian animal product industries.

References

Alvarez, A., C. Arais, and L. Orea. "Explaining differences in milk quota values: the role of economic efficiency." *American Journal of Agriculture Economics*, 88(1): 182–193, 2006.

Barrichello, R., Cranfield, J., Meilke, K. "Options for the reform of supply management in Canada with trade liberalization." *Canadian Public Policy*, XXXV(2): 203-217, 2009.

Boots, M., A. Lansink, and J. Peerling. "Efficiency loss due to distortions in dutch milk quota trade." *European Review of Agricultural Economics*, 24: 32–46, 1997.

Cairns, A., and K. Meilke. "Price ceilings on milk production quota values: future or folly?" C*anadian Journal of Agricultural Economics*, 60: 93–112, 2012.

Godah, A., C.G. Turvey, and A. Weersink. "Decomposition measures of technical efficiency for Ontario dairy farms." *Canadian Journal of Agricultural Economics*, 38(3): 439–456, 1990.

Stokey, N., R. Lucas, and E. Prescott. 1989. *Recursive Methods in Economic Dynamics*. Harvard University Press.

1 Appendix

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

Starting from (1), the producer's dynamic optimization problem is:

$$V(q_{i,t},\pi_{i,t},g_t,P_t) = \max_{c_{i,t},q_{i,t+1}} \; ln\big(c_{i,t}\big) + \frac{1-\lambda}{1+r}\, E_t V(q_{i,t+1},\pi_{i,t+1},g_{t+1},P_{t+1}) + \frac{\lambda}{1+r}\,\bar{V} \tag{15}$$
$$subject\;\; to\!:\;\; P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t) = c_{i,t} + P_t q_{i,t+1}$$

Substituting the budget constraint into the period objective function yields:

$$V(q_{i,t},\pi_{i,t},g_t,P_t) = \max_{q_{i,t+1}} \; log\big(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t) - P_t q_{i,t+1}\big)$$
$$+\frac{1-\lambda}{1+r}\, E_t V(q_{i,t+1},\pi_{i,t+1},g_{t+1}P_{t+1}) + \frac{\lambda}{1+r}\,\bar{V} \tag{16}$$

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

$$\frac{P_t}{(P_t+\pi_{i,t})q_{i,t}(1+g_t)-P_t q_{i,t+1}} = \frac{1-\lambda}{1+r} E_t V'(q_{i,t+1},\pi_{i,t+1},g_{t+1},P_{t+1}) \tag{17}$$

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

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

$$\Rightarrow V'(q_{i,t+1},\pi_{i,t+1},g_{t+1},P_{t+1}) = \frac{(P_{t+1}+\pi_{i,t+1})(1+g_{t+1})}{(P_{t+1}+\pi_{i,t+1})q_{i,t+1}(1+g_{t+1})-P_{t+1}q_{i,t+2}} \tag{18}$$

Substituting (18) into (17) and using the definitions of $c_{i,t}$ and $c_{i,t+1}$ yields the Euler equation:

$$\frac{P_t}{c_{i,t}} = \frac{1-\lambda}{1+r} E_t\left[\frac{P_{t+1}+\pi_{i,t+1}}{c_{i,t+1}}(1+g_{t+1})\right] \tag{19}$$

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:

$$c_{i,t}^* = \alpha(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{20}$$

$$P_t q_{i,t+1}^* = (1-\alpha)(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{21}$$

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

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

$$\Rightarrow \quad \frac{1}{q_{i,t}(1+g_t)(P_t+\pi_{i,t})} = \frac{1-\lambda}{1+r} E_t \frac{1}{P_t q_{i,t+1}} \tag{22}$$

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

$$\frac{1}{q_{i,t}(1+g_t)(P_t+\pi_{i,t})} = \frac{1-\lambda}{1+r} \frac{1}{(1-\alpha) q_{i,t}(1+g_t)(P_t+\pi_{i,t})} \tag{23}$$

$$\Rightarrow \quad 1-\alpha = \frac{1-\lambda}{1+r} \quad \Rightarrow \quad \alpha = 1 - \frac{1-\lambda}{1+r} \tag{24}$$

Thus verifying my guess that α is a constant. The optimal policy functions $c^*_{i,t}$ and $q^*_{i,t+1}$ are therefore:

$$c^*_{i,t} = (1 - \frac{1-\lambda}{1+r})(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{25}$$

$$P_t q^*_{i,t+1} = \frac{1-\lambda}{1+r}(P_t q_{i,t}(1+g_t) + \pi_{i,t} q_{i,t}(1+g_t)) \tag{26}$$