RURAL ECONOMY

The Simple Analytics of Transferable Production Quota: Implications for the Marginal Cost of Ontario Milk Production

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Staff Paper 96-17

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Abstract

Using the fact that separate markets exist for used and unused quota, this paper derives a formula to compute the marginal cost of the milk production using a competitive dynamic optimization model. It is showed that, under a perfect competitive quota market, the difference between unused quota and used quota prices gives an exact measure of rental value of quota and thus marginal cost. Policy risk is showed to have no effect on the calculation of equilibrium rental value of quota. The formula is modified to allow for the presence of a transfer assessment. It is showed that the effect of transfer assessment on the calculation of equilibrium rental value of quota depends on the elasticities of demand and supply for quota as well as the level of the transfer assessment. Using empirically estimated elasticities of demand and supply for quota, above modified formula is applied to compute the marginal costs of Ontario milk production over the period 1980/81 to 1994/95. While it represents an improvement over Barichello's approach, the measured marginal costs are not totally satisfactory. The problem lies in the fact that the monthly rental rates are unstable both within the dairy year and across the time series. The results here suggest that one must be cautious in the use of the difference between unused and used quota prices as a measure of rental rate.

The Simple Analytics of Transferable Production Quota:
Implications for the Marginal Cost of Milk Production In Ontario

I. Introduction

For the past 15 years binding production quotas have been used to regulate the production of milk, boilers, eggs and turkeys in Canada. These production quotas have resulted in significant rents being realized by the original quota holders, with the aggregate value of quota rights amounting to billions of dollars. Largely because of these rents supply management has been a controversial policy. However, orderly marketing is supported by all farm organizations and political parties; while being opposed by consumers and most economists.

In a market where production is constrained by quotas there is a gap between the price received by producers and the marginal cost of production. In addition, the marginal cost of production is not directly observable unless there is a rental market for quota. In situations where quota rental is prohibited,[1] as is the case in the Canada dairy industry, the competitive rental value is unknown. Consequently, the marginal cost of production is not observable. This creates serious problems in conducting welfare analysis of these regulated markets and in making assessments of their regional and international competitiveness (Barichello 1981, Forbes, Hughes and Warley 1982, Veeman 1982, Schmitz 1983, Moschini 1989, Graham *et. al.* 1990, Schmitz and Schmitz 1994, Lambert *et. al.* 1994, Ewasechko and Horbulyk 1995, Meilke *et. al.* 1996). Lambert *et. al.* suggested that removing interprovincial trade barriers would shift milk production from Ontario to Quebec, while Ewasechko and Horbulyk concluded that Quebec would reduce its milk production. The conflicting conclusions arise because of differences in how provincial marginal costs were calculated. Lambert *et. al.* based their marginal cost estimates on observed

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[1] Though production quota is an popular policy instrument in many countries, including tobacco and peanuts in the United States, milk, boilers, eggs and turkeys in Canada, and dairy in Australia and the European Community, treatments on transferability of production quota among producers are rather different cross country and commodity. In the United States, for example, tobacco quotas are only allowed to be leased among the producers within county. In Ontario and Quebec, dairy quota are only allowed be traded in centralized auction markets within province.

quota prices, while Ewasechko and Horbulyk calculated marginal cost based on cost of production survey data.

To estimate marginal cost in an output constrained market, the rental value of quota is needed. A number of studies have addressed this issue but the only observable variable, in most Canadian quota markets, is the capitalized price of quota. To transform this capitalized value into a rental rate, which can then be used to retrieve the marginal cost of production, requires an estimate of the 'true' discount rate used by producers. Estimating either the rental value or the discount rate is fraught with difficulties and estimates of discount rates and marginal costs vary widely across studies, commodities and time periods.

The objective of this paper is to propose a way to derive the marginal cost of milk production when production quotas are traded in regulated, centralized auction markets. It relies neither on a prior estimate of the marginal cost of production nor on an estimate of the discount rate. To do this, a particular feature of the Canadian milk quota market is exploited (Barichello 1984). Namely, that separate markets exist for used and unused quota.

A formula to calculate the rental value of quota, based on a competitive dynamic optimization model is proposed. A dynamic model is needed because of the distinction between used and unused quota. Industrial milk quotas are annual quotas (dairy year). Once a unit of quota is used, it cannot be used again until the following year. While Barichello recognized that the rental value of quota can be inferred from the difference between unused and used quota prices, the explicit derivation of his rental value formula from a dynamic optimization model offers a number of insights.

After developing the basic model, the assumption of a perfectly competitive quota market is relaxed and the effects of the transfer assessment (tax) that is levied on the sale of milk quota is evaluated. The results show that in the presence of an assessment tax knowledge of the elasticity of supply and demand for quota is required to estimate the rental value. The transfer assessment increases both unused and used quota values. Using the simple difference between unused and used quota prices, in this situation, results in biased estimates of equilibrium rental value. The direction and extent of this bias depends on the relative size of demand and supply elasticities for production quota as well as the size of the transfer assessment.

In the next section some background information on quota markets in Canada is presented followed by a review of the various approaches which have been proposed to estimate the marginal cost of milk production. A dynamic optimization model of a quota exchange is then presented, followed by an evaluation of the effects of a transfer tax on the rental value of quota. Finally, using observations on the prices of unused and used quota, along with previously estimated demand and supply elasticities for quota, an estimate of the annual rental value, discount rate and marginal cost of Ontario milk production from 1980/81 to 1994/95 is presented.

II. Background

Milk production, in Canada, is regulated at the federal and provincial levels with quantities as well as prices determined by the regulatory agencies. The Canadian Dairy Commission (CDC) sets the total quantity of industrial milk produced and allocates production shares to the provincial boards. The CDC also sets the national support price. The support price determination is guided by a full cost of production pricing formula.

Production quotas are not allowed to trade interprovincially and intraprovincial milk production is under the control of the provincial milk marketing boards. These boards make rules on quota ownership and quota transfer. Currently, production quota can not be rented. Three methods of quota transfer are allowed in Ontario and Quebec, which account for more than 80% of industrial milk production in Canada: 1) within-family transfers, 2) the purchase of an on-going dairy farm, and 3) through a centralized quota exchange.

The Ontario Quota Exchange began operation in March 1980. Since then sales have been conducted monthly. The quota exchange is the main method used by farmers to purchase or sell quota to accommodate small adjustments in their milk output. Producers wishing to trade on the quota exchange submit their bids, or offers, by midnight of the seventh day of each month in which they wish to trade. Each bid specifies the amount and type of quota the buyer wishes to buy and the unit price they are prepared to pay. Similarly, each offer specifies the amount of each quota type the seller is willing to sell at a specified price. The bids and offers for each type of quota are ranked according to price, and the total amount of quota bid for and offered at each price level is calculated. The market clearing price for each type of quota is then set at the price where the quantity of quota offered for sale is equal to the quantity of quota offered to be purchased. All offers to buy at the market clearing price or higher are met, and all offers to sell at the market clearing price or lower are satisfied.

A number of restrictions affect quota allocation and transfer, including the maximum quantity of quota a single producer is allowed to hold, minimum sales quantity of quota, transfer assessments, maintenance requirements and over-quota levies. Barichello and Dunlop (1987) and Lane and Brinkman (1988) provide a detailed discussion of the specifics of each type of regulation. However, the transfer assessment (tax) is an obvious regulation that affects the value of quota on the milk quota exchange. High quota values are often cited as a barrier to entry for new dairy farmers. The transfer assessment is designed to allow the marketing board to set aside some quota for distribution through a new entrant program. Currently, a 15% transfer assessment of the quota that is offered for sale on the exchange is applied by Ontario.

III. Previous Approaches to Estimating Marginal Cost: An Overview

Given the importance of knowing marginal cost in conducting welfare analysis, various approaches have been proposed to obtain this value for Canadian milk production. These approaches can be classified into two broad types, 1) those that estimate the marginal cost directly; and 2) those that infer the marginal cost based on capitalized quota values. Stennes and Barichello (1981) and Gouin (1988) computed average costs using cost of production survey data to approximate the marginal cost of milk production. However, survey methods, based on farm level averages, can only provide crude approximations of marginal costs. Moschini (1987) estimated econometrically the marginal cost of milk production from farm-level cost information. While an improvement over the traditional cost of production methods, a drawback of both of these approaches is that the cost data used to approximate the cost function, is also used by regulatory agencies to set the price of milk. Since the milk producers participating in the cost of production surveys know this, there is a common suspicion that costs are inflated.

The second approach is to derive the marginal cost based on the following equation

$$C'(Y) = p - R \tag{1}$$

where $C'(Y)$ is the marginal cost, Y is the quantity of milk produced, p is the output price and R is the rental value of quota. Equation (1) can be derived from a single output, static model under the assumption of competitive markets (Moschini 1989, Babcock and Foster 1992). When quotas are rented freely, the rental value of quota is directly observable and so is the marginal cost. Babcock and Foster (1992) derived the marginal cost of North Carolina flu-cured tobacco production based on the difference between the price of flu-cured tobacco and the observed rental value for tobacco quota. However, when quota rental is prohibited, only the capitalized value of quota is established. In this case, the rental value of quota and the marginal cost of production have to be derived from the capitalized value.

To obtain the rental value of quota from the capitalized value, two approaches are often used. Both approaches treat production quota as a capital asset providing a stream of annual returns and use the capital asset pricing model to determine the rental value. Arcus (1978), Albon (1979), Barichello (1981, 1984), and Veeman (1982) obtained the rental value by dividing the capitalized value of quota by a discount factor. The choice of an appropriate discount rate is crucial to this approach. Since expected capital gains, interest rates, planning horizons, and the degree of risk inherent in the asset are unknown, the choice of a discount rate is largely arbitrary. A common practice is to multiply the unused MSQ price by the prevailing interest rate. Alternatively, Moschini and Meilke (1988) assumed a constant expected rental value based on estimates of long-run marginal cost of milk production. They then computed discount rates for unused MSQ, used MSQ and fluid milk quotas. The derived discount rate was found to vary over time and across closely related assets.

Barichello (1984) recognized that prices are established for two types of industrial milk quota in Ontario, unused and used. Further, Barichello argued that the rental value for quota can be inferred from the difference between the capitalized values of unused and used quota, without any arbitrary choice of discount factor. Barichello's rental value formula was adopted in Hickling's report to Industry, Science and Technology Canada to obtain the rental value of quota and the marginal cost of milk production.

However, Barichello’s formula can only be applied under the assumption of a perfectly competitive quota auction. In reality, various regulations influence quota markets in the Canadian dairy sector. Hence, when equation (1) is applied to observed data, all deviations from marginal cost pricing - whether they are caused by production quotas or by some other factor - are imputed to the existence of quotas. This in turn creates biased estimates of the rental value and marginal cost.

IV. A Model of Trade in Quota

Suppose that there are *N* farmers of two types, low cost *l* and high cost *h*, the difference between these two types of farms is solely technical so that *l* type farms have lower marginal and total costs over all output levels than farms of the *h* type. At the beginning of the first dairy year, an aggregate production quota (*Q)* is distributed by the marketing board to these *N* farmers without reference to their marginal costs.[2] Each farmer receives an allocation of quota so that $\sum_{i=1}^{N} Q_i = Q$. This allocation is not efficient in the sense that it does not result in equalized marginal costs across farms. The heterogeneous marginal costs create an incentive for trading production quotas between the two types of farms.

[2]From now on the word 'year' should be taken to mean the dairy year.

It is assumed that quota rental is prohibited and that quota is traded in organized markets. There are two centralized quota auction markets, one for used quota and another for unused quota. The only difference between these two quotas is that a farmer who buys unused quota can use it in the same year, while a farmer who buys used quota has to wait until the next year to use it. Hence, at the beginning of the next year, the two quotas are identical. With only two types of farms, *h* type farms will be sellers of quota, while *l* type farms will be buyers.

To avoid unnecessary complications, it is assumed that the quota auctions for both quotas (used and unused) are operated only once a year, at the beginning of the year. It is also assumed that producers have perfect knowledge of their annual production and that production quotas are automatically enforced so that milk output is identical to quota holdings. With these assumptions, the level of milk production for the i^{th} farmer in the first year *t* is

$$Y_{it} = Q_i + S_{it}^n . \tag{2}$$

A positive S_{it}^n denotes unused quota bought and a negative S_{it}^n unused quota sold in year *t* by farmer *i*.

The production constraint of the i^{th} farmer in year *t+1* is

$$Y_{it+1} = Y_{it} + S_{it}^u + S_{it+1}^n = Q_i + S_{it}^n + S_{it}^u + S_{it+1}^n \tag{3}$$

where a positive S_{it}^u denotes used quota bought and a negative S_{it}^u used quota sold in year *t* by farmer *i*.

Though used quotas can not be utilized until the next year, the buyer pays and the seller receives the money for used quota in the current period. Hence, the net income of the i^{th} farmer in year *t* is

$$_{it} = p_t Y_{it} - C_{it}\left(Y_{it}\right) - w_t^n S_{it}^n - w_t^u S_{it}^u \tag{4}$$

where p is the price of milk, $C_{it}(\cdot)$ is a farmer-specific cost function with increasing marginal costs, and w^n and w^u are the capitalized values of unused and used quotas.

The only random factor introduced in the model is the uncertainty regarding the continuation of the current dairy policy.[3] This uncertainty makes the holding of milk quota a risky investment. It is reasonable to assume that farmers know the policy in the current year but are uncertain about the policy in the future. Hence, producers' optimal choices are made in an environment of policy risk in period *t*, when policy in *t+1* is unknown. To make policy risk explicit, producers are assumed to form a subjective probability on the continuation of the *status quo*. Let α be the producer's probability that the current policy will continue and 1-α be the probability that the current policy will be terminated.

The objective of the i^{th} farmer is to maximize the total expected utility of net income over the expected life (*T* periods) of the production assets

$$EU_i = E\left[\sum_{t=1}^{T} \frac{1}{\prod_{t=1}^{T}\left(1+\quad_t\right)^t} U\left(\quad_{it} \middle| t\right)\right] \tag{5}$$

where $U(\cdot)$ is a twice differentiable, concave, instantaneous utility function, δ is the rate of time preference, and $E(\cdot|t)$ is an expectation conditional on information at time t.

The decision problem faced by the i^{th} farmer is to choose the purchases and sales of unused and used quota so as to maximize the expected utility of returns to this asset over *T* periods, subject to equations (3) and (4). The solution to this stochastic dynamic decision problem can be found by solving the following recursive equation

[3]A number of authors (Veeman 1982, Lermer and Stanbury 1985, Larue and Oxley 1991, Barichello 1993, Beck *et. al.* 1995) have speculated about the influence of the GATT negotiations and their influence on quota values.

$$V_{it}\left(Y_{it}\right)=\underset{\left(S_{it}^{I},S_{it}^{II}\right)}{Max}\left\{U\left(\ {}_{it}\right)+E\left(1+\ {}_{t+1}\right)^{-1}\left[\ V_{it+1}^{P}\left(Y_{it+1}\middle|t\right)+\left(1-\ \right)V_{it+1}^{N}\left(Y_{it+1}\middle|t\right)\right]\right\} \qquad (6)$$

s.t. (3) and (4)

where $V_{it}\left(Y_{it}\right)$ is the present discounted value of expected utility evaluated along the optimal path (the optimal value function) at time *t*, V_{it+1}^{P} is the optimal value function obtained from solving the dynamic programming problem associated with an extension of the current policy, and V_{it+1}^{N} is the optimal value function obtained from solving the dynamic programming problem associated with an elimination of the current dairy policy.

First-order conditions for an interior optimum are

$$S_{it}^{n}:\ U'\left(\ {}_{it}\right)\left[p_t-C_{it}^{'}\left(Y_{it}\right)-w_t^{n}\right]+\ EV_{it+1}^{P\ '}\left(Y_{it+1}\right)\left(1+\ {}_{t+1}\right)^{-1}=0 \qquad (7.1)$$

$$S_{it}^{u}:\ U'\left(\ {}_{it}\right)\left(-w_t^{u}\right)+\ EV_{it+1}^{P}{}'\left(Y_{it+1}\right)\left(1+\ {}_{t+1}\right)^{-1}=0 \qquad (7.2)$$

It is assumed that the second order conditions are satisfied. More importantly, there is a simple envelope relation between the value $V_{it}^{'}\left(Y_{it}\right)$ and $U_{it}^{'}\left(\ {}_{it}\right)$ along the optimal path (Blanchard and Fisher 1993, p 281). Considering the effect of a small change in Y_{it} on both sides of (6) and using the production constraint (3) yields

$$V^{'}\left(Y_{it}\right)=\ EV_{it+1}^{P\ '}\left(Y_{it+1}\right)\left(1+\ {}_{t+1}\right)^{-1}=U'\left(\ {}_{it}\right)\left[p_t-C_{it}^{'}\left(Y_{it}\right)-w_t^{n}\right] \qquad (8)$$

where the second equality follows from (7.1).

Equations (7.1) and (7.2) can be rewritten as

$$p_t-C'\left(Y_{it}\right)=w_t^{n}-\frac{E\left\{\left(1+\ {}_{t+1}\right)^{-1}U_{it+1}{}'\left(\ {}_{it+1}\right)\left[p_{t+1}-C'\left(Y_{it+1}\right)\right]\right\}}{U'\left(\ {}_{it}\right)} \qquad (9.1)$$

$$w_t^{u}=\ \frac{E\left\{\left(1+\ {}_{t+1}\right)^{-1}U_{it+1}{}'\left(\ {}_{it+1}\right)\left[p_{t+1}-C'\left(Y_{it+1}\right)\right]\right\}}{U'\left(\ {}_{it}\right)} \qquad (9.2)$$

Equation (9.1) says that the value of unused quota (w_t^n) is equal to the sum of the current plus the discounted future rental value of quota. Equation (9.2) says that the value of used quota (w_t^u) equals the discounted future rental value. These equations show that the capitalized values of unused and used quotas are influenced by the presence of policy risk. Since $E\left\{U_{it+1}'\left(\quad_{it+1}\right)\left[p_{t+1}-C'\left(Y_{it+1}\right)\right]\right\}$ is positive, an increase in α (certainty of the current policy) leads to an increase in the capitalized value of quota.

Combining (91) and (9.2) yields

$$p_t - C_{it}'\left(Y_{it}\right) = w_t^n - w_t^u = R_t \tag{10}$$

where R_t is the current rental value of quota.

The aggregate analog to (10) is

$$p_t - C_t'\left(Y_t^*\right) = R_t^* \tag{11}$$

where R_t^* is the competitive equilibrium rental value that clears both quota markets such that total production equals the total available quota Q in a given year, such that

$$\sum_{i=1}^{N} S_{it}^{n}\left(R_t^*\right) = 0 \tag{11a}$$

$$\sum_{i=1}^{N} S_{it}^{u}\left(R_t^*\right) = 0 \tag{11b}$$

$$\sum_{i=1}^{N} Y_{it} = Q \tag{11c}$$

Although equation (11) looks similar to (1), it has different implications. Equation (11) shows that the difference between the price of unused and used quota gives this year's market-clearing rental value. This result is consistent with Barichello's formulation that uses the difference between prices of unused and used quotas as a measure of the rental rate. The empirical significance of this result is obvious. The rental value of quota and the marginal cost of milk production can be derived from observed data, without any arbitrary choice of capital gain, interest rate, planning horizon, and the degree of risk inherent in the asset.

Two further results follow from equation (11). First, farmers' expectations regarding future policy changes do not affect the current year's market-clearing rental value of quota because expectations about future policy change only effect the future returns of production quota. Hence, large changes in the capitalized value of quota are consistent with a stable rental value and a stable marginal cost function. Consequently, if the rental rate of quota is calculated using the difference between unused and used quota prices, then the presence of policy risk does not cause any bias. In contrast, if rental rates are calculated using either unused quota values or used quota values discounted by an interest rate, then the presence of policy risk results in a biased estimate. As argued in Leamer and Stanbury (1983) and Beck *et. al.* (1995), this bias could be substantial.

Second, equation (11) can be used in calculating the appropriate discount rate. Rearranging equations (8.1) and (8.2) yields

$$\frac{U'(\ _{it})}{E\left(1+\ _{t+1}\right)^{-1}\left[U_{it+1}'(\ _{it+1})\right]} = \frac{E\left(R_{t+1}|t=0\right)}{w_t^u} = \frac{E\left(R_{t+1}|t=0\right)}{w_t^n - R_t} \tag{12}$$

The right hand side of equation (12) is the inverse of the marginal rate of substitution between profit at time t and *t+1*, which equals the discount rate. The discount rate is commonly derived as the ratio of the current rental value over the unused or used MSQ price. Equation (12) indicates that, if the current rental value is a correct measure of the next period’s rental value, the discount rate is under-estimated by the ratio of the current rental value over unused MSQ. In contrast, if the current rental value is a correct measure of the next period’s rental value, the ratio of the current rental value over used MSQ gives a correct estimate of the discount rate. Is it appropriate to replace next periods rental value by the current rental value? The answer depends on the stochastic process of rental values. To see this, suppose that MSQ rental values follow a random walk, with normally distributed innovations: $R_{t+1} = R_t + \quad_{t+1}, \quad _{t+1} \text{ - } N(0, \ ^2)$. It follows that $ER_{t+1} = R_t$. Denoting the discount rate as r_t yields

$$r_{t+1} = \frac{R_t}{w_t^u} = \frac{R_t}{w_t^n - R_t} \tag{13}$$

The discount rate can be correctly derived by the ratio of the current rental value over used MSQ price only if the MSQ rental value follows a random walk. Otherwise, the discount rate cannot be directly observed (though the marginal cost is observable).

V. Effects of a Transfer Assessment

The transfer assessment levied on quota sales, by the marketing boards applies to both unused and used quotas offered for sale in the auction market. Let τ denote the percentage of quota that is withheld by the marketing board. Under the assumption that there are only two types of producers, *h* type producers are effected directly, while *l* type producers are effected indirectly by the transfer assessment.

For a quota seller $k \in M$, their profit in a dairy year t is

$$_{kt} = p_t Y_{kt} - C(Y_{kt}) - w_t^n (1- \quad) S_{kt}^n - w_t^u (1- \quad) S_{kt}^u \tag{14}$$

This specification indicates that the transfer assessment acts like a value tax on the seller of quota.

Solving the maximization problem described by (6) subject to (3) and (13) for the k^{th} producer of h type gives the following first order conditions

$$p_t - C'(Y_{kt}) = w_t^n (1- \quad) - \quad (1+ \quad)^{-1} \frac{E\{U_{kt+1}'(\quad_{kt+1})[p_{t+1} - C'(Y_{kt+1})]\}}{U'(\quad_{kt})} \tag{15a}$$

$$w_t^u\left(1-\quad\right)=\frac{E\left\{U_{kt+1}'\left(\quad_{kt+1}\right)\left[p_{t+1}-C'\left(Y_{kt+1}\right)\right]\right\}}{EU'\left(\quad_{kt+1}\right)} \tag{15b}$$

Substituting (15b) into (15a) yields

$$p_t-C'\left(Y_{kt}\right)=\left(1-\quad\right)\left[w_t^n-w_t^u\right] \tag{16}$$

Equations (15a), (15b) and (16) indicate that the transfer assessment effects not only the prices of unused and used quotas but also the appropriate calculation of the rental value of quota. However, this is only a part of the story since *l* type farms are also affected by the transfer assessment.

The maximization problem for *l* type farms, in the presence of the transfer assessment, is similar to maximizing (6) subject to (3) and (4). Hence equations (8) and (9) still apply to these producers. Moreover, equation (9) for l type producers still holds. Suppose the aggregate analog to (9) and (16) exist. Then, there is an R_t such that the quota market clears and the total quantity of production equals the total quantity of quota available in a given year

$$\sum_{k=1}^{M} S_{kt}^n\left(\left(1-\quad\right)R_t\right)=\sum_{j=1}^{H} S_{jt}^n\left(R_t\right) \tag{17a}$$

$$\sum_{k=1}^{M} S_{kt}^u\left(\left(1-\quad\right)R_t\right)=\sum_{j=1}^{H} S_{jt}^u\left(R_t\right) \tag{17b}$$

$$\sum_{i=1}^{N} Y_{it}=Q \tag{17c}$$

How does the transfer assessment effect the calculation of the equilibrium rental rate? To answer this question, the effect of the transfer assessment on the prices of unused and used quotas must be determined. Totally differentiating (17a) and (17b) with respect to τ and converting the results into elasticities gives

$$\frac{\quad}{w_t^n}\frac{w_t^n}{\quad} = \frac{\quad}{(1- \quad) - {}_t^n \big/ {}_t^n} \tag{18a}$$

$$\frac{\quad}{w_t^u}\frac{w_t^u}{\quad} = \frac{\quad}{(1- \quad) - {}_t^u \big/ {}_t^u} \tag{18b}$$

where ${}_t^n = \frac{w_t^n}{\sum_{j=1}^{H} S_{jt}^n}\frac{\sum_{j=1}^{H} S_{jt}^n}{w_t^n}$ and ${}_t^u = \frac{w_t^u}{\sum_{j=1}^{H} S_{jt}^u}\frac{\sum_{j=1}^{H} S_{jt}^u}{w_t^u}$ are the demand elasticities for unused and used quotas, and ${}_t^n = \frac{w_t^n}{\sum_{i=1}^{M} S_{it}^n}\frac{\sum_{i=1}^{M} S_{it}^n}{w_t^n}$ and ${}_t^u = \frac{w_t^u}{\sum_{i=1}^{M} S_{it}^u}\frac{\sum_{i=1}^{M} S_{it}^u}{w_t^u}$ are the supply elasticities for unused and used quotas.

Equations (18a) and (18b) indicate that the effect of the transfer assessment on the price of unused quota hinges on the relative size of the demand and supply elasticities as well as on the level of the transfer assessment. In general, as long as the supply and demand elasticities have their normal signs (< 0, > 0), then the effect of the tax is to raise the price of quota ($\frac{w_t^n}{\quad} > 0$ and $\frac{w_t^u}{\quad} > 0$). Moreover, the effect of the transfer assessment on the prices of unused and used quotas is different, if the ratio of the demand to supply elasticity is different for the two types of quota.

To calculate the rental value in the presence of the transfer assessment, prices of unused and used quotas must be adjusted by equations (18a) and (18b). Hence, equation (10) becomes

$$p_t - C'(Y_t) = w_t^n - w_t^u + \left[\frac{w_t^n}{(1- \quad) - {}_t^n \big/ {}_t^n} - \frac{w_t^u}{(1- \quad) - {}_t^u \big/ {}_t^u}\right] \tag{19}$$

Equation (19) shows that to obtain the rental value of quota in the presence of the transfer assessment, information on the demand and supply elasticities for quota is required. The rental value of quota can no longer be inferred directly from knowledge of the capitalized values of quota in the presence of a transfer tax. In the absence of the transfer assessment *(=0)*, equation (10) is restored.

Depending on the size of demand and supply elasticities for quota, the difference between unused MSQ and used MSQ prices could either over or underestimate the equilibrium rental value. This is troubling for empirical work because we have little evidence on the size of the relevant elasticities. Lambert *et. al.* (1994) estimated demand and supply price flexibilities for unused MSQ and used MSQ in Ontario. Their estimates suggest that $^{n} = -250$, $^{n} = 6.67$, $^{u} = -5$, and $^{u} = 10$ for Ontario. While it is not surprising to observe that the demand for MSQ in Ontario is very elastic, it is surprising to observe that the supply of MSQ is also very elastic. Their estimates also suggest that the demand for unused MSQ in Ontario is much more elastic than that for used MSQ. Substituting these observed parameters into equation (19) yields the following formula for estimating the MSQ rental value

$$p_t - C'(Y_t) = 1.0039 w_t^n - 1.1111 w_t^u \qquad (20)$$

VI. Rental Values, Discount Rates[1] and Marginal Costs

In Ontario, the quota exchange is operated once a month. However, there is no auction for used quota in the first two months of the dairy year. As a result, there are monthly observations on the price of unused quota and 10 prices for used quota each year. Since the theoretical model is based on the dairy year, (20) must be modified when it is applied to monthly data. Suppose that a buyer purchases a unit of used MSQ in October. The opportunity cost for a buyer of used MSQ in October rather than December, equals the interest on the principal for two months. A similar result applies to sellers. The value of used quota must therefore reflect the time value of money from month to month during the dairy year. Consequently, equation (20) becomes

$$R_{mt} = 1.0039 w_{mt}^{n} - 1.1111 w_{mt}^{u} \prod_{z=m}^{12} \left(1 + r_{zt}\right) \tag{21}$$

where r_m is the monthly interest rate, and subscript m indicates the month of the dairy year.

The prices of unused and used quota are available from DFO. However, unused and used MSQ prices were reported as dollars per liter before August 1990 and as dollars per kilogram of butterfat afterwards. Unused and used MSQ prices after August 1990 were converted to dollars per litre using a 12 month weighted average of butterfat test results. As a proxy for the interest rate the monthly prime business loan rate in Canada is used To compute marginal costs, information is required on the average industrial milk price. This price is measured by the class 3-6 blend price less transportation costs, marketing board fees and the in-quota levy in Southern Ontario. However, the class 3-6 blend price was not reported after August 1991. The class 3-6 blend prices after August 1991 were obtained by taking the base price plus the class 3-6 price differential adjusted for quality factors, including butterfat, protein, and other solids.

Using equation (21), the rental value of quota, the discount rate, and marginal costs are calculated for each month from 1980/81 to 1994/95. The monthly values for each variable were unstable, both within the dairy year and across the time series. Hickling, noting the seasonality of quota values, singled out the seasonality of marginal cost as the main source of such volatility. To the extent that seasonality is the chief source of variability it should be reasonably consistent from year to year and it could be arbitraged away. Seasonality cannot account for estimated marginal costs which vary from 0.03 in March to 0.40 in October of the same year. Other possible factors such as quota enforcement rules (over-quota levy and maintenance requirements), market thinness and rules which impede effective arbitrage between the used and unused quota markets may explain the erratic quota price movements.

To reduce short-run variability, two different rental values are calculated based on December figures[4] and a ten-month (October-July) average. The annual rental value is computed using Barichello's formula, equation (20) and equation (21). These three calculations are denoted as Formula A, Formula B, and Formula C in Table 1. Annual discount rates and marginal costs are derived from equations (13) and (11), using the results from formulas A, B, and C (Table 2 and Table 3). The measured marginal costs still exhibit considerable variation, over time, and in a few cases are even negative.

The variability of measured annual marginal costs over time is troubling. Imputed marginal costs reflect expectations about the cost structure of the industry so they encompass changing expectations about future feed prices, but it is hard to reconcile this with imputed marginal costs ranging from 17 cents per litre, in 1983/84 when grain prices were high, to 30 cents in 1986/1987 when grain prices were low (Table 3, annual average, Formula C). While policy risk could be higher in 1986/1987 than in 1983/84, with the start of the GATT negotiations, this should have been reflected in the price of both used and unused quotas. Moreover, imputed marginal cost in 1991/1992 is negative. To have some sense of how reasonable the inferred marginal costs are, they are compared to estimates of the average cost of producing industrial milk in Canada (Table 4). The computed marginal costs for Ontario milk production seem to fluctuate 'excessively', and are often quite low compared to average variable cost estimates.

VII. Conclusions

Using the fact that separate markets exist for used and unused quota, a formula to compute the marginal cost of milk production using a competitive dynamic optimization model is

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[4]Hickling suggested the use of the December rental value as a representative annual rate.

developed. With a perfectly competitive quota market, the difference between unused quota and used quota prices gives an exact measure of the rental value of quota and thus marginal cost. Policy risk is shown to have no effect on the calculation of the equilibrium rental value of quota. After modifying the formula to allow for the presence of a transfer assessment, it is shown that its effect on the calculation of the equilibrium rental value of quota depends on the elasticities of demand and supply for quota as well as the level of the transfer assessment.

Using empirically estimated elasticities of demand and supply for quota, the formula is used to compute the marginal costs of Ontario milk production over the period 1980/81 to 1994/95. The measured marginal costs are often unsatisfactory. The calculated monthly rental rates are unstable, both within the dairy year and across the time series. The results suggest that the use of the difference between unused and used quota prices as a measure of rental rate, while conceptually correct, often produces unrealistic results. It is possible that the assumptions of the theoretical model could be relaxed to provide an explanation for the high volatility of the monthly rental values, calculated using (21). Possible avenues for exploration are the effects of quota enforcement rules (over-quota levy and maintenance clause) and rules which impede effective arbitrage between the used and unused quota markets. The quota bidding rules and the lack of arbitrage between the used and unused quota markets may be responsible for the volatility in the difference in the two price series. Consider a producer who is planning to increase the size of their herd in the next few months. They have the option of buying unused quota and increasing production quickly, or buying used quota and increasing production in the next dairy year. The producers estimate of their marginal cost, output price and time value of money will determine the amount they are willing to bid for used and unused quota. They must either bid on the used exchange or the unused exchange. Producers are not allowed to submit a bid in the used auction, conditional on not having bought quota in the unused auction. This rule prevents effective arbitrage between the two quota auction markets and breaks the link between their values, thereby exacerbating price instability.

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Table 1. Nominal Annual Rental Values of Industrial Milk Quotas, Ontario, 1980/81-94/95*

Dairy Year	Annual Average			December		
	Formula A	Formula B	Formula C	Formula A	Formula B	Formula C
1980-81	0.10	0.07	0.06	0.14	0.11	0.09
1981-82	0.10	0.08	0.06	0.07	0.05	0.03
1982-83	0.29	0.25	0.22	0.27	0.23	0.19
1983-84	0.30	0.24	0.20	0.25	0.20	0.14
1984-85	0.26	0.19	0.13	0.22	0.17	0.10
1985-86	0.34	0.27	0.21	0.27	0.21	0.13
1986-87	0.21	0.14	0.09	0.19	0.13	0.05
1987-88	0.23	0.17	0.13	0.13	0.08	0.04
1988-89	0.31	0.25	0.21	0.30	0.25	0.18
1989-90	0.14	0.09	0.05	0.06	0.01	-0.04
1990-91	0.32	0.26	0.23	0.17	0.13	0.08
1991-92	0.53	0.46	0.41	0.32	0.27	0.22
1992-93	0.52	0.42	0.34	0.48	0.39	0.27
1993-94	0.24	0.13	0.05	0.20	0.11	0.04
1994-95	0.37	0.25	0.12	0.28	0.17	-0.02

*Formulas A, B, and C indicate how the rental value of quota is calculated. Formula A is based on equation (10), $R_t = w_t^n - w_t^u$, where R_t is the current rental value of quota, w^n and w^u are the capitalized values of unused and used quotas). Formula B is based on equation (20), $R_t = 1.0039 w_t^n - 1.1111 w_t^u$. Formula C is based on equation (21), $R_{mt} = 1.0039 w_{mt}^n - 1.1111 w_{mt}^u \prod_{z=m}^{12} (1 + r_{zt})$, where r_m is the monthly interest rate, and subscript m indicates the month of the dairy year.

Table 2. Nominal Discount Rates of Industrial Milk Quotas, Ontario, 1980/81-94/95*

Dairy Year	Annual Average			December		
	Formula A	Formula B	Formula C	Formula A	Formula B	Formula C
1980-81	0.39	0.29	0.23	0.54	0.43	0.34
1981-82	0.43	0.33	0.26	0.32	0.22	0.14
1982-83	0.68	0.57	0.51	0.70	0.60	0.49
1983-84	0.54	0.44	0.36	0.50	0.39	0.28
1984-85	0.42	0.31	0.21	0.44	0.33	0.21
1985-86	0.51	0.40	0.31	0.45	0.34	0.22
1986-87	0.33	0.23	0.15	0.31	0.21	0.08
1987-88	0.39	0.28	0.21	0.28	0.17	0.07
1988-89	0.56	0.46	0.38	0.60	0.50	0.37
1989-90	0.30	0.20	0.11	0.14	0.03	-0.09
1990-91	0.60	0.49	0.41	0.43	0.32	0.21
1991-92	0.76	0.66	0.59	0.64	0.54	0.45
1992-93	0.55	0.45	0.36	0.57	0.47	0.32
1993-94	0.23	0.12	0.04	0.25	0.14	0.05
1994-95	0.33	0.23	0.10	0.27	0.16	-0.02

*Formulas A, B, and C indicate how the rental value of quota is calculated. Formula A is based on equation (10), $R_t = w_t^n - w_t^u$, where R_t is the current rental value of quota, w^n and w^u are the capitalized values of unused and used quotas). Formula B is based on equation (20), $R_t = 1.0039 w_t^n - 1.1111 w_t^u$. Formula C is based on equation (21), $R_{mt} = 1.0039 w_{mt}^n - 1.1111 w_{mt}^u \prod_{z=m}^{12} (1 + r_{zt})$, where r_m is the monthly interest rate, and subscript m indicates the month of the dairy year.

Table 3. Nominal Marginal Costs of Ontario Milk Production, 1980/81-94/95*

Dairy Year	Annual Average			December		
	Formula A	Formula B	Formula C	Formula A	Formula B	Formula C
1980-81	0.21	0.24	0.26	0.17	0.20	0.22
1981-82	0.24	0.26	0.28	0.26	0.29	0.30
1982-83	0.06	0.10	0.13	0.08	0.12	0.16
1983-84	0.07	0.13	0.17	0.11	0.16	0.22
1984-85	0.12	0.18	0.25	0.16	0.21	0.27
1985-86	0.05	0.12	0.18	0.12	0.19	0.26
1986-87	0.19	0.26	0.30	0.21	0.27	0.35
1987-88	0.18	0.24	0.28	0.27	0.32	0.36
1988-89	0.12	0.18	0.22	0.13	0.18	0.25
1989-90	0.29	0.34	0.38	0.38	0.42	0.47
1990-91	0.12	0.17	0.21	0.27	0.31	0.35
1991-92	-0.15	-0.08	-0.03	0.05	0.10	0.15
1992-93	-0.14	-0.04	0.04	-0.10	-0.01	0.11
1993-94	0.16	0.28	0.36	0.21	0.29	0.36
1994-95	0.06	0.18	0.32	0.12	0.24	0.43

*Formulas A, B, and C indicate how the rental value of quota is calculated. Formula A is based on equation (10), $R_t = w_t^n - w_t^u$, where R_t is the current rental value of quota, w^n and w^u are the capitalized values of unused and used quotas). Formula B is based on equation (20), $R_t = 1.0039 w_t^n - 1.1111 w_t^u$. Formula C is based on equation (21), $R_{mt} = 1.0039 w_{mt}^n - 1.1111 w_{mt}^u \prod_{z=m}^{12} (1 + r_{zt})$, where r_m is the monthly interest rate, and subscript m indicates the month of the dairy year.

Table 4. World Milk Prices, Average Costs (AC) and Marginal Costs (MC) of Ontario Milk Production, 1980/81-94/95

Dairy Year	AC of Industrial Milk Production*		World Reference Milk Price	Annual Average MC of Industrial Milk Production		
	Total AC	Variable AC		A	B	C
1980-81	/	/	0.166	0.21	0.24	0.26
1981-82	/	/	0.198	0.24	0.26	0.28
1982-83	/	/	0.204	0.06	0.10	0.13
1983-84	/	/	0.184	0.07	0.13	0.17
1984-85	/	/	0.161	0.12	0.18	0.25
1985-86	/	/	0.120	0.05	0.12	0.18
1986-87	/	/	0.107	0.19	0.26	0.30
1987-88	0.45	0.34	0.151	0.18	0.24	0.28
1988-89			0.193	0.12	0.18	0.22
1989-90	0.48	0.36	0.154	0.29	0.34	0.38
1990-91	0.49	0.37	0.156	0.12	0.17	0.21
1991-92	0.50	0.38	/	-0.15	-0.08	-0.03
1992-93	0.51	0.38	/	-0.14	-0.04	0.04
1993-94	0.61	0.43	/	0.16	0.28	0.36
1994-95	0.59	0.43	/	0.06	0.18	0.32

*Costs of production data were calculated by Canadian Dairy Commission, using survey data from Manitoba, Ontario, Quebec, and New Brunswick.