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CATPRN

Canadian Agricultural Trade Policy And Competitiveness Research Network

COST STRUCTURE OF THE ONTARIO DAIRY INDUSTRY REVISITED: DISTRIBUTIONAL ASPECTS

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ABSTRACT

The initially stated objective of the Canadian dairy supply management–farm revenue risk reduction–has been met well by the program. However, it is less clear whether the program has served all farms equally well. Namely, it is not known how successful the program was in enhancing the cost-effectiveness of smaller farms. This paper uses the 2006 Ontario dairy farm-level accounting data to compare the estimated cost structure with that identified by Moschini (1988). Next, farm size and profit distribution changes are assessed. Finally, the paper provides a simple framework for examining the relationship between current farm size and quota purchases by individual farms. The results suggest that the general cost pattern identified in the early 1980s has been retained. Average cost declines as output increases at lower output levels. However, the minimum-cost farm size has increased about threefold. Additionally, both output and profit distributions have become more skewed, with a lesser contribution by smaller farms. There is evidence that the possibility of quota exchange facilitated the greater expansion of larger farms and that the process of divergence in size and profit between small and large farms is continuing. These results have bearing on the sustainability of smaller farms.

Key words: supply management, cost structure, quota purchases

1.0 INTRODUCTION

A comprehensive supply management system for dairy products has been developed over the last four decades in Canada. According to the Canadian Dairy Commission (2009), the purpose of instituting supply management was “to address the unstable markets, uncertain supplies and highly variable producer and processor revenues that were common in the 1950s and 1960s.” In addition, Jacobson (1988) identifies preservation of small family farms as one of the implicit objectives of supply management. Phillips (2003) finds that the Canadian dairy supply management system has been quite successful in achieving farm revenue and market stability. However, it is less clear whether the program has served farms of different sizes equally well. Namely, it is not known how successful the program was in enhancing the cost-effectiveness of smaller farms.

Moschini (1988) estimated a cost function for Ontario dairy farms using six years (1978 – 1983) of farm-level data for a semi-panel rotating sample of about 80 farms per year. The results indicated that the average cost generally declines with size and is minimized at about 5,000 hectolitres per year, which was an above-average farm size at the time. The average cost, for most farms, was below the combined farm gate price paid for milk for fluid and industrial purposes. This was consistent with the idea of a higher price resulting from a limited market supply (Barichello 1981). In addition, sizeable cost-savings from future output expansion for most farms were identified.

While Moschini’s study offered a significant insight into the cost structure of Ontario dairy farms in the late 1970s and early 1980s, it did not focus on the distributional aspects of the cost savings. Lippert (2001) identifies a 1999 OECD report¹ that examined the distributional effects of agricultural support in the selected OECD countries and found an asymmetric distribution of realized benefits for dairy farms in Canada. It was found that most of the program benefits, in the form of direct payments and profit gains from market price support, are captured by the large operations. Similar results, found in the assessments of EU dairy policy by Guyomard et al (2004), Moro et al (2005), and Cathagne et al (2006), show the generality of the issue. However, this body of literature is still lacking an assessment of the changes in the distribution of program benefits in a supply managed dairy industry over a longer period of time.

The purpose of this paper is to address this gap by assessing the changes in the cost performance within the Ontario dairy industry, especially as it relates to farm size. The paper uses the 2006 Ontario dairy farm-level cost data to compare the current cost structure of the Ontario dairy industry and the one estimated by Moschini (1988). In addition, changes in the distribution of farm sizes and profit since the early 1980s are examined. Finally, the paper estimates the effect of current quota holdings on quota purchases by individual farms to identify possible links between the distributional changes and the initial farm size.

¹ The original document was not available to the author.

2.0 CONCEPTUAL FRAMEWORK

It is assumed that, in a given year, all farms first chose input levels to minimize cost for their respective quota holding (maximum allowable output level). Subsequently, depending on the farm performance (realized profit), a farmer decides whether to buy some additional quota or sell some of the existing quota for the year to come.

The farms' quota holding is assumed to be binding in most cases, meaning that the maximum allowable output level is below the level where price and marginal cost are equal. Consequently, for these farms, future expansion is beneficial. At the same time, there may be farms that are above their optimal quota holding or some that are planning to exit the industry. These farms would benefit from sales of quota and would provide a source of quota for the farms seeking expansion. Additional quota is purchased using the realized profit in the given year (profit remaining after all productive factors are paid). The next two sections specify the framework for defining the cost minimization and quota purchase decisions.

2.1 Cost Function

Following Moschini (1988), a common production technology for all dairy farms is assumed. Each farm owns the right to produce a given level of output (quota) and this determines the position of each farm on the common production function

$$y = f(x) \tag{1}$$

where

y is a vector of output quantities; and

x is a vector of input quantities.

Farms chose input quantities to minimize cost, given their respective quota holding and input prices. Under fairly general conditions, this allows for specifying a common cost function, continuous, nonnegative, non-decreasing in input prices and output, positively linearly homogeneous and concave in input prices (Moschini 1988)

$$C(y, w) = \min_{(x)} \{w^T x : y = f(x)\} \tag{2}$$

where

C is the total cost;

y is vector of output quantities; and

w^T is a (transposed) vector of input prices.

Using Sheppard's Lemma, factor share equations can be derived

$$\frac{\partial C}{\partial w_j} = s_j \tag{3}$$

where

s_j is cost share of input j ; and

w_j is j^{th} input's price.

Moschini (1988) does not go further into examining inter-temporal adjustments in output due to the cross sectional nature of the available data. Nevertheless, some inter-temporal

inferences can still be made, even when using a “snapshot” of farms at a given point in time. The next section presents this idea by relating quota purchases to realized farm profit.

2.2 Quota Purchases Function

Given the cost function specified in Equation (2), farm profit, realized for a given quota level, can be defined as

$$\pi = Py - C(y, w) \quad (4)$$

where

π is profit remaining after all productive factors (including the opportunity cost of owner's labour and capital) are paid; and

P is the vector of output prices.

For the farms whose quota level is below the point where the marginal milk cost and milk price are equal, an increase in milk output would lead to a higher realized profit in the next year, given the current technology and milk price. Under the assumption that the additional quota that will be used in the next (unobserved) year, is purchased using some share of the realized profit at the end of the current (observed) year, it can be written that

$$P_q Q = \sigma \cdot (Py - C(y, w)) \quad \text{for } y_1 \text{ such that } \frac{\partial C(y, w)}{\partial y_1} \leq P_1 \quad \text{and} \quad Py \geq C(y, w) \quad (5)$$

where

P_q is the unit price of quota;

Q is the quantity of quota purchased;

σ is the share of realized profit used for quota purchases;

y_1 is milk output; and

P_1 is milk price.

The coefficient σ can be interpreted as an expression of individual farmer expectations. A constant σ across all farms would indicate identical farmer expectations about the important states of affairs in the future (prices, technology, etc.). From Equation (5), an implicit, twice continuously differentiable² function for quota purchases can be derived

$$Q = \frac{\sigma \cdot (Py - C(y, w))}{P_q} = Q(\sigma, y, w, P, P_q,) \quad (6)$$

Dividing Equation (6) by y_1 , yields

$$\frac{Q(\sigma, y, w, P, P_q,)}{y_1} \equiv \% \Delta y_1 \quad (7)$$

Equation (7) is an identity representing the percentage change in milk output between the current year and the following year³. Quota purchases, as a percent of the current output, depend on the curvature of the quota purchases function. This is illustrated in Figure 1. For clarity of

² The differentiability property follows from the properties of the cost function.

³ It is assumed that this change in output will be implemented in the next production year. While it is possible that, in reality, some of the quota purchases were included in the current output, it is reasonable to assume that the expected future production is a major determinant of the quota purchase decision. Thus, for analytical consistency with the cost minimization theory, it will be assumed that there is no output expansion in the current year.

presentation, all variables other than milk output are omitted. $Q_a(y_I)$, $Q_b(y_I)$, $Q_c(y_I)$ are, respectively, quota purchases functions with a positive, zero, and negative second derivative with respect to milk output. The slope of the line connecting the origin and any point on the quota purchases function represents quota purchases as a share of the current milk output. For $Q_a(y_I)$, this share is larger for larger farms (y_I^h) compared to smaller farms (y_I^l). The percent of quota expansion is the same for all farm sizes for $Q_b(y_I)$, and decreases with output for $Q_c(y_I)$.

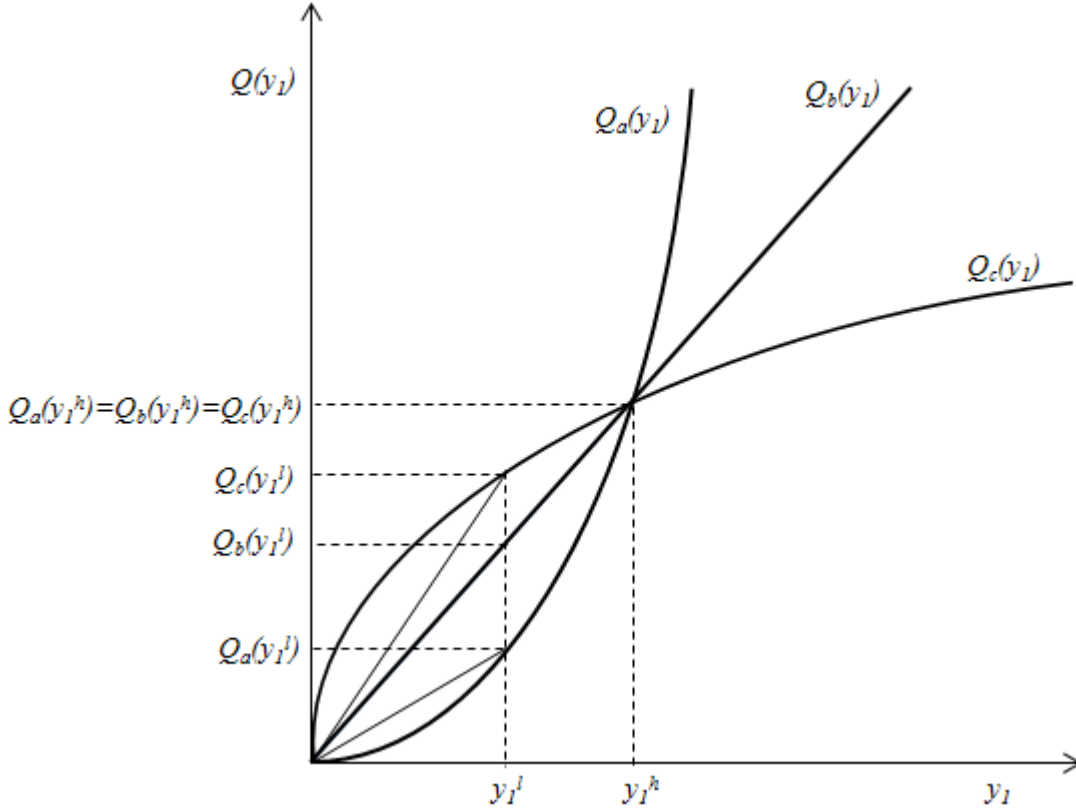


Figure 1. Quota expansion at different output levels depending on the curvature of the quota purchases function

A concave quota purchases function would imply that larger farms' quota purchases represent a smaller percentage of their current output compared to the smaller farms. This would, in turn, indicate a potential convergence in farm size in the long run. Analogously, a convex quota purchases function would indicate a divergence in farm size in the long run, while a liner function would indicate preservation of the size spread in the long run.

3.0 METHODS AND MATERIALS

3.1 Cost Function

Following Moschini (1988), the following Box-Cox transformation of the trans-log multi-output functional form of the total cost function is used

$$\begin{aligned}
\ln(C) = & \alpha_0 + \sum_{i=1}^I \alpha_i \frac{(y_i^\lambda - 1)}{\lambda} + \sum_{j=1}^J \beta_j \ln(w_j) + \frac{1}{2} \sum_{j=1}^J \sum_{n=1}^J \beta_{jn} \ln(w_j) \ln(w_n) \\
& + \frac{1}{2} \sum_{i=1}^I \sum_{m=1}^I \alpha_{im} \left[\frac{(y_i^\lambda - 1)}{\lambda} \right] \left[\frac{(y_m^\lambda - 1)}{\lambda} \right] + \sum_{i=1}^I \sum_{j=1}^J \mu_{ij} \left[\frac{(y_i^\lambda - 1)}{\lambda} \right] \ln(w_j) \\
& + \varepsilon
\end{aligned} \tag{8}$$

The corresponding factor share equations are

$$s_j = \beta_j + \sum_{n=1}^J \beta_{jn} \ln(w_n) + \sum_{i=1}^I \mu_{ij} \left[\frac{(y_i^\lambda - 1)}{\lambda} \right] + \eta_j \tag{9}$$

where

y_i and y_m are quantities of outputs;

w_j and w_n are input prices;

I and J denote the total number of outputs and inputs, respectively;

α_0 , λ , α_i , β_j , β_{jn} , α_{im} , and μ_{ij} are parameters to be estimated; and

ε and η_j are random error terms.

The rationale for using a multi-output function is that dairy farms often produce crops and livestock in addition to milk. Thus, a single output function may not be appropriate⁴.

It is assumed that the cost and cost share error terms (ε and η_j) are correlated for any given farm but uncorrelated across farms. Accordingly, Equations (8) and (9) were estimated using the procedure for estimating Seemingly Unrelated Regressions (Zellner 1962). The procedure was implemented using SHAZAM econometric software, based on Judge et al (2000). Four equations were estimated – the cost function and three cost share functions, since one cost share function needs to be excluded to avoid the singularity problem.

Parameter restrictions for symmetry and homogeneity in input prices were built into the cost function and cost share equations prior to estimation as shown in Equations (10) and (11). Equation (10) implies symmetry of cross-price derivatives of the cost function while Equation (11) implies homogeneity-of-degree-1 in input prices.

$$\beta_{jn} = \beta_{nj} \tag{10}$$

$$\sum_{j=1}^J \sum_{n=1}^N \beta_{jn} = 0 \tag{11}$$

⁴ Moschini (1988) uses farm-specific variables (milking technique, horsepower of the largest tractor, regional location, education of the operator, feeding technique, quality of land, quality of buildings, type of dairy cows, age of the operator, seasonality of milk shipment, capacity utilization and debt/equity ratio) in addition to output levels and input prices. Empirical implications of the difference in model specification are likely to be small, as all the evaluations were done at the average values of the structural variables. However, further examination of this issue would require a data-set larger than was available for this study.

Next, fitted cost values can be calculated using the estimated regression parameters. From this, Average Incremental Cost (*AIC*) values are calculated following Baumol et al (1982) and Moschini (1988)

$$AIC = \frac{C(y_1, \bar{y}, \bar{w}) - C(0, \bar{y}, \bar{w})}{y_1} \quad (12)$$

where

y_1 is milk output;

\bar{y} is the vector of other outputs fixed at the median; and

\bar{w} is the vector of input prices fixed at the median.

The *AIC* represents the portion of the total average cost that can be attributed to milk output, in addition to other outputs. As the total cost at any given milk level also depends on the levels of other outputs, other outputs are set at their median values in order for the *AIC* values for different milk levels to be comparable. The calculated *AIC* can be used to assess the basic cost structure of the Ontario dairy industry – to identify economies of size, minimum average cost point, and the spread between the milk price and average cost. In addition, *AIC* can be used to compare profit at different milk output levels.

Profit for the milk enterprise for each farm can be calculated by multiplying the farm output level with the difference between the milk price and the average cost (*AIC*). Cumulative distributions of yield and profit for a sample of farms, derived at different points in time, can then be used to assess the changes in the contribution of different farm sizes to the total industry output and profit. The next section outlines the empirical model for assessing the role of current farm size in the industry's distributional change at a given point in time.

3.2 Quota Purchases Function

Assuming output prices do not vary across farms⁵, quota purchases in Equation (5) can be specified as a function of quota price, output quantities, and input prices. The following functional form is selected

$$Q = \gamma_0 + \phi P_q + \sum_{i=1}^I \gamma_i y_i + \sum_{i=1}^I \sum_{m=1}^I \gamma_{im} y_i y_m + \sum_{j=1}^J \omega_j w_j + v \quad (13)$$

where

Q is quantity of quota purchased by individual farms;

y_i and y_m are quantities of outputs as defined in Equation 8;

w_j is price of input j as defined in Equation 8;

$\gamma_0, \phi, \gamma_i, \gamma_{im},$ and ω_j are the regression parameters to be estimated; and

v is the random error term.

Assuming that the error terms and explanatory variables are uncorrelated and that the expected value of the error term is equal to 0, estimating the above regression using Ordinary

⁵ While the price of milk does not vary across farms, realized prices of other outputs might vary. However, these differences are likely to be small for a single market. Thus, to avoid undue complexity of the model, a constant output prices are assumed.

Least Squares produces unbiased parameter estimates. The error terms and the explanatory variables are uncorrelated if the inner product of the row vector of regression errors, v^T , and the matrix of explanatory variables, $X = [P_q \ y \ w]$, equals zero ($v^T X = 0$). In addition, if the error terms are normally distributed with a constant variance, the regression t-statistics will be reliable for assessing the statistical significance of the regression parameters (Davidson and Mackinnon 2004).

The selected functional form takes into account the effect of each output on quota purchases, as well as interactions between outputs. The coefficient γ_i captures the effect of each output i on quota purchases irrespective of the level of production. γ_{im} captures the effect of output i on quota purchases at different levels of output m . Given that milk output is denoted y_1 , parameter γ_{11} is the second derivative of the quota purchases function with respect to milk output. The parameter indicates how milk output affects quota purchases at different levels of milk output. The sign and statistical significance of the parameter indicates whether there is a disproportional effect of the current milk output on quota purchases.

If γ_{11} is not statistically significantly different from zero, then the effect of current output on quota purchases is γ_1 , which is the same for all output levels and represents quota purchases as a share of current output. In other words, if γ_{11} is zero, then the quantity of quota purchased (*ceteris paribus*) is a constant share of current output for farms of all sizes. If, however, γ_{11} is statistically significantly different from zero, then quota purchases are

$$Q = \delta_0 + (\delta_1 + \gamma_{11}y_1)y_1 + c \quad (14)$$

where c represents the remaining elements of Equation (13). Thus, quota purchases, as a share of current milk output ($\delta_1 + \gamma_{11}y_1$), are larger (smaller) for larger farms if γ_{11} is greater (less) than zero. In order to estimate the above presented empirical models, individual farm cost data were used. The next section describes the data and the calculations that were performed.

3.3 Data and Calculations

This paper employs the Ontario Dairy Farm Accounting Project (ODFAP) data for 2006. ODFAP provides a detailed breakdown of inventories, expenses and revenues for a rotating sample of about 80 dairy farms in Ontario. The 2006 data contain a sample of 74 farms. In addition to the dollar value of revenues and expenditures on inputs, the purchased input quantities are reported. Thus, it is possible to calculate the implicit input prices. For some inputs, however, quantities are not reported, so certain simplifying assumptions needed to be made in order to recover input prices.

3.3.1 Cost Function

There were three outputs: milk, livestock, and crops. Quantity of milk in litres per year per farm was used as the milk output variable. Number of head of livestock sold, adjusted for weight⁶, was used as the livestock variable. Sales of grains in tons per year indicated the crop output.

⁶ The numbers of heads of livestock sold were multiplied by the following weight coefficients: 1.5 for beef bulls, 1.25 for beef cows, 1 for dairy bulls, dairy cull cows, and dairy breeding cows, 0.4 for heifers, 0.33 for feeder cattle, and for boars and sows, 0.25 for calves and feeder pigs, 0.17 for sheep, and 0.1 for gilts.

Inputs were aggregated into four groups: labour, feed, other intermediate inputs and capital. For each group, total factor cost shares and price indexes were calculated. Implicit prices for the components of the four input groups were normalized around the sample median and a weighted average was calculated for each input group. This average was used as the aggregate input price.

The ODFAP reports the total number of labour hours and the expense for hired farm labour as well as hired family labour. From this, an implicit labour wage can be computed. Due to reporting inconsistency of expenses for farm management, a figure of \$60,000 per farm per year was imputed. This corresponds to roughly 1.5⁷ average nonfarm wages in Ontario. The calculated implicit price for labour was then normalized so that the sample median equals 1.

Both value and quantity of feed and grain purchases, harvested quantity and inventories are reported, and from these, an implicit price for each category was calculated. The feed price index was calculated as a weighted average of the normalized implicit prices for purchased feeds together with purchased and harvested grain crops, grainlage, hay, and haylage net of inventory changes. Positive inventory changes are subtracted from the input quantity while negative inventory changes are added. Purchased feeds included salt and minerals, commercial feed, dairy ration, protein supplement, byproduct feeds, brewer grains, and finishing ration. Grain crops included wheat, barley, oats, mixed grains, and grain corn.

Other intermediate inputs included seed, herbicides, fertilizers, diesel fuel and gasoline, electricity, milk replacer, veterinary services, drugs, feed processing, bedding, artificial insemination fees, stable supplies, milking supplies, livestock test and registration, milk trucking, marketing cattle, DFO administration fees, semen purchased, embryos purchased, and livestock insurance. Some simplifying assumptions had to be made, since no quantities for any intermediate inputs except fertilizer were reported. It was assumed that all farmers used equal per-acre quantities of seed, herbicides and pesticides, diesel fuel and gasoline. This allowed for calculating an implicit per-hectare price for these inputs. For electricity, it was assumed that the quantity used was directly proportional to the barn size. An aggregate price index was calculated as a weighted average of the normalized prices for fertilizer, seed, herbicides/pesticides, diesel fuel and gasoline, and electricity. Furthermore, it was assumed that the aggregate price of the remaining intermediate inputs was highly correlated with the aggregate price index for seed, herbicides and pesticides, diesel fuel and gasoline. This allows for using the calculated price index as a proxy price for the whole input group.

Even though most capital is owned, to account for the full cost of capital, the notion of user cost of capital is used. The user cost of capital was calculated as a sum of the interest on capital, taxes on capital (real estate taxes) and capital depreciation. The interest on capital was calculated as the product of the real interest rate (the ten year average⁸ prime lending rate minus the ten year average inflation rate) and the total value of capital. Depreciation rates of 15% and 5% were applied to machinery and buildings, respectively, while no depreciation was applied to land and livestock. To obtain the total cost of capital, the user cost of capital was added to the sum of the rental cost of land and buildings and the repair cost for buildings and machinery.

⁷ Average number of operators per farm, taking into account recent statistical estimates, was assumed to be 1.5.

⁸ The ten-year averages were calculate up to 2006.

Moschini (1988) accounts for the price capital by first calculating implicit prices for different capital items by deflating the reported value of a capital item by its quantity and then by aggregating the implicit prices of different capital items into a single implicit price index for all capital. However, the 2006 ODFAP data report the quantities of livestock, but not quantities of other capital inputs. Thus, the data structure does not allow a complete replication of Moschini's method for calculating the price of capital. Instead, the available livestock data were used to calculate the implicit price of livestock, and this price was used as a proxy for the price of capital.

All explanatory variables were normalized around the median before estimation. Table 1 displays some summary statistics of the dependent and the explanatory variables used in the regression. Comparing the position of the mean, relative to the median, indicates that the distribution of the cost variable and all three output variables (median is 1 for all three outputs) are positively skewed. This means that there are relatively few large observations compared to the number of smaller observations. The variation in the variables, indicated by the standard deviation and the minimum and maximum values, is quite high for the cost and all output variables. The level of skew and variation is much lower for the input prices and input cost

Table1. Selected summary statistics for the variables used in the cost function estimation					
Variable Name	Symbol	Mean ^a	Standard Deviation	Minimum	Maximum
Cost (\$)	<i>C</i>	429,800 (327,163)	317,490	171,080	1,816,300
Outputs					
Milk	<i>y₁</i>	1.403	1.240	0.238	6.558
Crops	<i>y₂</i>	2.198	4.663	0.000	33.392
Livestock	<i>y₃</i>	1.314	1.228	0.111	7.025
Input price indexes					
Labour	<i>w₁</i>	1.125	0.431	0.459	2.571
Feed	<i>w₂</i>	1.037	0.225	0.644	1.706
Intermediate Inputs	<i>w₃</i>	1.079	0.348	0.420	2.256
Capital	<i>w₄</i>	0.898	0.203	0.412	1.167
Factor Cost Shares					
Labour	<i>s₁</i>	0.232 (0.230)	0.065	0.118	0.401
Feed	<i>s₂</i>	0.265 (0.263)	0.073	0.132	0.562
Intermediate Inputs	<i>s₃</i>	0.235 (0.235)	0.051	0.069	0.395
Capital	<i>s₄</i>	0.268 (0.264)	0.065	0.106	0.414

^a Median values, if different from 1, are reported in brackets.

shares. Feed, labour, and other intermediate input prices are positively skewed, while the price of capital is negatively skewed.

3.3.2 Output and Profit Distributions

In order to compare the output and profit distributions in the early 1980s with the ones in 2006, a yield distribution for the period 1978-1983 was obtained using the eight output percentile

values presented in Table 6 from Moschini (1988)⁹. Due to the lack of data on each individual farm, the eight percentile points were then used to construct smoothed cumulative distribution curves for milk output and profit in Microsoft Excel.

The actual cumulative output at the i^{th} percentile for the 1978-1983 sample was approximated by the product of the mean of the the i^{th} percentile farm and the preceding available percentile farm output, and the distance between the two percentiles. For example, the cumulative output at the 25th percentile was calculated by multiplying the mean of the 25th percentile and the 1st percentile farm output ($\frac{1}{2}(y_1^{25^{th}} + y_1^{1^{st}})$) by 24 (the distance between the 1st and 25th percentile). The 50th percentile cumulative output was calculated by multiplying the mean of the 50th percentile farm and the 25th percentile farm output ($\frac{1}{2}(y_1^{50^{th}} + y_1^{25^{th}})$) by 25 (the distance between the 50th and the 25th percentile). The same procedure was used for the other six percentile points.

Profit¹⁰ at different milk output levels for the period 1978 – 1983 was calculated by reading off and subtracting the Average Incremental Cost (AIC) values in Moschini (1988) Figure 1 from the average price for fluid and industrial milk (\$40/hl) and by multiplying the difference by the corresponding output level. The cumulative profit distribution was derived analogously to the cumulative output distribution.

To test for the validity of the approximation procedure used for deriving the cumulative output and profit distributions, actual cumulative output and profit distribution for 2006 were calculated using all 74 observations. An 8-point approximation technique, analogous to the one used for the period 1978-1983 was then used for 2006. The deviation between the actual sample distribution and the 8-point approximation was in the range of one percentage point. The blend milk price net of deductions, used for the calculation of milk enterprise profit in 2006 was \$65.83 (OMAFRA 2006).

3.3.3 Quota Purchases Function

Quota purchases were recorded in kilograms of butterfat equivalent per day, while quota price was in dollars per kilogram of butterfat equivalent. Both values were centered on the median prior to estimation. Other explanatory variables (output quantities and input prices) were defined as in the previous sections.

About a third of the sample farms (28) purchased, on average, 4.1 kg/day of quota (or about 7% of current quota holding), and only these farms were included in the estimation. This was based on two reasons. First, any possible relationship between the explanatory variables and the nonzero dependent variable is likely to be lost due to the large number of zero values. Second, even farms that sold quota were assigned zero value for quota purchases in the original

⁹ Moschini (1988) reports milk output values at 1st, 25th, 50th, 75th, 85th, 90th, and 100th percentile.

¹⁰ This measure captures profit from milk production but not from other outputs. However, it is unlikely that this would significantly distort the result, as crops and livestock are generally not the major outputs. In addition, the crops and livestock enterprise profit margins are likely to be much smaller due to the competitiveness of the markets for crops and livestock relative to the milk market.

data set. These farms are inappropriate for inclusion in the quota purchases equation. Since the data on quota sales were generally not reported, it was impossible to determine which farms with no quota purchases did not sell any quota. Thus, only the farms with non-zero quota purchases were considered for estimation.

4.0 RESULTS

4.1 Cost Function

The estimated regression parameters and the respective t-statistics for the cost function and cost share equations are reported in Table 2. Similar to the Moschini (1988) estimate, the sign of the λ parameter (the exponent on the output variables) is positive and statistically different from zero at the 1% level, indicating the typically U-shaped average cost curve. Milk and crop outputs were statistically significant while livestock was not. All input prices were statistically significant as well. Of the remaining interaction coefficients, only 7 were statistically significant at the 5% level. None of the interaction parameters for the three outputs were statistically significantly different from zero at the 5% level, indicating global separability of outputs (Moschini 1988).

The estimated cost function was tested for non-negativity, monotonicity, and concavity at the median of the explanatory variables and found to be nonnegative and increasing in input prices and all three outputs. On the other hand, the function did not satisfy the condition for concavity in input prices at the tested point (the Hessian $\frac{\partial^2 C}{\partial w_i \partial w_j}$ was indefinite).

The non-concavity of the cost function could be corrected by imposing either local or global concavity (Ryan and Wales 2000). However, as demonstrated Dewart and Wales (1987), imposing global curvature on a trans-log function underpins its flexibility. Imposing local concavity at a single point, alternatively, may not guarantee concavity at any other point (Ryan and Wales 2000). Since the focus of this paper is on the more general structural characteristics, rather than on the details of the current cost structure, little is to be gained by re-estimating the model and imposing local concavity.

Figure 2 shows the fitted average (*AIC*) and marginal cost values for milk output. The general cost structure has not changed since the early 1980s. Similar to the Moschini (1988) estimate, the *AIC* curve has a typical U-shape, indicating economies of size at lower output levels and diseconomies at higher output levels. Similarly, marginal cost declines at the lowest levels of output and increases at higher levels. The output level at which the marginal milk cost equals price is higher than the output of the largest farm in the sample. In this sense, future expansion is beneficial for all farms.

Table 2. Estimated coefficients for the Ontario dairy industry cost function for 2006

Parameter	Estimate	t-statistic
λ	0.33234	3.058
α_0	12.70500	393.410
α_1	0.44876	5.062
α_2	0.06054	3.470
α_3	0.05598	0.812
α_{11}	0.07007	0.318
α_{12}	0.10364	1.285
α_{13}	-0.23575	-0.912
α_{23}	-0.13767	-1.986
α_{22}	0.01221	1.125
α_{33}	0.21035	1.891
β_1	0.23582	39.280
β_2	0.24889	26.457
β_3	0.23530	40.425
β_4	0.27999	20.811
β_{11}	0.04872	3.650
β_{12}	-0.01181	-0.760
β_{22}	0.03315	1.046
β_{13}	-0.03365	-3.636
β_{14}	-0.00326	-0.077
β_{23}	0.02687	1.766
β_{24}	-0.04821	-0.957
β_{33}	-0.01497	-1.156
β_{34}	0.02175	0.886
β_{44}	0.02972	0.195
μ_{11}	-0.03425	-2.462
μ_{12}	0.04117	2.010
μ_{13}	0.04066	3.121
μ_{14}	-0.04757	-1.570
μ_{21}	-0.00486	-1.676
μ_{22}	-0.01187	-2.592
μ_{23}	0.00648	2.471
μ_{24}	0.01024	1.604
μ_{31}	-0.02399	-2.139
μ_{32}	0.00497	0.286
μ_{33}	-0.01281	-1.184
μ_{34}	0.03184	1.251

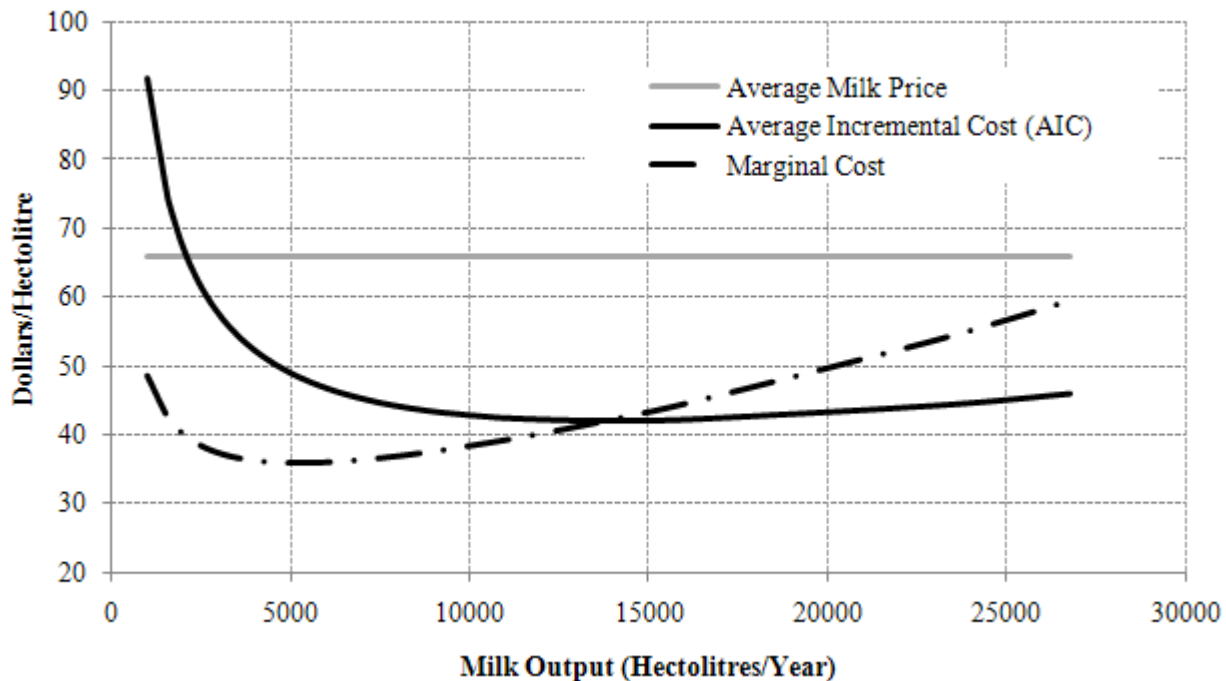


Figure 2. Estimated average and marginal cost for the Ontario dairy industry for 2006

The scale of output has increased since the last cost estimate. While the smallest farm in the period 1978-1983 produced about 400 hectolitres of milk per year, the minimum output in 2006 was more than double, at about 1,000 hectolitres. For the period 1978-1983, average cost was minimized at about 5,000 hectolitres, while in 2006, minimum average cost was at about 15,000 hectolitres of milk per year. The largest farm in 2006 (about 26,000 hectolitres/year) was more than three times the size of the largest farm for the period 1978-1983 (about 8,000 hectolitres/year). These results indicate the cost-savings identified by Moschini (1988) cannot explain all the size increase, and that there has been a significant technological change that shifted the average cost curve outward.

Similar to the situation between 1978 and 1983, average cost for more than 90% of farms was more than covered by the average farm gate price for industrial and fluid milk (net of deductions) of \$65.83/hl. The remaining 10% high-cost farms were the smallest farms in the sample. Some of these farms may have off-farm sources of income to keep them going. However, it is reasonable to expect that some of them may exit the industry and thus provide a source of quota expansion for the low-cost farms seeking to buy quota in the future.

At the minimum, average cost was below the milk price by about \$23/hl, and more than 90% of the sample farms were below the output level associated with the minimum average cost. This indicates potential costs-savings from a size increase for most farms. In the period 1987-1983, the spread between the average farm gate price for industrial and fluid milk and the estimated minimum average cost was about \$10. In percentage terms, the spread increased slightly from about 33% of the average milk price in the period 1978-1983 to about 35% in 2006. Thus the increase in the nominal production cost was slightly less than the increase in milk prices

between the early 1980s and 2006, and as a result the marginal cost of producing milk is only 65% of the price of milk and 35% are monopoly rents that accrue to quota holders. The next section looks more closely into the implications of the changes in milk output and cost for the contribution of different farm sizes to the total industry output and profit.

4.2 Changes in Output and Profit Distributions

The calculated cumulative distributions of output and profit are presented in Figure 3. The panel on the left illustrates the change in farm size (milk output) distribution between the period 1978 – 1983 and 2006, while the panel on the right shows the change in profit distribution. The figure shows six cumulative distribution curves. Four curves were derived using the approximation procedure described earlier, while two curves, marked as 2006 (actual), were derived using all 74 observations in the 2006 sample. The deviation between the 2006 approximations and the actual output and profit distributions is less than one percentage point for the most part. This provides confidence that the 1978-1983 approximations are appropriate.

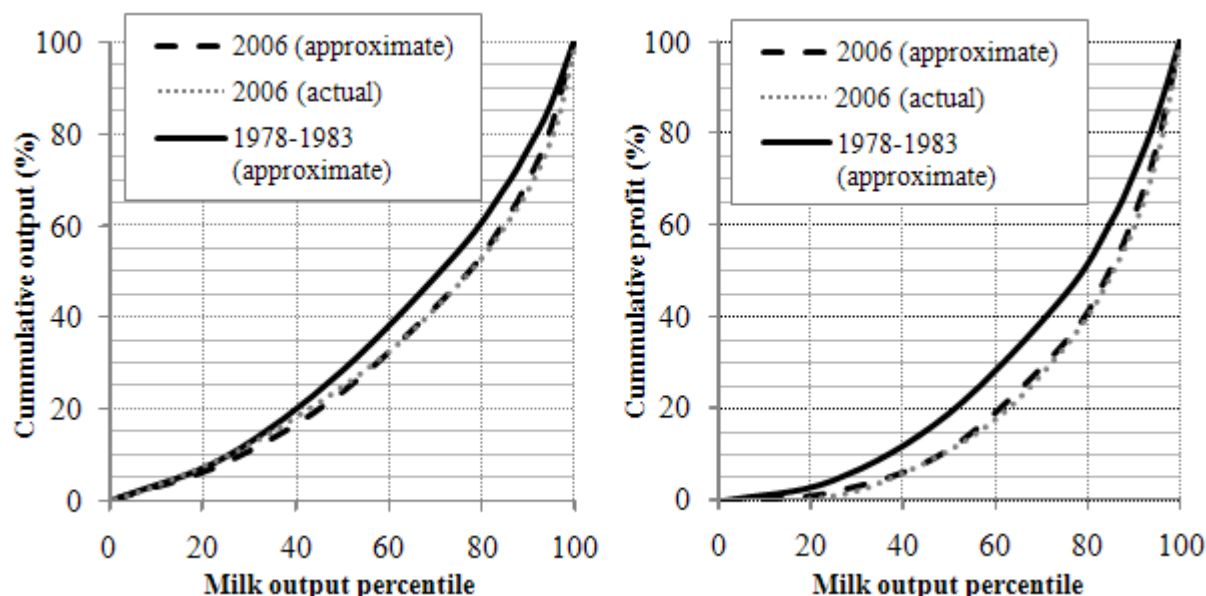


Figure 3. Changes in farm size and profit distribution between the period 1978-1983 and 2006

The output distribution curve for the period 1978 – 1983 is relatively flat at the lower size percentiles, while it gets steeper for the higher percentiles. This indicates an uneven distribution of farm sizes. For example, the bottom 50% of the farms (output-wise) produced about 30% of the total milk output in the period 1978 – 1983. The size distribution became more uneven by 2006, when the bottom 50% of the farms produced about 25% of the total output for the sample. Thus, while all farm sizes increased, the large farms increased in size relatively more than the smaller farms.

The panel on the right in Figure 3 illustrates the change in profit distribution across different farm sizes between the period 1978 – 1983 and 2006. In the period 1978 – 1983, the

bottom 50% of farms (size-wise) contributed about 20% to the industry profits. The distribution of profit became even more asymmetric than the size distribution by 2006. For example, the bottom half of the farms amounted to only about 10% of the cumulative profit in 2006. This is consistent with the finding of Moschini (1988) that there were large potential cost savings from size increase. But, it seems that having a large output to begin with, enabled some farms to be more successful in expansion. However, this is not completely clear because the farms observed in 2006 may not be the same farms observed between 1978 and 1983, given the rotating nature of the ODFAP sample. In order to assess whether the divergence in size is still occurring and whether it could be attributed to differences in the initial farm size, the relationship between the current farm size (milk output) and quota purchases in 2006 was assessed. The next section presents the results of this assessment.

4.3 Quota Purchases Function

The quota purchases function was estimated using Ordinary Least Squares procedure in SHAZAM. The adjusted R^2 for the regression was 0.94, indicating a good fit. The elements of the inner product of the vector of error terms and the matrix of explanatory variables were equal to 0 up to the 4th decimal place. The mean of the error terms was equal to 0 up to the 8th decimal place. According to the available heteroskedasticity tests in SHAZAM, the homoskedasticity assumption could not be rejected at the 5% level of significance. The Jarque-Bera normality test indicated insufficient evidence for rejecting the normality of residuals assumption at the 5% level of significance. Thus, the estimated regression parameters are unbiased and efficient and the corresponding t-statistics can be used for interpreting the statistical significance of the estimated parameters.

The estimated regression parameters for the quota purchases function are reported in Table 3. Nine of the 15 parameters were statistically significant at the 1% level. Outputs, as well as interactions between outputs were generally significant, while input prices, except for other intermediate inputs, were not. This can be interpreted by the long-run nature of the quota purchase decision. Input prices are variable in the short run, while output quantities tend to be more variable in the long run. Thus, it would be expected that the variability in quota purchases is better explained by the differences in output quantities than by input price differences.

The parameter associated with quota price had the expected negative sign and was statistically significant at the 1% level. The parameter capturing the effect of crop output on quota purchases constant for all farm sizes (γ_2) was not statistically significant. However the interaction parameters between outputs were all significant except γ_{22} . Both the linear (γ_1) and the quadratic (γ_{11}) coefficients for milk output were positive and significant at the 1% level. This means that quota purchases increased with farm size at an increasing rate.

In other words, in 2006, larger farms increased their quota holding by a greater percentage than smaller farms. This finding implicitly falsifies the hypothesis that all expanding farms used the same share of the realized profit to buy additional quota, since it was found that the cost function was convex in milk output for most of the output range. This can be interpreted as an indication of heterogeneity of farmer expectations where larger farms consistently invested more in quota expansion compared to the smaller farms. The results are also consistent with the

finding that there has been a considerable asymmetric outward expansion of the average cost curve between 1983 and 2006 and indicate that this expansion had not come to a halt by 2006.

Table 3. Estimated parameters for the quota purchases function

Parameter	Estimate	t-statistic
γ_0	14.727	3.264
φ	-14.324	-3.481
γ_1	4.8477	5.998
γ_2	0.069	0.075
γ_3	-11.172	-3.506
γ_{11}	8.027	3.136
γ_{12}	-3.649	-3.471
γ_{13}	-23.676	-5.010
γ_{23}	3.690	3.893
γ_{22}	0.189	1.831
γ_{33}	15.920	4.880
ω_1	-1.184	-1.811
ω_2	-2.518	-1.858
ω_3	1.987	2.214
ω_4	-1.845	-1.066

5.0 CONCLUSIONS

The focus of this paper was on determining how the more recent cost structure of the Ontario dairy industry compares to the one identified over 25 years ago, in order to understand the relationship between those cost structures and the changes in farms size and profit in the last two and a half decades. Furthermore, deriving some inference about the possible developments in the future was also one of the paper's objectives.

The ODFAP data indicate that there have been significant changes in the size of Ontario dairy farms over the last 25 years. These changes are consistent with the findings by Moschini (1988) that, for most farms, there were potential cost savings from farm size increases in the early 1980s. This also corresponds with the results obtained by Elskamp and Hailu (2012), who find that scale efficiency is an important factor affecting quota purchase decisions in Ontario. However, not all of the expansion can be explained by these economies of size. The results of this study suggest that there have been technological changes that increased the minimum average cost output about threefold. Additionally, there is evidence that the possibility of quota trading might have contributed to the differences in expansion rates of farms of different sizes. Namely, quota purchases as a share of current output in 2006 were statistically significantly higher for larger farms compared to smaller farms. This might explain why, compared to the situation two and a half decades ago, large farms contribute more to the total industry output.

While most farms' average cost is more than covered by the combined milk price, the distribution of profits has become more skewed. The contribution of smaller farms to the total

industry profits has shrunk significantly compared to 25 years ago. These results have implications for the Canadian dairy policy, since preservation of smaller family farms is one of its implicit objectives. It should, however, be noted that similar size increases of large farms have been identified in the non-supply managed Washington State dairy industry, where technological change was identified as the key factor in farm expansion (Skolrud et al 2007; Melhim et al 2008). But, unlike in Ontario, Washington's smallest farms grew in size relatively quickly. This could be an indication that supply management has slowed down the growth of smaller Ontario dairy farms. However, it seems that the growth of all size classes is an ongoing process.

Assuming that the 2006 data are not an exception, the polarization between many slow-growing smaller farms and few faster-growing large ones is likely to continue, provided that this growth is supported by a sufficient supply of production quota. This supply is most likely to come from the smallest, high-cost farms exiting the industry. More research for the years following 2006 is recommended. Additionally, further insights could be provided by examining yearly distributional changes over last 20 to 30 years.

REFERENCES

- Barichello, R. R. 1981.** *The Economics of Canadian Dairy Industry Regulation*. Technical report E/I2. Ottawa: Economic Council of Canada.
- Bank of Canada. 2009.** *Inflation Calculator*.
http://www.banqueducanada.ca/en/rates/inflation_calc.html (accessed April 25, 2009).
- Baumol, W. J., J. C Panzar and R. D. Willig. 1982.** *Contestable Markets and the Theory of Industry Structure*. New York: Harcourt Brace Jovanovich Inc.
- Canadian Dairy Commission (CDC). 2009.** *Supply Management*.
http://www.cdc.ca/cdc/index_en.asp?caId=812 (accessed April 25, 2009).
- Cathagne , A., H. Guyomard and F. Levert. 2006.** *Milk Quotas in the European Union: Distribution of Marginal Costs and Quota Rents*. Working Paper 01/2006. EDIM (European Dairy Industry Model) Project, Brussels.
- Davidson, R. and J. G. McKinnon. 2004.** *Econometric Theory and Methods*. New York: Oxford University Press.
- Diewert, W. E. and T. J. Wales. 1987.** "Flexible Forms and Global Curvature Conditions." *Econometrica* 55: 43–68.
- Elskamp, R. and G. Hailu. 2013.** *Do Efficient Dairy Producers Purchase Quota*. Canadian Agricultural Trade Policy and Competitiveness Research Network (CATPRN) working paper 2013-02.

- Guyomard, H., D. Moro and P. Sckokai. 2004.** *Estimating Dairy Quota Rents in the European Union: A Review of Issues*. Working Paper 01/2004. EDIM (European Dairy Industry Model) Project, Brussels.
- Jacobson, R. E. 1988.** "Supply Management Options: National Impact and Policy." *Journal of Dairy Science* 71: 2297-2303.
- Judge, G. G., R. C. Hill, W. E. Griffiths, H. Lütkepohl and T. C. Lee. 2000.** *Introduction to the Theory and Practice of Econometrics*. New York: Wiley and Sons.
- Lippert, O. 2001.** *The Perfect Food in a Perfect Mess: The Cost of Milk in Canada*. The Fraser Institute, Vancouver, B.C.
- Melhim, A., E. Donoghue and C. R. Shumway. 2008.** *Do the Largest Firms Grow and Diversify the Fastest? The Case of U.S. Dairies*. Working paper 2008-7. School of Economic Sciences, Washington State University, Washington.
- Moro, D., M. Nardella and P. Sckokai. 2005.** *Regional Distribution of Short-Run, Medium-Run and Long-Run Quota Rents Across EU-15 Milk Producers*. Paper presented at the International Congress of the European Association of Agricultural Economists, Copenhagen, August 23–27.
- Moschini, G. 1988.** "The Cost Structure of the Ontario Dairy Industry: A Microeconomic Approach." *Canadian Journal of Agricultural Economics* 36: 187–206.
- Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2006.** *Dairy Enterprise Budget*.
<http://www.omafr.gov.on.ca/english/busdev/bear2000/Budgets/livestock/cattle/dairy.xls>.
 (accessed April 20, 2006)
- Phillips, R. 2003.** "Future of Dairy Policy in Canada." *Advances in Dairy Technology* 15: 151–169.
- Ryan, D. L. and T. J. Wales. 2000.** "Imposing Local Concavity in the Trans-Log and Generalized Leontief Cost Functions." *Economics Letters* 67: 253–260.
- Skolrud, T. D., E. O'Donoghue, C. R. Shumway, and A. Melhim. 2007.** "Farm Growth, Consolidation, and Diversification: Washington Dairy Industry." *Choices* 2007: 125–28.
- Zellner, A. 1962.** "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *Journal of the American Statistical Association* 57: 348–368.