Efficiency and Regulation: 
The Case of Ontario and New York Dairy Farms

Peter Slade & Getu Hailu

University of Guelph

July 1, 2011
Ongoing public and academic debate regarding supply management

See Goldfarb (2009); Robson and Busby (2010); Barichello, Cranfield and Meilke (2009)
Dairy Farm Policy

- Canada
  - Pricing formula
  - Quantity restrictions
  - Import restrictions

- United States
  - Marketing orders
  - Price support
  - Countercyclical subsidy
  - Import Restrictions
Dairy Farm Policy

- Canada
  - Pricing formula
  - Quantity restrictions
  - Import restrictions

- United States
  - Marketing orders
  - Price support
  - Countercyclical subsidy
  - Import Restrictions
Producer subsidy equivalents

Figure: Producer Subsidy Equivalent for Canadian and US Dairy
Theoretical Implications

- Production decisions based on "rules of thumb", changed only when shown to be sub-optimal (Winter, 1971)
Theoretical Implications

- Production decisions based on "rules of thumb", changed only when shown to be sub-optimal (Winter, 1971)
- Natural selection through competition
Existing literature

  - Use same datasets (1992-1998)
  - Calculate technical efficiency using a nonparametric stochastic frontier model
Existing literature

  - Use same datasets (1992-1998)
  - Calculate technical efficiency using a nonparametric stochastic frontier model
Data

- Time period: 2000-2009
Data

- **Time period:** 2000-2009
- **Sources**
Data

- Time period: 2000-2009
- Sources
- Subsampling
Data

- Time period: 2000-2009
- Sources
- Subsampling
- Variables
  - Output: milk, crops & livestock
  - Input: feed, labour, capital & other
Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>New York</th>
<th>Ontario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean dairy cows per farm</td>
<td>106</td>
<td>67</td>
</tr>
<tr>
<td>Mean output per cow (liters)</td>
<td>8,635</td>
<td>8,096</td>
</tr>
<tr>
<td>Mean milk price ($CAD)</td>
<td>0.46</td>
<td>0.69</td>
</tr>
<tr>
<td>Mean crop revenue ($CAD)</td>
<td>10,024</td>
<td>25,306</td>
</tr>
<tr>
<td>Livestock revenue per cow ($CAD)</td>
<td>276</td>
<td>108</td>
</tr>
<tr>
<td>Mean purchased feed per cow ($CAD)</td>
<td>1,239</td>
<td>779</td>
</tr>
<tr>
<td>Mean labour quantity index per cow</td>
<td>84.89</td>
<td>87.56</td>
</tr>
<tr>
<td>Mean physical assets ($CAD)</td>
<td>988,145</td>
<td>1,366,125</td>
</tr>
<tr>
<td>Mean physical assets per cow ($CAD)</td>
<td>9,303</td>
<td>20,259</td>
</tr>
<tr>
<td>Mean other quantity index per cow</td>
<td>771</td>
<td>1181</td>
</tr>
</tbody>
</table>
Empirical Strategy

- Data envelopment analysis (3 models)
Empirical Strategy

- Data envelopment analysis (3 models)
  1. Pooled model
Empirical Strategy

- Data envelopment analysis (3 models)
  1. Pooled model
  2. Separated model
Empirical Strategy

- Data envelopment analysis (3 models)
  1. Pooled model
  2. Separated model
  3. Intermediate model: uses additional reference years which have similar technology
Empirical Strategy

- Data envelopment analysis (3 models)
  1. Pooled model
  2. Separated model
  3. Intermediate model: uses additional reference years which have similar technology

- Econometric estimation of the distance function
Data Envelopment Analysis
Data Envelopment Analysis
Data Envelopment Analysis

- Technical efficiency = \( \frac{OA}{OB} \)
Data Envelopment Analysis

- Cost efficiency = \( \frac{OC}{OB} \)
- Allocative efficiency = (Cost efficiency) / (Technical efficiency)
Bootstrapping
Bootstrapping
Bootstrapping

\[(\hat{\theta}^*(x, y) - \hat{\theta}(x, y))|\hat{\rho}(\chi_n) \approx (\hat{\theta}(x, y) - \theta(x, y))|\rho.\]  \hspace{1cm} (1)
Econometric Estimation

\[ \ln \delta_{it} = C + \sum_{j=1}^{J} \alpha_j \ln y_{itj} + \sum_{k=1}^{K} \beta_k \ln x_{itk} + \sum_{t=1}^{T} \gamma_t \ln td_{it} + u_{it} \] (2)

\[ -\ln x_{it1} = C + \sum_{j=1}^{J} \alpha_j \ln y_{itj} + \sum_{k=2}^{K} \beta_k \ln (x_{itk}/x_{it1}) + \sum_{t=1}^{T} \gamma_t \ln td_{it} + e_{it} \] (3)

where:

\[ e_{it} = u_{it} - \ln \delta_{it} \] (4)

- Duality is used to derive the cost function and cost efficiency scores analytically.
## DEA results

### Table: Weighted Average Efficiency Scores from Separated Model
(Non-corrected scores in parenthesis)

<table>
<thead>
<tr>
<th>Region</th>
<th>Technical Eff</th>
<th>Allocative Eff</th>
<th>Cost Eff</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>0.769 (0.885)</td>
<td>0.917 (0.912)</td>
<td>0.704 (0.809)</td>
</tr>
<tr>
<td>Ontario</td>
<td>0.732 (0.832)***</td>
<td>0.751 (0.736)***</td>
<td>0.549 (0.609)***</td>
</tr>
<tr>
<td>Overall</td>
<td>0.757 (0.868)</td>
<td>0.863 (0.855)</td>
<td>0.654 (0.744)</td>
</tr>
</tbody>
</table>

Non-corrected scores are in parenthesis.
* *, **, **** represent significant differences between regions at the .1, .05 and .01 levels.
### Econometric Results

<table>
<thead>
<tr>
<th>Description</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>-0.7835</td>
<td>0.0111***</td>
</tr>
<tr>
<td>Livestock</td>
<td>-0.0296</td>
<td>0.0069***</td>
</tr>
<tr>
<td>Crop</td>
<td>-0.0049</td>
<td>0.0014***</td>
</tr>
<tr>
<td>Labour</td>
<td>0.2659</td>
<td>0.0142***</td>
</tr>
<tr>
<td>Capital</td>
<td>0.1731</td>
<td>0.0119***</td>
</tr>
<tr>
<td>Other</td>
<td>0.2412</td>
<td>0.0127***</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>0.0698</td>
<td>0.0236***</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.5464</td>
<td>0.1812***</td>
</tr>
</tbody>
</table>
Econometric Results (ctd.)

Table: Weighted Average Efficiency Scores from Parametric Estimation

<table>
<thead>
<tr>
<th></th>
<th>Technical Eff</th>
<th>Alloacative Eff</th>
<th>Cost Eff</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>0.927</td>
<td>0.847</td>
<td>0.785</td>
</tr>
<tr>
<td>Ontario</td>
<td>0.933**</td>
<td>0.734***</td>
<td>0.684***</td>
</tr>
<tr>
<td>Total</td>
<td>0.929</td>
<td>0.810</td>
<td>0.753</td>
</tr>
</tbody>
</table>

*, **, **** represent significant differences between regions at the .1, .05 and .01 levels.
Triangulation

Table: Correlation and Rank Correlation of DEA and Econometric Efficiency Scores

<table>
<thead>
<tr>
<th></th>
<th>Correlation</th>
<th>Rank Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>0.67</td>
<td>0.70</td>
</tr>
<tr>
<td>Allocative</td>
<td>0.37</td>
<td>0.30</td>
</tr>
<tr>
<td>Cost</td>
<td>0.31</td>
<td>0.26</td>
</tr>
</tbody>
</table>
## Input usage

Table: Change in Input Usage Necessary to Achieve Cost Efficiency

<table>
<thead>
<tr>
<th></th>
<th>Feed</th>
<th>Labour</th>
<th>Capital</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>-21.4%</td>
<td>-18.2%</td>
<td>-29.7%</td>
<td>-14.6%</td>
</tr>
<tr>
<td>Ontario</td>
<td>64.2%</td>
<td>-26.6%</td>
<td>-61.4%</td>
<td>-39.9%</td>
</tr>
</tbody>
</table>
## Explaining efficiency

<table>
<thead>
<tr>
<th></th>
<th>Technical Efficiency</th>
<th></th>
<th>Allocative Efficiency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Standard error</td>
<td>Estimate</td>
<td>Standard error</td>
</tr>
<tr>
<td><strong>Ontario</strong></td>
<td>-4.28e-02</td>
<td>6.32e-03***</td>
<td>-2.61e-01</td>
<td>1.78e-02***</td>
</tr>
<tr>
<td><strong># of cows</strong></td>
<td>-9.34e-06</td>
<td>6.00e-05</td>
<td>2.34e-04</td>
<td>1.59e-04</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>-1.86e-03</td>
<td>2.59e-04***</td>
<td>-1.28e-03</td>
<td>5.99e-04**</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>9.24e-03</td>
<td>6.17e-03</td>
<td>1.31e-02</td>
<td>1.35e-02</td>
</tr>
<tr>
<td><strong>Tie-stall</strong></td>
<td>-1.45e-02</td>
<td>1.36e-02</td>
<td>3.95e-02</td>
<td>3.37e-02</td>
</tr>
<tr>
<td><strong>Pipeline</strong></td>
<td>-1.88e-02</td>
<td>1.64e-02</td>
<td>-9.05e-02</td>
<td>4.20e-02**</td>
</tr>
<tr>
<td><strong>Parlour</strong></td>
<td>-1.40e-02</td>
<td>1.59e-02</td>
<td>-4.16e-02</td>
<td>3.94e-02</td>
</tr>
<tr>
<td><strong>bST</strong></td>
<td>3.52e-08</td>
<td>6.60e-07</td>
<td>1.67e-05</td>
<td>3.27e-06***</td>
</tr>
</tbody>
</table>
Does scale matter?

- Number of cows not significant
- Scale efficiency
  - Ontario - 91.6%
  - New York - 92.7%
  - Overall - 92.1%
Conclusions
Conclusions

- Ontario farms less allocatively efficient than New York farms
Conclusions

- Ontario farms less allocatively efficient than New York farms
- Ontario farms are overcapitalized, relying too heavily on homegrown feed
Ontario farms less allocatively efficient than New York farms
Ontario farms are overcapitalized, relying too heavily on homegrown feed
Both empirical techniques have the same broad findings across regions, through the correlation between them is very low
Conclusions

- Ontario farms less allocatively efficient than New York farms
- Ontario farms are overcapitalized, relying too heavily on homegrown feed
- Both empirical techniques have the same broad findings across regions, through the correlation between them is very low
- Scale is not a major differentiator
Thank you
Data Envelopment Analysis

- Define the production possibilities set

\[ \hat{\Psi} = (x, y) \in \mathbb{R}^{N+M} \]  (5)

where

\[ y \leq \sum_{i=1}^{n} \lambda_i y_i \]
\[ x \geq \sum_{i=1}^{n} \lambda_i x_i \]
\[ \lambda_i \geq 0 \text{ for } i = 1, 2 \ldots n. \]
\[ \sum \lambda_i = 1 \]
Data Envelopment Analysis (ctd)

- Measure technical efficiency
  \[ \hat{\theta}(x, y) = \inf \{ \theta | (\theta x, y) \in \hat{\Psi} \} . \] (6)

- Measure cost efficiency
  \[ \text{Cost Efficiency}_i = \frac{C_i^*}{C_i} . \] (7)

  where
  \[ C_i^*(y_i, w_i) = \min \{ w_i x | x \in \hat{\Psi} \} . \] (8)
Econometric estimation

- Econometric estimation of the distance function

\[ D_i(X, Y) = \max \{ \delta_i : (X/\delta_i, y) \in \Psi \} \]  \hspace{1cm} (9)

\[ \theta_i = 1/\delta_i \]  \hspace{1cm} (10)
Concept of efficiency

- Technical efficiency
Concept of efficiency

- Technical efficiency
- Cost efficiency
Concept of efficiency

- Technical efficiency
- Cost efficiency
- Allocative efficiency $= \frac{CE}{TE}$