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# Do Efficient Dairy Producers Purchase Quota?

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# 1 Introduction

Canada adopted a system of supply management for industrial milk in the early 1970s to stabilize and the raise farm price, which fluctuated dramatically in the 1950s and 60s. However, since its inception, milk production quota has morphed into a high valued capital asset. In the initial stages of supply management, quota ownership was only transferable, and attempts were made to hide its underlying value. The attempted enforcement of this zero valuation objective ceased to exist after the introduction of the monthly quota exchange in 1980. The quota exchange facilitated the trading of production quota among willing buyers and sellers at market prices in Ontario.

One of the major recent criticisms brought forth by the Conference Board of Canada is that: “high [milk] prices, profits, and quota values discourage inefficient producers from leaving the market” (Goldfarb 2009, 9). High quota values may create significant entry and expansion barriers; limiting the growth of the dairy industry. Figure 1 illustrates that the real value of one kilogram of Ontario dairy quota was stable at approximately \$10,000 to \$15,000 in 1990s<sup>2</sup>. But the last decade has seen a considerable appreciation in the value of quota to well over \$30,000, and this is seen by the Ontario Milk Marketing Board (i.e., Dairy Farmers of Ontario (DFO)) as an impairment to the viability of the Ontario dairy industry. In fear of continual appreciation in value, the DFO intervened into the quota market on two separate occasions to prevent further appreciation of quota values. The DFO first implemented a progressive transfer tax in 2006 and a price cap of \$25,000/unit of quota in 2009 (Cairns and Meilke 2012).

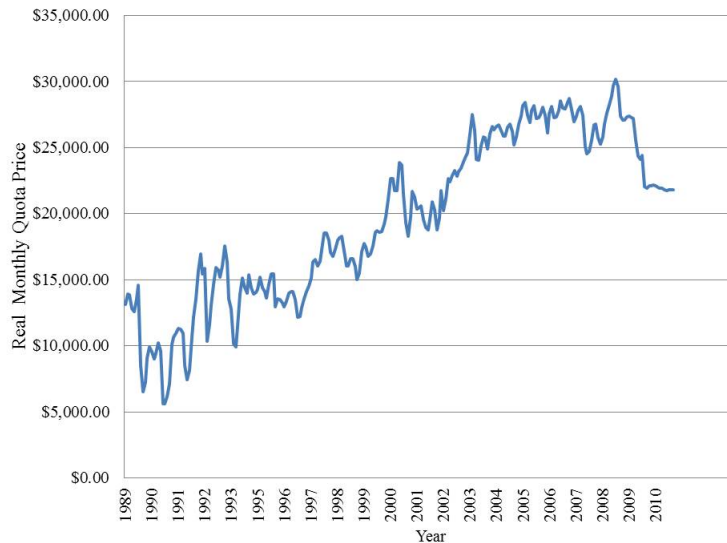


Figure 1: Ontario Real Monthly Quota Price 1989- 2010

Source: Dairy Farmers of Ontario Statistical Handbook (1989-2010)

Note: Deflated by Monthly Consumer Price Index (2002=100) Source: Statistics Canada

Inefficient allocation of resources in supply regulated industries has received considerable attention in the literature (Barichello 1999; Boots et al 1997). Barrett et al (2012) explains the distorting effects of the U.S. tobacco production quota policy showing that the main factor that contributed to increased productivity after the tobacco

<sup>2</sup>One kilogram of quota allows a dairy producer to deliver one kilogram of butterfat per day to provincially licensed milk processors. This is roughly equivalent to the annual milk (butterfat) production of an average dairy cow.

quota buyout in 2004 was the reallocation of resources. More specifically, efficient reallocation of resources occurred because of the entry and exit of producers into and out of the tobacco industry

The findings by Barrett et al (2012) and others that examined the effects of non transferable quota (Alston 1981; Burrell 1989) speak to the benefits (i.e., gains in efficiency, productivity, welfare) from the reallocation of production in supply managed industries. However, unlike the U.S. tobacco sector, the quota markets in the Canadian dairy supply managed industries are well developed. A well-functioning quota market is argued to facilitate quota exchanges from inefficient to efficient producers (Alston 1981).

The purpose of this study is to examine the effect of farm level production efficiency on milk production quota exchanges in a supply managed industry. To test the effect of production efficiency, we first estimate the cost and scale efficiency of Ontario dairy producers using Data Envelopment Analysis (DEA); second we estimate the effects of cost and scale efficiency on quota purchase decisions through the Ontario Quota Exchange over the period 2003 to 2005. Our study predates the recent policy changes in the Ontario Quota Exchange. Examples of the recent policy changes in the quota market include: 1) A progressive transfer tax (2006). 2) A price cap of \$25,000 on the resale and purchase price of quota (2009). 3) Restrictions on the number of bids and offers to one per producer (2010). 4) Restrictions on the maximum bid size to 10% of existing quota holdings (2010) (DFO 2010). The selection of the study time frame (i.e., 2003-2005) was intentional to achieve an undistorted view of quota exchanges in the Ontario dairy industry. The current price cap of \$25,000 on quota values has created a large divergence between the supply of and demand for quota. The aggregate quantity of quota bids has increased by 77% from 21,739.24 kilograms in 2009 to 97,106.73 kilograms in 2010, paralleled with a 52% reduction in annual offers from 5,414 kilograms in 2009 to 2,588 kilograms in 2010. As seen in Figure 2, this divergence in the demand for and supply of quota has resulted in a 40% overall reduction in quota transferred through the quota exchange from 2006 to 2009.

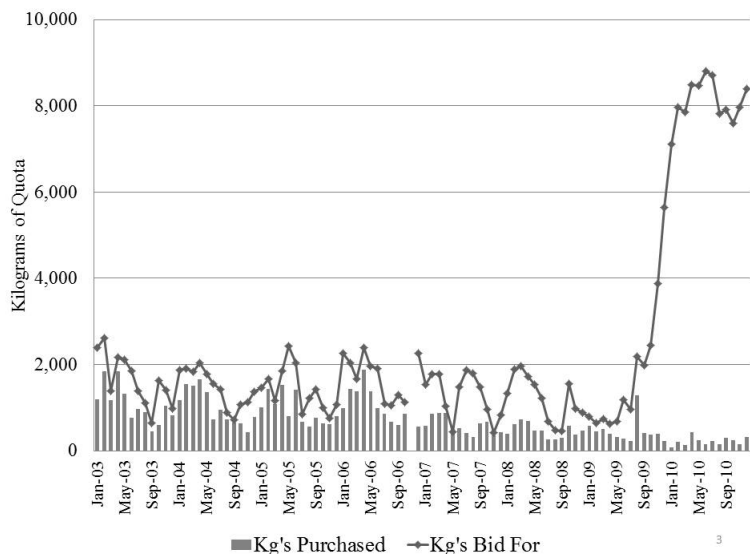


Figure 2: Quota Bids and Quota Purchases  
Source: Dairy Farmers of Ontario

The paper proceeds by modeling efficiency theory in a constrained profit maximizing framework. Using comparative statics, the theoretical relationship between efficiency and quota exchanges is then derived. The data sources are described, and the variable specification of cost efficiency and additional control variables is provided. Results of the empirical model are presented and discussed. The paper concludes with a discussion of the results, implications and policy recommendations for the Ontario dairy industry.

## 2 Microeconomics of the Efficiency Theory

The traditional theory of quota values has been thoroughly analyzed in literature examining dairy production under supply management or similar production constraining regulations (Barichello 1999; Moschini 1988; Chen and Meilke 1998; Guyomard et al 1996). The literature consists of three fundamental theories that reference production quota transfers among producers: (1) capital asset theory; (2) life cycle theory; and (3) efficiency theory. The capital asset theory states producers view quota as a financial asset. This theory argues that producers may purchase quota as a speculative asset, with plans to capitalize on potential gains in values (Burrell 1989). The producer lifecycle theory is rooted in the dynamics of family farms and the inter-generational transfer of the farm family business (Bragg and Dalton 2004). The lifecycle theory states that producers will only purchase quota during time periods that coincide with appropriate stages in their lifecycle and growth dynamics of the family. We focus on the efficiency theory to explain quota purchases. Efficiency theory states that the rental value of quota (i.e., the difference between the price of milk and the marginal cost of milk production) provides a monetary incentive for quota exchanges among producers. Heterogeneity in production efficiency may lead to differences in the marginal cost of production among producers, further leading to variations in quota value across producers. (Alvarez et al 2006). The differences in producers' valuation of quota provides monetary incentives to sell quota to (buy quota from) producers with higher (lower) willingness to pay for quota.

Our paper builds upon the profit maximization approach used by Alvarez et al (2006) to model factors affecting the price of quota. We use a profit maximization framework following Alvarez et al (2006) and apply their theoretical findings to model the key parameters of the efficiency theory (i.e., cost and scale efficiency). Using comparative statics, we then demonstrate the relationship between cost efficiency and quota exchanges (i.e., sales and purchases).

Consider a simplified illustration of a dairy industry where each producer is a price-taker, in both the variable input and output markets. The allocation of production quota to control milk production adds a production constraint to the long run profit maximizing equation for the  $i$ -th dairy producer, as given by equation 1:

$$\pi(p,w)=\max_{y_{ij}} \{ \pi = py_{ij} - C(y_{ij}, w_k) \} \tag{1}$$

$$\text{subject to } y_{ij} \leq (\bar{Q}_i)$$

where  $y_{ij}$  is a vector of output quantities where  $j$  denotes the specific output: ( $j = 1, 2, \dots, m$ ),  $C(\cdot)$  is a well behaved variable cost function,  $C' > 0$ ,  $C'' < 0$ ,  $w_k$  is a vector of input prices where  $k$  denotes the specific input: ( $k = 1, 2, \dots, n$ ),  $p_j$  is a vector of output prices and  $\bar{Q}_i$  is the initial producer allocation of quota. The constrained profit maximization problem can be optimized using the following Lagrangean equation:<sup>3</sup>

$$L = p_j y_{ij} - C(y_{ij}, w_k) + \lambda_i (\bar{Q}_i - y_{ij}) \quad (2)$$

Assuming an interior solution, the first order conditions for equation 2 can be represented as the following <sup>4</sup>:

$$\frac{\partial L(y, w)}{\partial y} = p_j - \frac{\partial C(y_{ij}, w_k)}{\partial y_{ij}} - \lambda_i = 0 \quad (3)$$

$$\frac{\partial L(y, w)}{\partial \lambda} = \bar{Q}_i - y_{ij} = 0 \quad (4)$$

Equation 5 equates the Lagrangean multiplier ( $\lambda_i$ ) to the difference between the output price and the marginal cost of production, evaluated at the quota level.

$$\lambda_i = p_j - \frac{\partial C(y_{ij}, w_k, \bar{Q}_i)}{\partial y} \quad (5)$$

If we relate this Lagrangean multiplier to the dairy industry, ( $\lambda_i$ ) is analogous to the additional profit a producer can receive for increasing production by one unit. In the context of supply management, relaxing the production constraint in equation 2 by one unit is equivalent to increasing production by one kilogram of quota. The above relationship allows us to interpret ( $\lambda_i$ ) as the value a producer is willing to pay to increase production by one kilogram of quota. Intuitively, the interpretation is attractive because a producer that can increase profit from increasing production by one unit will be willing to pay a high value for that right to increased production.

Next, we relax the assumption that all producers must produce on the cost frontier. Previous literature in the Ontario dairy industry has identified inefficiencies among producers, motivating the introduction of an efficiency parameter into the analysis (i.e., Hailu et al 2005; Weersink et al 1990; Slade 2011). Equation 6 represents the feasible production set and vectors of  $n$ -inputs and  $m$ -outputs by  $(\Psi)$ , and  $(X, Y)$ , respectively, where  $R$  is set of real numbers:

$$\Psi = \left\{ (X, Y) \in R^{(n+m)} \right\} \quad (6)$$

Under the assumption that producers exhibit cost minimization behaviour, consistent with the profit maximization assumption, we derive a measure of cost efficiency. Following Alvarez et al (2006), we focus on the traditional

<sup>3</sup>Alternatively, an unconstrained profit maximization framework incorporating quota trading can also be used to derive the same result. But for simplicity the Lagrangean method is used to model the profit maximizing behaviour of dairy producers under no quota trading.

<sup>4</sup>The corner conditions are removed from the analysis because the majority of producers in our sample are producing at or near quota constraints, suggesting the assumption of a binding constraint is appropriate.

approach to measure cost efficiency specified by Farrell (1957).<sup>5</sup> The measurement for cost efficiency is the ratio of efficient (minimum feasible) costs  $C^*(y_{ij}, w_k)$  and actual costs  $C(y_{ij}, w_k)$ :

$$\vartheta_i = \frac{C^*(y_{ij}, w_k)}{C(y_{ij}, w_k)} \quad (7)$$

where the measure of cost efficiency is represented by the parameter ( $\vartheta_i$ ) that is bounded between zero and one ( $0 < \vartheta_i \leq 1$ ). If a producer is operating at the point where the isoquant is tangent to the cost line, the producer will be cost efficient with  $\vartheta_i = 1$ . Alternatively, if a producer is not operating at the tangency point, the producer will be inefficient with a value of  $\vartheta_i < 1$ . Assuming that cost efficiency is independent of output and input levels (Kumbhaker and Lovell 2000), we take the partial derivative of equation 7 with respect to output levels.

$$\frac{\partial C(y_{ij}, w_k)}{\partial y} = \frac{\partial C^*(y_{ij}, w_k)}{\partial y} \vartheta_i^{-1} \quad (8)$$

where the actual marginal costs and efficient (theoretical minimum) marginal costs are represented by  $\frac{\partial C(y_{ij}, w_k)}{\partial y}$  and  $\frac{\partial C^*(y_{ij}, w_k)}{\partial y}$ , respectively. Equation 8 illustrates that variations in cost efficiency leads to heterogeneity among producers' marginal cost levels. Recall the rearranged first order condition of the Lagrange in equation 5, if we substitute equation 8 into equation 5, the first order condition of the Lagrangean multiplier can be represented by equation 9:

$$\lambda_i = p_j - \frac{\partial C^*(y_{ij}, w_k, \overline{Q}_i)}{\partial y} \vartheta_i^{-1} \quad (9)$$

Equation 9 illustrates the relationship between cost efficiency and a producer's willingness to pay for quota. To determine the normative effect of cost efficiency on producer's willingness to pay for quota, we take the partial derivative of equation 9:

$$\frac{\partial \lambda_i}{\partial \vartheta} = \frac{\partial C^*(y_{ij}, w_k, \overline{Q}_i)}{\partial y} \vartheta_i^{-2} > 0 \quad (10)$$

As shown in equation 10, cost efficiency positively affects producer's willingness to pay for quota. The theoretical finding suggests greater efficiency levels increase producers' willingness to pay for quota.

### 3 Econometric Model

To explore the relationship between net quota purchases and cost efficiency, we specify the following econometric model:

$$\begin{aligned} NetQuotaPurchases_i = & \beta_0 + \beta_1 Cost\ Efficiency_i + \beta_2 Scale\ Efficiency_i + \beta_3 Age_i + \beta_4 BarnUtilization_i + \beta_5 HerdSize_i + \\ & \beta_6 Year2004_i + \beta_7 Year2005_i + \beta_8 Previous\ Moderate\ Growth_i + \beta_9 Previous\ Rapid\ Growth_i + \beta_{10} Previous\ Moderate\ Exit_i + \\ & \beta_{11} Previous\ Rapid\ Exit_i + \varepsilon_i \end{aligned}$$

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<sup>5</sup>Further discussion of the measure for cost efficiency will be provided in the data section, including the decomposition of overall cost efficient into the scale efficiency and pure cost efficiency components.

where  $\beta$  is a  $(n \times k)$  matrix of estimated coefficients, ( $k$  is the number of explanatory variables including a constant intercept term),  $\varepsilon$  is a  $(n \times 1)$  vector of residuals, and individual producers are indexed by  $(i)$ , and the explanatory variables of the model are: cost efficiency, scale efficiency, producer age, barn utilization, herd size, previous quota purchases and yearly dummy variables. Finally, the dependent variable, net quota purchases, is specified as both a continuous (actual net purchases) and discrete variables (i.e., dummy variable for each: net buyers, inactive, and net sellers). Ordinary Least Square (OLS) estimation is used when net quota purchase is specified as a continuous variable, and the Multinomial Logit model is used when net quota purchase is specified as discrete variables. Of the 240 observations, 140 are categorized as inactive, 80 net purchasers and 20 net sellers of quota.

## 4 Data

The data used in the study comes from three sources: the Ontario Dairy Farm Accounting Project (ODFAP), Statistics Canada, and Dairy Farmers of Ontario. The data collected by ODFAP consists of disaggregated, farm level data, with over 1,500 variables including expenses and revenue. In addition, the physical structure of each farm is described including: herd size, milking system, and feeding technology. The majority of farms surveyed by ODFAP are quite specialized in milk production; however it is common for farms to include feedlot operations and or specialty crop production. Similar to other studies, we focus upon dairy farms receiving a significant portion (90%) of their total revenue from milk production.<sup>6</sup> Accompanying the ODFAP data set is a detailed data set provided by the DFO of the quota purchases and sales facilitated through the quota exchange. Figure 3 illustrates the proportion of quota transferred through the three mechanisms. Historically, the quota exchange was responsible for allocating approximately one-half of annual quota transfers, followed by within family transfers and on-going operations. Transactions are detailed in the data set by the quantity and price at which quota was traded. Finally, farm price indexes from Statistics Canada are used to formulate the prices required to estimate cost efficiency.

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<sup>6</sup>Revenue thresholds that have been used in previous literature include: Moschini (1988); Weersink et al (1990); and Boots et al (1997) whom restrict the sample of producers surveyed to a minimum of 90, 70, and 50 percent of total farm income from dairy revenue, respectively.



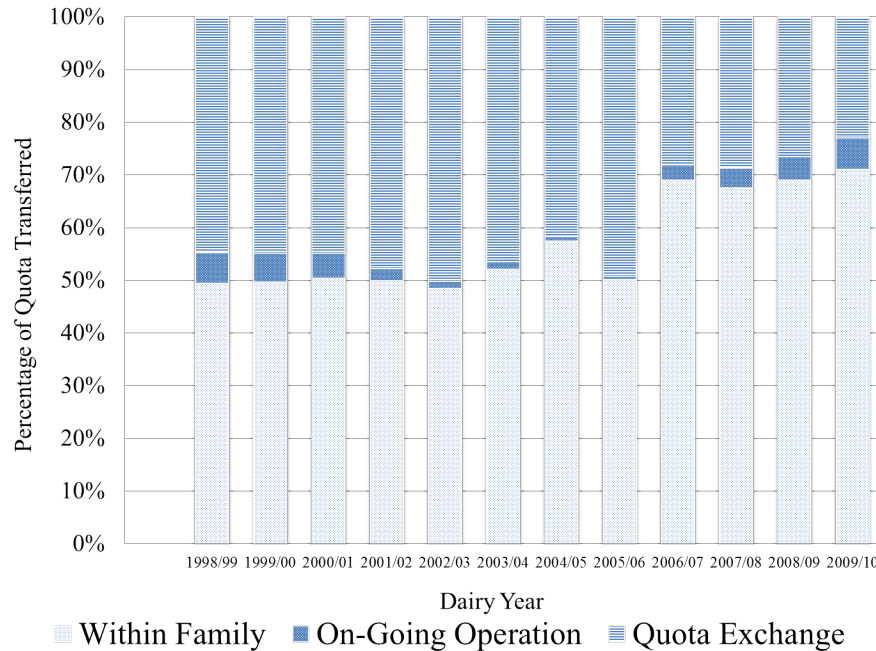


Figure 3: Summary of Ontario Quota Transfers from 1994-2010

Source: Dairy Farmers of Ontario Statistical Handbook

The dependent variable annual net quota purchases, is calculated as the difference between total annual purchases and total annual sales.<sup>7</sup> Historically, the quota exchange has been the main market mechanism used by producers to exchange quota (Chen and Meilke 1998), but producers have two other mechanisms to transfer quota: in-family transfers, and on-going operation purchases.

The main independent variables are cost and scale efficiencies. Similar to other studies (i.e., Weersink et al 1990) cost efficiency is estimated using a non-parametric benchmarking technique with a two-output, four-input production framework. The Data Envelopment Analysis (DEA) approach is a deterministic frontier, and lacks *a priori* assumptions about the functional form of the underlying cost function (Coelli et al 2005). An alternative approach to cost efficiency estimation is an econometric approach, known as Stochastic Frontier Analysis (SFA) (Kumbhakar and Lovell 2000). SFA is a parametric technique that includes a random component to represent exogenous factors outside of the firm’s control. Attempts to assert superiority between these two methods have yielded mixed results (See Bauer et al (1998) for an empirical comparison of DEA and SFA using U.S. banking data). For the purpose of this analysis, DEA has been selected as an appropriate frontier estimator. Acknowledging that the major limitation of the DEA approach is the omission of a random component, it appears that this limitation may not be too worrisome in the context of a supply regulated industry.<sup>8</sup>

<sup>7</sup>Restrictions of the Ontario quota exchange, prevent producers from submitting an offer to sell and bid to purchase quota on the same exchange. However, there is no restrictions on producers buying and selling quota in the same year, motivating the “net” calculation of the dependent variable. It should also be noted that there was only one producer who reported buying and selling quota in the same year.

<sup>8</sup>Regulations on milk price and output levels removes a large portion of the randomness that would have been captured by the random component of the SFA approach. In addition, milk production is sheltered from exogenous variables (i.e., weather) as the majority of dairy cows are housed in barns, reducing the exposure to random shocks that other industries may be vulnerable to (i.e., crop production).

## 4.1 The Data Envelopment Analysis (DEA)

DEA uses firm level production data to construct an envelopment of the most efficient firms in the sample. Firms that lie within the envelopment are considered inefficient under DEA terminology. Recall the introduction of the feasible production set in equation 6 represented by ( $\Psi$ ):

$$\Psi = \left\{ (X, Y) \in R^{(M+N)} : X \text{ can produce } Y \right\}$$

The  $n \times 1$  input matrix and  $m \times 1$  output matrix are represented by X and Y, respectively, and represent all of the data for N firms. Under the assumption of constant returns to scale, (CRS) that will be relaxed to estimate scale efficiency, DEA estimates the optimal input vector ( $x_i^*$ ) for individual firms by creating a hull around the observed firms. The following cost minimization linear programming problem is solved N times, once for each firm in the sample:

$$\begin{aligned} \min_{\lambda} \quad & w_i^T x_i \\ \text{subject to:} \quad & \\ & Q\lambda_i - y_i \geq 0 \\ & \theta_i x_i - X\lambda_i \geq 0 \\ & \lambda_i \geq 0 \text{ for } i = 1, 2, \dots, n \end{aligned}$$

where:

$x$ : vector of input quantity (nx1)

$y$ : vector of output quantity (mx1)

$w$ : vector of input prices (nx1)

$\lambda$ : vector of constants (nx1)

We construct a measurement of cost efficiency  $\theta_i$  for the  $i$ th firm as did Farrell (1957) and Coelli et al (2005):

$$\theta_i = \frac{w_i x_i^*}{w_i x_i}$$

To incorporate the rich information embodied in the cost efficiency measurement, we choose to calculate scale efficiency following Fare and Grosskopf (1985). Building upon the the traditional technology (input/output) approach, Fare and Grosskopf (1985) apply duality theory to calculate scale efficiency from a cost perspective. We now relax the assumption of CRS to allow for variable returns to scale (VRS). VRS is achieved through the above linear programming problem by imposing  $\sum_{i=1}^n \lambda_i = 1$  to the above system of equations (11). Under the assumption of

VRS, firms are benchmarked against other producers (convex combinations of firms) operating at the most efficient scale of similar size (Coelli et al 2005).<sup>9</sup>

Figure 4 provides an input orientated illustration comparing cost efficiency measurements under CRS and VRS.<sup>10</sup> The efficient frontier under the assumption of CRS is represented by OG, indicating producer B is the only efficient producers. Focusing on firm D, we can measure the departure of firm D from the CRS frontier as:  $\theta_{CRS} = \frac{F^c}{D^c}$ . Furthermore, when we assume the less restrictive model of VRS, the frontier shifts and firms AEBC are considered cost efficient. The cost efficiency measure for firm D under VRS now becomes  $\theta_{VRS} = \frac{E^c}{D^c}$ .

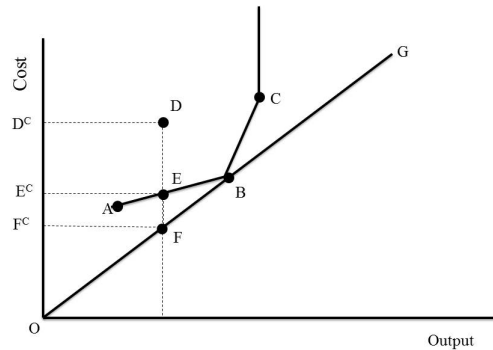


Figure 4: Graphical Illustration of VRS and CRS in a Cost Structure  
Source: Fare and Grosskopf (1985)

Assuming all producers face the same input and output prices, we take the ratio of cost efficiency measured under the assumption of CRS and cost efficiency measured under the assumption of VRS to get the following scale efficiency measurement:

$$Scale\ Efficiency = \frac{Cost\ Efficiency_{CRS}}{Cost\ Efficiency_{VRS}} = \frac{F^c}{E^c}$$

The measure of scale efficiency is bounded by zero and one, and suggests that a scale efficient firm must compose the CRS frontier as given by the linear programming problem in equation 11. Therefore, any deviations from the optimal scale (i.e., CRS) will be captured through this measurement.

Summary statistics of mean cost and scale efficiency scores of producers categorized by NQP (i.e., inactive, buyers and sellers) are provided in Table 1. Cost efficiency values for the sample of dairy farms range between 26% to 100%, with an average of 65.5%, suggesting that the sample of dairy producers are not fully successful in achieving minimum possible costs for a given output. Other things constant, there is an opportunity to produce the same level of output with approximately 35% less cost. Average scale efficiency calculated for the sample of

<sup>9</sup>Intuitively, the assumption of VRS will result in different efficiency levels compared to CRS. In fact, the VRS efficiency scores will be at least equal to or greater than the CRS efficiency scores. Under VRS, the convex combination of firms creating the hull envelopes the firms more compactly than CRS, resulting in higher efficiency scores under the VRS assumption.

<sup>10</sup>Alternatively, Figure 2 could have been illustrated in an output orientation. However, due to the production constraints imposed by quotas in supply management, the input orientation appears to be more appropriate.

producers ranged from 37% to 100% with an average of 86%. Buyers on average have higher cost and scale efficiency levels relative to sellers and inactive producers. Approximately 54% of the farmers in the “buyers” category attained a cost efficient level above the sample mean, while 80% attained scale efficiency levels above the sample mean.

The presence of cost and scale inefficiency for our sample of Ontario dairy farms are generally consistent with previous studies. Weersink et al (1990) estimates an overall technical efficiency score of 91.8% and an average scale efficiency score of 96.8% for Ontario dairy farms (1989 data?). Haghiri et al (2004) estimate an overall technical efficiency estimate of 53.2% for Ontario dairy farms, and 60.2% estimate for New York dairy farms under a pooled analysis. Finally, Hailu et al (2005) estimates an average cost efficiency of 92% with concavity of cost function imposed.

	Number of Producers	Mean $NQP^a$	Mean Cost Efficiency	Mean Scale Efficiency
Inactive	140	0	0.637	0.825
Buyers	80	6.764	0.691	0.895
Sellers	20	-4.750	0.639	0.839
Sample	240	1.859	0.655	0.849

Table 1: Summary Statistics of Average Cost and Scale Efficiency Scores  
<sup>a</sup>= Net Quota Purchase

Additional control variables specified in the empirical model are: herd size, producer age, previous purchasing behaviour, quota price, and barn utilization. Following previous literature (i.e., Burrell, 1989) dummy variables are created to capture past purchasing behaviour. Implicit quantities of quota bought (sold) in the previous years are calculated by dividing expense (revenue) by quota price as follows:

$$Implicit\ Quota\ Quantity_{t-1} = \frac{Quota\ Purchase\ Expense(Revenue)_{t-1}}{Quota\ Price_{t-1}}$$

Further transformation of the implicit quota quantity into a percentage of quota holding from the previous year is calculated by dividing implicit quantity by previous quota holdings as follows:

$$\% \text{ of Net Quota Purchase}_{t-1} (\%NQP_{t-1}) = \frac{Implicit\ Quota\ Quantity_{t-1}}{Quota\ Holdings_{t-1}}$$

Previous purchases and sales are then categorized into five dummy variables: rapid exit (if  $NQP < -15\%$ ); moderate exit (if  $-15\% < NQP < -2.5\%$ ) maintain (if  $-2.5\% < NQP < 2.5\%$ ); moderate growth if ( $2.5\% < NQP < 15\%$ ); and rapid growth behaviour (if  $NQP > 15\%$ ).<sup>11</sup> Table 2 provides a summary of the threshold values used to categorize these five variables, including average rates of purchasing and selling specific to each category.<sup>12</sup> The sample of

<sup>11</sup>Upper threshold values are based on Burrell (1989), whereas the lower threshold values are based from previous literature examining productivity increases. According to Veeman and Gray (2010), structural and productivity increases have resulted in a 43% increase in milk productivity per cow between 1991 and 2007; interpretable as a 2.5% increase per annum. The annual increase is used to construct lower threshold values to differentiate past quota purchases responding to natural productivity changes from quota purchases aimed to increase production. (Veeman and Gray 2010).

<sup>12</sup>A sensitivity test for the robustness of the estimates to varying threshold values was performed. Six different scenarios including different upper and lower threshold were estimated, with consistent results from all six estimation to the main conclusion that the effect of cost efficiency is statistically insignificant.

Ontario dairy producers is consistent with previous literature, identifying sellers are less numerous relative to purchasers and approximately 30% of the sample are trying to get bigger. In addition, producers appear to exit the market quicker than they enter, as can be seen from the average rate of rapid exit of -34%, as compared to the average rapid growth rate of 23%.

Dummy Variable	Threshold Values	# of Producers	Mean % of Quota Bought/Sold
Rapid Growth	$\%NQP_{t-1} > 15\%$	15	23%
Moderate Growth	$2.5\% < \%NQP_{t-1} < 15\%$	54	7%
Maintain	$-2.5\% < \%NQP_{t-1} < 2.5\%$	156	0%
Moderate Exit	$-15\% < \%NQP_{t-1} < -2.5\%$	12	-7%
Rapid Exit	$\%NQP_{t-1} < -15\%$	3	-34%

Table 2: Specification of Previous Purchases and Sales Dummy Variables

Producer's age, herd size and barn utilization are calculated at the beginning of the year. Producer's age is measured in years of the primary operator and herd size is measured by the number of milking cows. The concept of asset utilization refers to the maximum attainable output level, given a specific technology, and factors of production. Utilization of individual factors of production is one component of the overall resource utilization and provides a measure to understand the ability of the firm to optimally utilize resources to obtain the maximum potential output (Shaiku and Moudud 2004). The dairy barn is a major investment, therefore barn utilization may provide a short run performance measurement that captures additional size dimensions not modeled by the long run measure of cost and scale efficiency. Barn utilization is constructed as a ratio of beginning quota holdings to the maximum barn capacity:<sup>13 14</sup>

$$Barn\ Utilization = \frac{Beginning\ Quota}{Maximum\ Barn\ Capacity}$$

Year dummy variables are created to captures differences among the three years of the study. Summary statistics of the dependent and independent variables are provided in Table 3.<sup>15</sup>

<sup>13</sup>Alternatively, herd size could have replaced beginning quota holdings to calculate the ratio. Quota holdings appears to be more direct interpretation of production expectations, as it suggests the level of production a producer wishes to attain, whereas herd size may not align completely with quota holdings as herd performance plays an important role in conversion rate of kilogram of quota to milking cow. An alternative model specified with herd size was estimated, with robust results to the preferred model specification.

<sup>14</sup>We have also considered the effect of robotic milking systems in the specification of the variable. The average capacity of one robotic milking system is 50-60 cows, therefore producers may be fully utilizing robotic milkers, but given the specification of barn utilization, may be considered under utilizing fixed assets. A survey of the producers in the sample revealed that four of 240 producers (1.67%) operated with robotic milkers, indicating the potential distorting effects of the specification of barn utilization variable will be minimal

<sup>15</sup>Note that maintain dummy variable and year 2005 dummy variable are omitted to avoid dummy variable bias.

Variable	Units	Inactive	Buyers	Sellers
		Average Values		
Cost Efficiency	Percentage	0.637	0.691	0.639
Scale Efficiency	Percentage	0.825	0.895	0.839
Producer Age	Years	47.736	44.675	44.950
Barn Utilization	Percentage	0.805	0.793	0.785
Herd Size	Number of head	54.293	75.175	58.500
Moderate Exit	Dummy Variable*	6	1	5
Moderate Growth	Dummy Variable*	22	29	3
Rapid Growth	Dummy Variable*	2	13	0
Rapid Exit	Dummy Variable*	2	1	0

Table 3: Summary Statistics of Explanatory Variables

Note: the (\*) values indicate the total number of producers in each category that is specified as a dummy variable.

## 4.2 Endogeneity Issue

Specification of the explanatory variables and the nature of the data set warrant a thorough investigation of endogeneity. More specifically, endogeneity of cost and scale efficiencies are investigated in the linear model. Long run cost and scale efficiencies are annual measures, calculated in the same time period as producer’s decisions to participate in the quota market (the dependent variable). For this reason, it is difficult to determine the nature of causality. For example, it is unclear whether more (scale and cost) efficient producers purchase more quota or quota purchases affect (scale and cost) efficiency due to significant adjustment costs (Vasavada and Chambers 1986).

To test and correct for a potential endogeneity problem, instrumental variable (IV) estimation is explored. Previous literature has found that over capitalization and business organization have an effect on efficiency levels of Canadian farms (Brinkman 2002; Weersink et al 1990). To reflect the effect of business structure on scale efficiency, we follow Weersink et al (1990) and specify a dummy variable of corporate organization, to instrument for scale efficiency. To reflect over capitalization of dairy operations, mean asset per cow is used to instrument cost efficiency. Mean asset per cow is calculated as the ratio of beginning asset levels of each farm and beginning herd size:

$$\text{Mean Asset per cow} = \frac{\text{Beginning Asset Level}(\$)}{\text{Beginning Herd Size}}$$

An F-test of the joint significance of the each instrument is computed to test for its relevancy with the endogenous variable (i.e., the correlation strength between mean asset per cow and cost efficiency; and business organization and scale efficiency). For a single endogenous variable, a common rule of thumb characterizing weak instruments is an F-test statistic below 10 (Stock et al 2002). The calculated F-test statistic for cost efficiency and scale efficiency are 38 and 33, respectively, alleviating concerns of the strength of each instrument. Following the identification of an appropriate instrument, we perform two separate Hausman tests. Under the null hypothesis of the Hausman test, the OLS and IV estimators are both consistent, but the OLS estimator is more efficient (Hausman 1978). At the 5% level, we fail to reject the null hypothesis that there is no statistical difference between the OLS and IV

estimations for both instrumented variables.

## 5 Results

The MNL model is estimated using maximum likelihood in the [R] statistical programming package. A pseudo R-squared value of 18.98% was reported, indicating similar model fit to related literature (Burrell 1989). Marginal effects of the MNL model are calculated at the sample mean and are reported in Table 4 in addition to the OLS results from the linear model. Test Statistics are provided in Table 4 and are constructed using White’s heteroskedastic-consistent covariance matrix (White 1980). The results of the empirical model suggest that the decision to purchase quota may be more complex than first anticipated.<sup>16</sup>

Our main results shows that the marginal effect for cost efficiency is negative and statistically insignificant for net buyers, suggesting that cost efficiency may not effect the decision to participate in the quota exchange. On the other hand, the marginal effect for scale efficiency is positive and statistically significant for net buyers, suggesting that farms with larger scale efficiency tend to buy more milk production quota. Additional producer characteristics found to explain quota purchases in the sample of Ontario dairy producers include: previous quota purchasing behaviour; previous quota selling behaviour; and barn utilization.

Variables	MNL Model			Linear Model
	Inactive	Buyer	Seller	OLS
Cost Efficiency	0.09 (0.43)	-0.04 (-0.22)	-0.043 (-0.40)	-1.976 (-1.12)
Scale Efficiency	-1.21(-3.14)***	1.25 (3.10)***	-0.038 (-0.23)	5.573 (1.70)*
Producer Age	0.007 (2.12) ***	-0.005 (-1.55)	-0.002 (-1.18)	-0.030 (-1.17)
Barn Utilization	0.48 (3.05)***	-0.54 (-3.73) ***	0.057 (0.70)	-5.62 (-2.28) **
Moderate Exit	-0.17 (-1.14)	-0.18 (-1.81) *	0.35 (2.37) ***	-1.754 (-1.45)
Moderate Grow	-0.23 (-3.79) ***	0.25 (3.56) ***	-0.024 (-0.6)	1.754 (1.83) *
Rapid Grow	-0.44 (-3.79) ***	0.53 (4.58) ***	-0.09 (-4.84) ***	7.201 (3.09) ***
Rapid Exit	0.05 (0.27)	0.03 (0.16)	-0.08 (-4.88) ***	-0.881 (-0.87)
Herd Size	-0.001 (-0.84)	0.0004 (0.6)	0.0002 (0.70)	0.056 (3.17) ***
Year 2004	0.01 (0.16)	0.03 (0.48)	-0.04 (-0.95)	0.271 (0.35)
Year 2005	-0.017 (-0.23)	0.055 (0.84)	-0.038 (-0.87)	0.056 (0.06)
Predicted Probabilities	0.583	0.333	0.083	-
Pseudo $R^2$		0.1898		0.371
Sample Size			240	

Table 4: Marginal Effects of the MNL and OLS Model

\*, \*\*, \*\*\*\* represent significance differences between regions at the .1, .05 and .01 levels, respectively. Figures in parenthesis are test statistics.

The results of the empirical model suggest that the decision to purchase quota may be more complex than first anticipated. For example, the results suggest cost efficiency has limited explanatory power in explaining quota exchanges for this sample of Ontario dairy producers, whereas scale efficiency is found to explain quota purchases. The differing results between our empirical model and previous literature on the subject may be explained by the

<sup>16</sup>Multiple sensitivity analysis are preformed to explore the robustness of the empirical results including: alternate variable specification; and sub sampling. The results of the robustness check are omitted from the paper for simplicity, but are available from the authors by request.

variables specified in the empirical model to capture the efficiency theory. For example Burrell (1989) estimates long run marginal cost for quota purchases and finds quota was moving away from high cost producers to low cost producers. However, long run marginal cost of production may encompass: technology, scale of operation, environmental factors, and efficiency, whereas our empirical model estimates the cost and scale efficiency component separately. The positive and significant coefficient for net buyers on scale efficiency suggests producers are purchasing quota to achieve optimal size and are moving towards the constant returns to scale portion of the average cost curve. This positive sign is consistent with previous literature that showed larger dairy herd sizes are more profitable, due to higher efficiency levels (i.e., both technically and allocatively) (Mosheim and Lovell 2009).

Factors that were found to explain quota purchases in the sample of Ontario dairy producers include: producer age, past purchasing behaviour, and barn utilization. Consistent with the producer lifecycle theory, the negative sign for net buyer's age suggests older producers enter a disinvestment stage of their lifecycle, and are less likely to purchase quota. The magnitude of this inverse relationship suggests a 0.5% decline in the probability a producer will purchase quota given a 1% increase in age. It is also clear that scale efficiency affects quota purchases. Other factors that affect quota purchase are: barn utilization, and previous purchasing behaviour. A one percent increase in barn utilization, decreases the likelihood a producer will purchase quota by 54%. The statistically significant effect of barn utilization on quota purchases is consistent with the positive effect of scale efficiency, suggesting producers are striving to achieve optimal scale. This may also reflect the existence of high opportunity costs of under utilizing a dairy facility (i.e., forgone revenue, high fixed cost per head). Our result regarding barn utilization is consistent with previous literature examining financial challenges faced by U.S. dairy producers as they move towards a parlor based dairy system. Jones (1999) examined several expansion plans and the results suggest that modest growth plans (i.e., retro-fitting existing barns) were more attractive than ambitious in order to reduce debt levels to acceptable levels.

Empirical results indicate momentum in producers' decision to purchase quota, such that producers who bought quota in the previous year will be more likely to purchase quota in the current year. As producers increase the intensity of previous quota purchases above small "maintenance" quantities (i.e, exhibited moderate growth in the previous year), the probability of purchasing quota increases by 25%. Similarly, if a producer rapidly increased quota holdings in the previous year, the likelihood of quota purchases increases by 53%. This is consistent with the lifecycle theory, indicating that producers in the expansion phase will continue to buy quota over consecutive years (Burrell 1989).

Further, the results suggest that producers do not exit from the industry in consecutive years, or perhaps that producers are fully exited from the industry within one year as indicated by the insignificant sign on past quota sales. This behaviour is consistent with literature examining the Quebec dairy industry, indicating that producers sell quota in larger quantities than they buy (Doyon et al 2008). Herd size does not appear to affect quota purchases, a result inconsistent with evidence from previous literature suggesting that quota moves towards larger producers (Burrell 1989). However, the addition of scale efficiency in our model appears to have captured the size effect,



resulting in the effect of herd size on quota purchases to be statistically insignificant. Finally, year dummies did not have an effect on quota purchases.

## 6 Discussion and Conclusion

The objective of this paper is to empirically test the hypothesis that cost efficient producers will purchase quota. To empirically test the hypothesis, quota exchanges facilitated through the Ontario quota market are analyzed. Our empirical results are mixed in that cost efficiency did not have an effect on the quota purchase decision, whereas scale efficiency has a positive and statistically significant effect on net quota buyers. The results show that producers are responding to performance measures rooted in the scale of the operation, as indicated by the significant effect of scale efficiency and barn utilization on quota purchases. Finally, elements of the producer lifecycle theory (i.e., expansion phase and retirement phase) are important concepts to focus upon when examining quota purchases in supply managed industries. The momentum identified in this paper from the positive and significant effect of quota purchases indicate that quota purchases coinciding with the expansion phase of the producer's career may reflect growing financial and employment requirements of the family, and quota may be strategically purchased to meet these needs.

The results of the study in the context of Barrett et al's (2012) study of the U.S. tobacco industry are supportive. Despite the different specification of variables (our study uses cost and scale efficiency in place of productivity), our study found evidence that the quota market was facilitating the exchange of quota towards scale efficient producers. This result speaks to the debate surrounding supply management, and provides empirical evidence to challenge the criticism presented earlier suggesting elements of supply management discourage inefficient producers from exiting the industry. On the contrary, it appears that less scale efficient producers are transferring quota towards relatively more scale efficient producers. For example, one conclusion that we can make is that the large outlay of capital necessary to expand production in supply management (through quota purchases), may not prevent producers from attaining their most efficient scale.

Extrapolating the results from our study to the current state of the Ontario quota market is concerning. Coupling the evidence suggesting quota movement towards scale efficient producers with the recent implementation of quota policies identified at the beginning of this paper, raises concerns surrounding the long term effects of these policies on the viability of the industry. Under the current quota price cap, the efficient exchange of quota is jeopardized by the recent reduction in trade facilitated by the quota exchange. For example, restrictions on quota mobility that limit producer's accessibility to, and ease of transferability of quota may also reduce producer's ability to sustain purchasing momentum, identified in this analysis by the positive effect of previous quota purchases. Furthermore, the restriction on bid size eliminates a producers' ability to purchase large quantities of quota. This is worrisome as producers in the expansion phase of their career may be unable to achieve optimal production levels. More

specifically, producers with underutilized barns may be unable to reach full capacity and exploit economies of size.

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