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

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

Help ensure our sustainability.

Give to AgEcon Search

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

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

Efficiency and Regulation of Dairy Farms: A Comparison of Ontario and New York State

Peter Slade
Graduate Student
Department of Food, Agriculture and Resource Economics
University of Guelph, Canada
email: pslade@uoguelph.ca

Getu Hailu
Associate Professor
Department of Food, Agriculture and Resource Economics
University of Guelph, Canada

Selected Paper prepared for presentation at the Agricultural & Applied Economics Associations 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011

Copyright 2011 by Peter Slade and Getu Hailu. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

1 Introduction

The dairy industry is the largest agricultural sector in both Ontario and New York State, accounting for 20% and 48% of agricultural receipts in the respective regions (Ontario Ministry of Agriculture, Food and Resource Affairs, 2010; Department of Agriculture and Markets, New York State, 2010). While the two regions share similar climactic and business environments, the marketing institutions that govern producers differ markedly. In Ontario, as in the rest of Canada, dairy production is regulated by a system of supply management in which production is restricted to holders of dairy quota. Producers in the United States, face no such restrictions, but do benefit from marketing orders, price floors and a counter-cyclical subsidy.

While the deadweight loss of supply management has been the subject of academic debate (see Schmitz and Schmitz (1994) for a summary), there has been considerably less interest in the effect of supply management on production efficiency. Previous empirical studies of dairy farm efficiency in Canada (Weersink, Turvey, and Godah, 1990; Mbaga et al., 2003; Hailu, Jeffrey, and Unterschultz, 2005) have focused only on farms within the country. Given the relative nature of efficiency methods, these studies do not allow for an assessment of the impact of Canadian marketing institutions on the efficiency of producers. A previous study of New York and Ontario farms undertaken by Haghiri, Nolan, and Tran (2004), employed non-parametric stochastic frontier analysis to find the technical efficiency of producers in both regions. Their findings were inconsistent with previous estimates, and did not consider allocative efficiency, found to be the most significant source of efficiency differences in our analysis.

This paper employs recent data (2000-2009) to decompose the cost efficiency of producers in Ontario and New York into technical and allocative components using data envelopment analysis. A second stage regression is then employed to determine identifiable sources of inefficiency.

2 Dairy Farm Regulation

The Canadian system of supply management is upheld by three "pillars"; a managed price, production restrictions and trade barriers. The target price of fluid milk in Ontario is set by the Dairy Farmers of Ontario (a government authorized producers organization) according to a formula that bases price changes on the cost of production, consumers ability to pay and the Consumer Price Index. The target price for industrial milk is set at the national level by the Canadian Dairy Commission, with dairy producers receiving a weighted average of these prices.

In order to achieve these target prices, milk production is restricted through a quota scheme. The economic rents from supply management have been capitalized into the price of quota, which is bought and sold on a provincial quota exchange. Since the completion of the Uruguay Round Agreement on Agriculture in 1995, Canada has restricted imports through the imposition of tariff rate quotas. Less than 3-4% of domestic consumption is imported under minimal tariffs (under 10%), while additional imports face over-quota tariffs of over 200% (Barichello, 1999, 48).

The United States rationalizes its dairy marketing primarily through four government programs; federal (or state) milk marketing orders, the dairy price support program, the milk income loss contract (a countercyclical subsidy) and trade restrictions. The most important of these policies is the system of milk marketing orders, which specify a minimum price for milk within a region. This minimum price is based on the prices of manufactured dairy products, assumed product yields and make allowances (Jesse and Crop, 2001). As in Ontario, the producer price of milk is a blend of fluid and industrial milk prices, with fluid milk receiving a premium (or differential) that varies, both between and within, regions.

The federal government also commits to maintaining the price of milk above a certain support price through the purchase of manufactured dairy products. The Farm Bill of 1996 sought to phase out this program, however it has remained government policy in subsequent bills. Nonetheless the price floor has not been increased in this time, leading to few purchases in the past fifteen years (U.S. Congress, 2008).

In 2002, the American government introduced the milk income loss contract (MILC), a countercyclical subsidy that pays farmers 45% of the difference between the Boston Class I price of milk and $16.94/cwt, when the price falls below this threshold.[1] The maximum eligible production is capped at 2,985 cwt (approximately the production of 145 cows) (United States Department of Agriculture, 2008). Like Canada, the US implements tariff rate quotas that constrain imports to 3-5% of domestic consumption (Balagtas, 2007, 14).

Of particular interest to this paper is the extent to which these institutions allow a producer to deviate from cost-minimization and still remain profitable. According to Cairns, Meilke, and Bennett (2010), the marginal and average costs of production in Ontario in 2009 were $31.39/hL and $46.90/hL respectively, while the farm gate price of milk was $66.36/hL. This calculation however did not include the cost of quota; if quota was priced efficiently the rental cost of quota would leave a farmer with zero economic profit. However, much of the quota in existence today was received *gratis* (either from initial government distribution or through inheritance) or was purchased at a much lower cost at an earlier date.

As for American policies, Cox and Chavas (2001) suggest that the system of federal milk marketing orders raise the farm-gate price of milk 7.1% above the autarky price in the Northeast region. Additionally, the average payout from the MILC program was equivalent to 4.25% of the fluid grade price of milk in New York, between 2002 and 2009 . If we assume the autarky price loosely represents the marginal cost of production, then the combined effects of American policies would seem to offer fewer benefits to dairy producers than Canada's institution of supply management.

[1] This threshold is adjusted based upon the cost of feed.

3 Dairy Farm Efficiency

The substantial theoretical and empirical literature on economic efficiency has defined three types of efficiency: technical, allocative and cost (or economic). The concept of technical efficiency is generally attributed to Koopmans (1951), who defined a producer as technically efficient if any increase in output requires an increase in input, or conversely, if any decrease in input requires a concomitant decrease in output.

Similarly, cost efficiency is achieved when any increase in output requires an increase in cost (or a decrease in cost requires a decrease in output.) Allocative efficiency is calculated as the difference between technical and cost efficiency. Farrell (1957) succinctly defined allocative efficiency as the extent to which a firm uses the various factors of production in the best proportions in view of their prices.

Several schools of heterodox economics have refined the neo-classical belief in cost minimizing behaviour, adding theoretical heft to the myriad empirical evidence of the existence of inefficiency. Alchian (1950) suggests that firms should be seen as pursuing profits, as opposed to maximizing them. This pursuit, characterized by "adaptive, imitative and trial-and-error behaviour", typically results in less than maximal profits due to bounded rationality, exogenous shocks, and learning costs. Winter (1971) adds that firms typically operate on the basis of decision rules which are changed infrequently, only when shown to be sub-optimal. Inefficiency can therefore, arise when such rules are not yet clearly shown to be imperfect. Winter goes on to equate the market with biological evolution, suggesting that firms who fail to adapt will be naturally selected from the market. Thus, in competitive industries one can imagine competition limiting the amount of inefficiency in the marketplace.

The evolutionary critiques of Alchian and Winter are of particular relevance for the dairy industry. Institutions that shield producers from competition, preclude inefficient producers from being naturally selected from the market. With no threat of competition, firms are free to pursue goals other than profit maximization (such goals may include maximizing utility or maximizing the utility of profits.) Furthermore, as Hayek (1945) noted, competitive prices are a mechanism for communicating information, removing the competitive price from the marketplace eliminates a criterion that firms use to evaluate their decision rules.

4 Existing Literature

Haghiri, Nolan, and Tran (2004) analyzed the technical efficiency of Ontario and New York producers, using a stochastic non-parametric approach. Specifying three inputs and a single output, their novel method of efficiency measurement produced efficiency scores at odds with previous literature, finding Ontario and New York farms were on average 53.20% and 60.20% technically efficient. This paper extends their analysis, by making more fulsome use of the data sets, calculating allocative and cost efficiency, and performing a second stage analysis of efficiency scores.

The Ontario dairy sector has also been studied by Weersink, Turvey, and Godah (1990), who utilized data envelopment analysis to decompose the technical efficiency of Ontario dairy farms (using data from 1987) into pure technical, scale, and input congestion efficiency, finding respective scores of 96.79%, 99.84% and 94.94%. Hailu, Jeffrey, and Unterschultz (2005) measure the cost efficiency of Ontario farms from 1984-1996 using stochastic frontier analysis, and examine the sensitivity of these scores to the imposition of curvature on the cost function. Their analysis found a mean cost efficiency of 92% for Ontario farms (both with and without curvature imposed.)

Tauer (1993) employed non-parametric programing techniques to calculate the technical and allocative efficiency of New York farms in the short- and long-run. Finding technical efficiency to measure 74% and 79%, and allocative efficiency to measure 87% and 70%, in the short- and long-run respectively. A logistical regression of likely covariates on efficiency scores returned no significant variables.

More recently, Mosheim and Lovell (2009) adopted a shadow cost efficiency model to examine a cross-section of American dairy producers, finding technical, allocative and cost efficiency to measure 75%, 56% and 45%, respectively. Notably, the paper found efficiency to be positively correlated with farm size.

Kumbhakar et al. (2008) examined output growth in Norway using a distance function. The distance function was used to calculate output growth rate under three different policy regimes in Norway; a period before the quota regime was introduced (1976-1982), a period during which the most restrictive quota regime was in place (1983-1996) and a period with a more flexible quota scheme (1996-2005.) Output growth was found to be significantly affected by the particular policy regime, averaging 3.95%, 1.62% and 2.56% in the three periods respectively. Notably they also found that all periods exhibited technological regress which averaged .46% over all periods. The authors posited that this regress could be due to increasing regulation, lack of external competition, increasing technical inefficiency or a decreasing margin between output and input prices.

5 Methodology

Data envelopment analysis (DEA) relies on the specification of an input set, denoted as Ψ, and defined as:

$$\Psi = \{(x, y) \,\epsilon\, R_{+}^{K+M} : \text{x can produce y}\} \tag{1}$$

where $x \,\epsilon\, R_{+}^{K}$ and $y \,\epsilon\, R_{+}^{M}$ represent the input and output vector, respectively. The feasible set is convex, monotonic, and includes all observations. Efficient firms operate on the technological frontier (the boundary of the feasible set and its complement), while inefficient firms operate in the interior of the set. DEA estimates the efficient set by using convex combinations of data points. Under the assumption of variable returns to scale, the input set can be calculated as:

$$\hat{\Psi} = (x, y) \ \epsilon \ R^{N+M} \tag{2}$$

where

$$\begin{aligned} y &\leq \sum_{i=1}^{n} \gamma_i y_i \\ x &\geq \sum_{i=1}^{n} \gamma_i x_i \\ \gamma_i &\geq 0 \text{ for } i = 1, 2 \ldots n \\ \sum_{i=1}^{n} \gamma_i &= 1 \end{aligned}$$

Following Farrell (1957), a producer's technical efficiency can be measured as the radial distance from their observation, to the frontier of the input set. Allowing $\hat{\theta}$ to be the efficiency score:

$$\hat{\theta}(x, y) = \inf\{\theta | (\theta x, y) \ \epsilon \ \hat{\Psi}\} \tag{3}$$

The computation of cost efficiency is done by first specifying the minimum achievable cost, given the output of the firm:

$$C_i^{opt}(y_i, w_i) = \min\{w_i x \,|\, x \ \epsilon \ \Psi\}, \tag{4}$$

The optimal cost of producer i, is then divided by their observed cost to generate cost efficiency scores:

$$\text{Cost Efficiency}_i = \frac{C_i^{opt}}{C_i^{observed}} \tag{5}$$

Finally, allocative efficiency is calculated as cost efficiency divided by technical efficiency.

6 Data

Farm level data is taken from two sources: the Ontario Dairy Farm Accounting Project (ODFAP)[2] and the Dairy Farm Business Summary[3] from New York State. The Ontario Dairy Farm Accounting Project is a rotating panel consisting of a regionally stratified random sample of farms. Typically a farm remains in the panel for three to five years. On average approximately eighty farms are

[2]The Ontario Dairy Farm Accounting project is jointly administered by the Canadian Dairy Commission, the Dairy Farmers of Ontario, and the University of Guelph.

[3]The Dairy Farm Business Summary is administered by Cornell University.

surveyed in any given year. Given this paper's interest in dairy farms, producers who derive more than ten percent of total receipts from non-dairy operations are deleted (this threshold was previously used by Moschini (1988)).

The Dairy Farm Business Summary is a voluntary reporting program that covers 5.1% of farms in New York State[4]. Farms that enter are on average larger and more productive (in terms of milk output per cow) than the state average. To redress the bias of the New York data, a subsample was selected to emulate the average farm size and milk output per cow of the state population. In each year, seventy-five producers were chosen from the dataset.[5] The procedure for subsampling was as follows:

- Classify farms according to their size, using classes defined by Department of Agriculture and Markets, New York State (2010)
- Specify the number of farms that should be chosen from each class, each year, based on the proportion in the state population[6]
- Randomly select producers in each class for the first year
- Verify average herd size and average output per cow is within 80% of the state average, if not resample
- Producers included in previous subsamples are kept in subsequent years, with additional producers randomly added to satisfy the previous requirements

For this study three aggregate outputs (milk, livestock and crop) and four aggregate inputs (feed, labour, capital and other) are defined. All variables are aggregated using a fisher price index, allowing for an implicit quantity index to be calculated. All New York State prices and revenues are converted to Canadian dollars using the average yearly exchange rate available from the Bank of Canada (2010).

6.1 Milk

Both datasets include the quantity of, and revenue from, milk sales, allowing for the calculation of an implicit price. Pounds were converted to litres at a rate of 2.275 lbs/litre (Bailey, 2002).

[4]None of the farms in the New York state dataset have non-dairy receipts in excess of 10% of total receipts.

[5]The number seventy five was chosen, as it approximates the number of Ontario producers surveyed in a given year. Furthermore, there are not enough small farms in the dataset, to choose a larger subsample which is still reflective of the population.

[6]In certain years there were not enough small farms (less than fifty cows) in the dataset to mimic the percent within the population, in these instances, more farms from the next size category were added.

6.2 Crop output

The New York data set contained accrual crop revenue and production of six different crops (hay, hay silage, corn silage, grain corn, oats, wheat and other forage.) Problematically, most crops are also used as feed, with only the excess sold. To calculate the amount of each crop sold, we assume that crops are sold in the same proportion to which they are grown (except for pasture and forage which is assumed to be used exclusively as feed)[7]. External prices for crops are taken from Department of Agriculture and Markets, New York State (2010).

The Ontario data set offers both quantity and revenue of individual crops, allowing for the calculation of an implicit price. An examination of the implicit prices revealed some irregularities. As a result implicit prices that were 25% greater (less) than external prices (taken from the ODFAP annual reports) were reduced to the upper (lower) boundary of this range. Given that more crops were specified in this data set than in the New York data set, individual crops were aggregated into six categories, so to minimize the price variance within groups. A producer specific price was calculated as a weighted average of the prices within the group.

6.3 Livestock output

The New York data set provides two quantities of livestock sold (cull cows and dairy cows), and three categories of revenues from livestock sold (cows, calves and other livestock). The implicit price of dairy and cull cows was derived by assuming the ratio of the price of dairy and cull cows is the same as in the external prices from Department of Agriculture and Markets, New York State (2010). The quantity of calves was found by dividing the revenue from calf sales by the external price, while other livestock was converted into dairy and cull cow equivalents.

The Ontario data set contained the quantity and revenue for several livestock categories. These categories were aggregated to match the three categories from New York state, with prices calculated for each category as the weighted average of component prices.

6.4 Feed

While the Ontario data set offered detailed information on feed, the New York data set aggregated these costs into three broad categories. With these data constraints in mind, the price of 16% dairy ration was used as a proxy for feed price.[8]

[7]This assumption is validated in the Ontario data set, where significant amounts of hay forage are grown but only 1 farm reported sales

[8]The price in New York was available from the Department of Agriculture and Markets, New York State (2010, p 10), for Ontario it was calculated using the mean annual implicit price

6.5 Labour

In measuring labour expense, the literature diverges on the costing of family labour. Most studies (such as Hailu, Jeffrey, and Unterschultz (2005) and Moschini (1984)) price family and hired labour at the same wage rate. Other studies have attempted to estimate the opportunity cost of family labour. Mosheim and Lovell (2009), for example, employ USDA data, in regressing off-farm income on such variables as education, age of the operator, and location, and use the estimated coefficients to predict a wage for dairy farm operators. The first method is often preferred for its ease of calculation, however we contend that it is theoretically appealing as well.

Input prices are used to determine the optimal changes in input usage, therefore it is the marginal cost of these inputs that is of significance. If farms were to reduce or increase their labour by relatively small amounts, it is likely to be hired labour that is adjusted. Furthermore, the transaction costs involved in off-farm labour are likely quite high (especially for full-time workers), meaning the marginal benefit of off-farm labour (or the opportunity cost of on-farm labour) is likely less than an estimated wage rate. For these reasons, this study prices family and hired labour both at the prevailing wage rate for livestock workers.

The average wage rate of livestock workers in New York is taken from Department of Agriculture and Markets, New York State (2010). The Ontario wage rate for 2010 is taken from a survey done by Ontario's Progressive Dairy Operator's Group (cited in Lang (2010)), this rate is deflated by Statistics Canada's index of agricultural wage (2000-2007)[9] and the Ontario wage rate (2008-2009). Both data sets provide the total quantity of farm labour.

6.6 Capital

We specify three broad categories of capital; real estate, machinery and livestock, and specify the capital price of the jth input as:

$$r_j = i + \delta_j + \tau_j \tag{6}$$

where δ is the depreciation rate, taken implicitly from the depreciation cost in the data set. τ is the tax rate, assumed to be zero for livestock and machinery, and implicitly derived for real estate from the property taxes paid. The interest rate is calculated based on the weighted average cost of capital:

$$i = [(1 - g) * r_e] + [g * r_d] \tag{7}$$

where g is a measure of leverage, (Debt/Physical Assets), while r_e and r_d represent the cost of equity and debt. To be consistent with a long-term orientation these parameters were estimated as ten-year real averages of corporate bond yields, and the prime business rate plus two percent, respectively. Capital expense is then defined as the price of capital multiplied by its replacement value, plus rental and maintenance costs.

[9]The index of agricultural wage was discontinued in 2007

6.7 Other

Other inputs include fertilizer, seed, spray, insurance, utilities, fuel, bedding, veterinary services and drugs, and breeding expenses. Price indices for these inputs are given by the United States Department of Agriculture and Statistics Canada.

7 Results and discussion

We estimate cost efficiency by running by running separate DEA models for each year of our analysis (2000-2009). While previous studies have aggregated yearly data through the use of the Malmquist index, the unbalanced nature of our data precludes this technique.

Before reporting efficiency scores we check the data for outliers. Our particular method is loosely based on Wilson (1995). For each year we proceed as follows:

- Calculate baseline efficiency scores
- Calculate "super-efficiency" scores by removing observation k from the frontier, and calculating the efficiency score of k. Since k is not in the frontier, its efficiency can be greater than 100%.
- Producers whose "super-efficiency" scores are above 130% are sorted in decreasing order of their "super-efficiency" scores
- For each producer, k, above this threshold we calculate two new DEA models; one with the kth observation missing, and a second with with all observations with super-efficiency scores equal or greater to k's efficiency score missing
- We compare these new models to our baseline model by examining: the mean change in efficiency and the number of observations whose efficiency scores have changed

Given that DEA projects inefficient units unto a frontier created by a convex combination of efficient units, we can expect the removal of efficient units to change the efficiency scores of at least some other units. In this instance we find that firms whose super-efficiency is greater than 130% are on average an efficient peer for 55% of observations in that year.

If an observation is truly aberrant, than its removal should increase the mean of the efficiency scores, by shifting the frontier downward. Only two observations were found to influence the mean efficiency scores by more than 1%. The panel nature of the data allows us to compare observations on the same unit, across time. When the two units in question were examined, the particular observations showed peculiarities and were thus removed.

After removal of these two outliers, no other observation influenced the mean efficiency scores by more than 1%, and no three efficiency scores combined to influence the mean by more than 1.5%.

The mean results from the ten DEA models are contained in table 1. A Mann-Whitney-Wilcoxon test was used to test for differences between the two regions, finding significant differences in allocative and cost efficiency, though not in technical efficiency. This result differs from Haghiri, Nolan, and Tran (2004), in finding no significant difference in technical efficiency. One possible explanation for this difference is the subsampling procedure employed in this paper, which created a more representative sample of farms.

Table 1: Mean Efficiency Scores (Standard Deviation in Parenthesis)

	Technical	Allocative	Cost
New York	0.8770 (0.1266)	0.8944 (0.0858)	0.7850 (0.1412)
Ontario	0.8786 (0.1250)	0.8184 (0.1321)***	0.7203 (0.1641)***
Total	0.8778 (0.1258)	0.8589 (0.1162)	0.7548 (0.1556)

*, **, *** indicate significant differences between regions at the .1, .05 and .01 level, respectively.

While previous efficiency studies have typically reported a simple average of farm efficiencies, given our focus on comparison of two industries, we employ a weighted average for each region based upon production of milk. Table 2, shows the weighted average efficiency of New York producers is much greater than their simple average, especially for allocative and cost efficiency. For Ontario producers the increase is muted. In both calculations the allocative and cost efficiency of New York farms is greater than in Ontario, with these differences more significant under the weighted average.

Table 2: Weighted Average Efficiency Scores

	Technical	Allocative	Cost
New York	0.9139	0.9220	0.8447
Ontario	0.8991	0.8290	0.7473

The differences between the simple average and the weighted average scores are rationalized in table 3. In our sample of New York farms (which is reflective of the state population), less than 3% of the farms have a herd size greater than 500, however these farms account for over 21% of production. Conversely, the Ontario data contains no farms in this size category. With the exception of small farms, efficiency increases in size for both samples. As the table demonstrates New York farms are more efficient than Ontario farms in every size class, with the size difference between the two regions exacerbating the difference in average and weighted average efficiency scores.

Table 3: Farm size and Efficiency

		Herd Size				
		0-49	50-99	100-199	200-499	500+
New York	Percent of farms	26.00%	48.27%	16.13%	6.80%	2.80%
	Percent of milk produced	8.84%	29.60%	21.91%	18.32%	21.33%
	Mean technical efficiency	0.9076	0.8432	0.8824	0.9891	0.9886
	Mean cost efficiency	0.7960	0.7512	0.8003	0.9415	0.9714
Ontario	Percent of farms	46.50%	40.73%	8.97%	3.80%	0%
	Percent of Milk Produced	24.91%	39.41%	18.30%	17.38%	0%
	Mean technical efficiency	0.8748	0.8579	0.9475	0.9853	-
	Mean cost efficiency	0.7262	0.6903	0.7551	0.8883	-

Of particular interest to farmers and policy makers, is the required change in input usage to become cost efficient. Cost efficiency relies on comparing the inputs of one unit, to an optimal input vector derived from a convex combination of other observed units. We are therefore able to report the change in input usage necessary to become cost efficient. Tables 4 shows New York producers are prescribed an almost equiproportionate decrease in inputs (with the exception of other inputs). Conversely, table 5 demonstrates that Ontario farms are overcapitalized and are overly reliant on homegrown feed. To become efficient, Ontario producers would need to purchase more feed, which would then allow them to reduce the other inputs they use. Of particular note Ontario producers use almost 90% more capital than is necessary to produce the same level of output.

Table 4: Change in Input Usage Necessary to Achieve Cost Efficiency (New York)

	Feed	Labour	Capital	Other
Percent change	-17.78%	-17.55%	-24.38%	-4.71%
Dollar value	-72,918	-15,045	-26,936	-4,173
Mean cost of inefficiency = $119,073 (CAD)				

Table 5: Change in Input Usage Necessary to Achieve Cost Efficiency (Ontario)

	Feed	Labour	Capital	Other
Percent change	51.42%	-17.31%	-44.75%	-20.63%
Dollar value	10,572	-16,951	-978,892	-21,624
Mean cost of inefficiency = $233,081 (CAD)				

Our final analysis is a truncated regression of cost efficiency scores on regional dummies and other variables identified by previous research (Weersink, Turvey, and Godah, 1990; Bravo-Ureta and Rieger, 1990; Tauer, 1993), as having an effect on efficiency. The results of this regression are contained in table 6. The regression found being located in Ontario reduced efficiency by 5.3%, however, we caution that government policies may impact other variables, such as herd size, and leverage. Herd size, as expected, had a significantly positive effect on efficiency. Age had a significantly negative impact on efficiency, which is in keeping with other studies on farm efficiency. Notably, Tauer and Lordkipanidze (2000), suggested that as farmer's age they are less likely to adopt technologies, leading to lower efficiency at later stages of their farming career.

Table 6: Results of Truncated Regression on Cost Efficiency Scores

Variable	Coefficient (t-statistic)
Ontario dummy	-0.05388 (-5.44)***
Age	-0.001436 (-3.94)***
Herd size	0.0003396 (5.07)***
Leverage (Debt/Total Assets)	0.03179 (2.23)**
Tie-stall dummy	-0.09152 (-4.78)***
Pipeline dummy	0.01865 (0.88)
Parlour dummy	-0.0128 (-0.65)
bST expenditure	-3.439e-07 (-0.42)
Proportion of homegrown feed	-1.242e-06 (-0.11)
Time trend	-0.005616 (-4.01)***
Observations	1408
Log-likelihood	698.55

Intuitively, the leverage of a farm may be positively or negatively correlated with it's efficiency. The leverage of a farm may decrease its efficiency as it constrains the ability to invest in newer technologies. Conversely, higher debt levels may reflect increased investment in past periods, and thus have a positive impact on efficiency. We find the latter to be true in this study, however more refined time-series analysis is needed in order to derive the causal relationship.

While both data sets provide information on barn-type, the only comparable groupings that could be made were between tie-stall housing, and other types of housing (that are typically thought of as more modern.) As expected we find tie-stall housing to have a negative effect on efficiency. We were able to specify three types of milking technology, a bucket / bucket-dump system, a pipeline system and a parlour system. Using the bucket / bucket dump system as a control group, we find that producers with a pipeline were more efficient, while those with a parlour milking system were less efficient, though neither was significant.

While we determined that Ontario farms were required to employ more purchased (as opposed to homegrown) feed in order to achieve cost efficiency, the coefficient associated with the proportion of homegrown feed used (measured as grown feed divided by total feed) was insignificant. We also find the the use of bovine somatotropin (bST), a growth hormone which is used in New York, but is not approved for use in Canada, to be insignificant.

Finally, we find the coefficient of the time trend to be negative. We caution that this variable has no economic interpretation, given that we run separate models for each year, and our data is an unbalanced panel, changes in efficiency can be attributed either to technological progress (or regress), or to changes in the composition of the panel.

8 Conclusion

This paper employed data envelopment analysis to decompose the cost efficiency of New York and Ontario dairy farms into technical and allocative components. While mean technical efficiency was similar in the two regions, allocative and cost efficiency exhibited significant differences. Efficiency generally increased in farm size in both regions, with New York benefitting the presence of larger dairy farms. An examination of cost minimizing input vectors demonstrated that Ontario farms are significantly over-capitalized, and rely too heavily on homegrown feed. A regression of cost efficiency scores on likely covariates found region, farmer age, leverage and barn technology to have a significant impact on efficiency.

The results demonstrate that farms operating under the system of supply management make poorer allocative decisions than those in a competitive environment. The theoretical discussion at the beginning of the paper suggested possible reasons for this inefficiency (utility maximization, and removal of the price signal.) Further research is needed to gain a deeper understanding of the reasons for inefficiency under this system, and suggest avenues for improving efficiency within the context of supply management.

References

Alchian, A. 1950. "Uncertainty, Evolution and Economic Theory." *The Journal of Political Economy* 58:211–221.

Bailey, K. 2002. "Comparison of the US and Canadian Dairy Industries." Penn State, Staff Paper 349.

Balagtas, J. 2007. "U.S. Dairy Policy: Analysis and Options." Paper Prepared for Agricultural Policy for the 2007 Farm Bill and Beyond.

Bank of Canada. 2010. "Monthly and Annual Exchange Rates." Available at: `http://www.bankofcanada.ca/en/rates/exchange_avg_pdf.html`, accessed January 10, 2011.

Barichello, R. 1999. "The Canadian Dairy Industry: Prospects for Future Trade." *Canadian Journal of Agricultural Economics* 47:45–55.

Bravo-Ureta, B., and L. Rieger. 1990. "Alternative Production Frontier Methodologies and Dairy Farm Efficiency." *Journal of Agricultural Economics* 41:215–226.

Cairns, A., K. Meilke, and N. Bennett. 2010. "Supply Managemenet and Price Ceilings on Production Quota Values: Future or Folly." CATPRN Working Paper 2010-05.

Cox, T.L., and J. Chavas. 2001. "An Interregional Analysis of Price Discrimination and Domestic Policy Reform in the U.S. Dairy Sector." *American Journal of Agricultural Economics* 83:89–106.

Department of Agriculture and Markets, New York State. 2010. "Annual Statistical Bulletin 2009." Online, Available at: `http://www.nass.usda.gov/Statistics_by_State/New_York/Publications/Annual_Statistical_Bulletin/2009/Bulletin2009.pdf`, accessed January 20, 2011.

Farrell, M.J. 1957. "The Measurement of Productive Efficiency." *Journal of the Royal Statistical Society. Series A (General)* 120:253–290.

Haghiri, M., J. Nolan, and K. Tran. 2004. "Assessing the Impact of Economic Liberalization Across Countries: A Comparison of Dairy Industry Efficiency in Canada and the USA." *Applied Economics* 36:1233–1243.

Hailu, G., S. Jeffrey, and J. Unterschultz. 2005. "Cost Efficiency for Alberta and Ontario Dairy Farms: An Interregional Comparison." *Canadian Journal of Agricultural Economics* 53:141–160.

Hayek, F.A. 1945. "The Use of Knowledge in Society." *The American Economic Review* 35:519–530.

Jesse, E., and B. Crop. 2001. "Federal Milk Marketing Reform (Continued)." Paper No. 73. Department of Agricultural and Applied Economics, College of Agricultural and Life Sciences, University of Wisconsin-Madison.

Koopmans, T.C. 1951. *Activity Analysis of Production and Allocation*, New York: Wiley, chap. An Analysis of Production as an Efficient Combination of Activities. No. Monograph No. 13 in Cowles Commision for Research in Economics.

Kumbhakar, S., G. Lien, O. Flaten, and R. Tveteras. 2008. "Impacts of Norwegian Milk Quotas on Output Growth: A Modified Distance Function Approach." *Journal of Agricultural Economics* 59:350–369.

Lang, B. 2010. "Dairy Farm Wage Rates." Available at: `http://www.omafra.gov.on.ca/english/livestock/dairy/facts/wagerate.htm`, accessed January 10, 2011.

Mbaga, M., R. Romain, B. Larue, and L. Lebel. 2003. "Assessing the Technical Efficiency of Quebec Dairy Farms." *Canadian Journal of Agricultural Economics* 51:121–137.

Moschini, G. 1988. "The Cost Structure of Ontario Dairy Farms: A Microeconometric Analysis." *Canadian Journal of Agricultural Economics* 36:187–206.

—. 1984. "Quota Values and Price Uncertainty." *Canadian Journal of Agricultural Economics* 32:231–234.

Mosheim, R., and C.K. Lovell. 2009. "Scale Economies and Inefficiency of US Dairy Farms." *American Journal of Agricultural Economics* 91:777–794.

Ontario Ministry of Agriculture, Food and Resource Affairs. 2010. "Challenges and Trends in the Dairy Industry." Available at: http://www.omafra.gov.on.ca/english/livestock/dairy/facts/challeng.htm, accessed on March 30, 2011.

Schmitz, A., and T. Schmitz. 1994. "Supply Management: The Past and the Future." *Canadian Journal of Agricultural Economics* 42:125–148.

Tauer, L. 1993. "Short-run and long-run efficiencies of New York dairy farms." *Agriculture and Resource Economics Review* 22:1–9.

Tauer, L., and N. Lordkipanidze. 2000. "Farmer Efficiency and Technology Use with Age." *Agricultural and Resource Economics Review* 29:24–31.

Tauer, L., and A. Mishra. 2006. "Can the small dairy farm remain competitive in US agriculture?" *Food Policy* 31:458–468.

United States Department of Agriculture. 2008. "Milk Income Loss Contract Program Farm Bill 2008 Information Sheet."

U.S. Congress. 2008. "Food, Conservation and Energy Act 2008. H.R. 1950. 110th Congress."

Weersink, A., C. Turvey, and A. Godah. 1990. "Decomposition Measures of Technical Efficiency for Ontario Dairy Farms." *Canadian Journal of Agricultural Economics* 38:439–456.

Wilson, P. 1995. "Detecting Influential Observations in Data Envelopment Analysis." *Journal of Productivity Analysis* 6:27–45.

Winter, S. 1971. "Satisficing, Selection and the Innovating Remnant." *The Quarterly Journal of Economics* 85:237–261.