An Intertemporal Analysis of Efficiency Using DEA: The Case of the Canadian Life Insurance Industry Prior to 2000

Gilles Bernier, Ph.D.,
Industrial-Alliance Insurance Chair,
Laval University, Québec City

Komlan Sedzro, Ph.D.,
University of Québec at Montréal

ARIA Meeting, Denver, August 11, 2003.
Outline of Presentation

• Introduction: The Canadian L/H market
• Purpose of Study
• Efficiency Measurement Concepts
• Estimating Efficiency Using DEA
• Review of Prior Canadian Study
• Variables, Data Sources and Sample
• Tests and Hypotheses
• Methodology
• Results
• Interpretation of Results
• Limitations of Study
Introduction
The Canadian L/H Market

• Accounts for 1.46% of the world market (Rank # 9 in Y2001).
• Currently, 110 companies are monitored for financial soundness by OSFI (49 Canadian, 61 Foreign).
• Increasing concentration due to continuing consolidation since the demutualization wave of 1999-2000.
• The market is dominated by 3 large groups of stock co’s:
  – [Great-West / London Life & Canada Life], [Manulife Financial], [Sun Life Financial/Clarica].
Purpose of Study

• Extend our preliminary efficiency study which was presented at ARIA in 2002 (Montreal).

• Our goal is to conduct an intertemporal efficiency analysis of DEA ratings generated over the 1997-1999 period to determine, with statistical confidence, whether:
  – there were significant efficiency changes over time within groups of insurers prior to the Canadian demutualization wave of 1999-2000;
  – there were significant efficiency differences between domestic and foreign life insurers operating in Canada during that time period.

• In both types of tests, we aim at adjusting or controlling for the managerial constituent of inefficiency.
Efficiency Measurement Concepts

• As defined in Cummins (1999):
  – The **efficient cost frontier** represents the lowest costs attained by firms in the industry to produce a given bundle of outputs:
  • For a specific firm, **cost efficiency** (CE), the firm’s success in minimizing costs, can be decomposed as follows:

\[
\text{Cost} = \text{Pure Technical} \times \text{Scale} \times \text{Allocative Efficiency} \times \text{Efficiency} \times \text{Efficiency} \times \text{Efficiency}
\]

• **PTE** measures the firm’s success in using the best available technology. **SE** indicates whether the firm is operating with IRS, DRS or CRS (ideal). **AE** measures the firm’s success in minimizing operating costs by choosing the optimal mix of inputs.

• The **efficient revenue frontier (RE)** represents the maximum revenues earned by firms in the industry with a given amount of inputs.
Estimating Efficiency Using DEA

- DEA is a non-parametric mathematical approach to frontier estimation that is implemented by solving linear programming problems.
- DEA seeks a set of other insurers from the industry that dominate the insurer in question (e.g., a set of insurers that have lower costs than a specific insurer while having similar outputs and inputs).
- If a dominating set exits, then the insurer in question is identified as being less than fully efficient. Its efficiency is measured relative to this set:
  - Its cost efficiency score (between 0 and 1) is the ratio of the costs that would have been expended by the dominating combination of insurers to the costs the insurer actually incurred.
  - Its revenue efficiency score (between 0 and 1) is the ratio of the revenues of the given insurer to the revenues of the dominating set of insurers.
- Of course, when no dominating set exits, the insurer is considered “self efficient” and is given a score of 1.
REVIEW OF PRIOR CANADIAN STUDY

• Similarly to Cummins (1999), Bernier & Sedzro (2002) rely on DEA to conduct a preliminary efficiency analysis of the Canadian L/H sector over the period 1997-1999. Their conclusions are that:
  – many insurers seem to have a hard time choosing the cost-minimizing combination of inputs.
  – the most efficient insurers are close to achieving the optimal choice of outputs, therefore maximizing revenues.
  – there is evidence of a lack of “scale” mostly among small insurers.
  – the potential acquisition candidates are indeed among the small insurers which badly need to increase their CE through an improvement of their AE.
Variables, Data Sources and Sample

• **Outputs/Inputs Variables and their Prices:**
  – As in Cummins (1999), we define five output variables for the five major lines of business offered by life insurers, and four input variables, namely: administrative labor, agent labor, business services and financial capital.

• **Sources:**
  – **A. M. Best’s WinTRAC 2000 (L/H)** for yearly financials (drawn from the regulatory annual statements filed by insurers with OSFI) and 1999 ratings.
  – **Statistics Canada** (Catalogue No.72-002-XPB) for the wage variables of labor and business services inputs.

• **Period covered:** 1997-1999

• **Sample:** We eliminate firms with unusual characteristics and/or incomplete information. Final sample consists of 69 firms per year (about 97% of industry assets).
Tests and Hypotheses

- 2 types of tests are conducted:
  
  - Testing for efficiency changes over time within groups of insurers (DMU’s) prior to the demutualization wave:
    - 1st group: Domestic life insurers
    - 2nd group: Foreign life insurers
    - Null Hypothesis (H₀):
      - Each group of insurers was operating on the same efficiency frontier year after year [we compare 1997 to 1998, and 1998 to 1999].

  - Testing for differences in the performance of domestic versus foreign life insurers (DMU’S) in Canada over the period 1997-1999
    - Domestic versus Foreign life insurers in every given year [1997, 1998 and 1999]
    - Null Hypothesis (H₀):
      - In a given year, domestic and foreign life insurers were operating on the same frontier, as if the two groups were drawn from the same efficiency pool.
Methodology

- Given that we are interested by the efficiency performance of groups of insurers, rather than individual performance, we rely on the so-called “Program Evaluation Procedure” [first proposed by CCR (1981) and applied by Brocket & Golany (1996)] which involves the following 4 steps:

1. Split the group of all DMU’s (j = 1, 2, …, n) into two sub-groups of n₁ and n₂ DMU’s (e.g. domestic insurers in 1997 compared to 1998, or domestic versus foreign insurers in the same year). Run DEA separately for the two sub-groups.

2. In each of the two sub-groups separately, adjust inefficient DMU’s to their “level if efficient” value by projecting each DMU onto the efficiency frontier of its group. [Step 2 adjusts for the managerial component of inefficiency]

3. Run a polled (or “inter-envelop) DEA with all n DMU’s at their adjusted efficient levels.

4. Apply the Mann-Whitney rank test (as proposed by Brocket & Golany) to determine if the two groups have the same distribution of efficiency values within the pooled data set.
Methodology (cont’d)

• As Brocket & Golany explain:
  – If the hypothesis that two groups were drawn from the same efficiency pool were true, then running DEA separately for each group as in Step 1 should reveal the same frontier for both groups. Further, after the adjustment in step 2, we should expect to see all (or most) of the DMU’s rated as efficient in Step 3. This situation corresponds to a null hypothesis that the two groups share the frontier.
  
  – If, on the other hand, the two groups are different, even after adjusting the values of inefficient DMU’s in the two groups, then we shall witness an efficiency gap when the two groups of DMU’s are evaluated simultaneously.
Methodology (cont’d)

• As Brocket & Golany also explain:

  – The Mann-Whitney rank test can be used to measure the distance between the distribution of efficiency ratings determined in Step 3 for each group and a distribution in which all the DMU’s are efficient. It is done as follows:
    • Rank order all n DMU’s by their efficiency ratings in Step 3. In case of a tie, use the mid-rank for the tied observations.
    • Compute R = the sum of the rankings of DMU’s in the 1st group.
    • Compute the Mann-Whitney rank test statistic:
      \[ U = n_1 \times n_2 + \frac{n_1 \times (n_1+1)}{2} - R. \]
    • For \( n_1, n_2 \geq 10 \), compute the following Z statistic which has an approximately standard normal distribution:
      \[ Z = \frac{\left[ U - \left( \frac{n_1 \times n_2}{2} \right) \right]}{\left\{ \frac{\left[ (n_1 \times n_2) \times (n_1 + n_2+1) \right]}{12} \right\}^{0.5}} \]

  \( H_0 \) is accepted at a level of significance \( \alpha = 1\% \), if \( Z \in [-2.58, +2.58] \) (two-tail test)
Table 1

Results of Mann-Whitney tests applied on domestic insurers 1997-1998

<table>
<thead>
<tr>
<th></th>
<th>CE</th>
<th>RE</th>
<th>SE</th>
<th>TE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U</strong></td>
<td>1349</td>
<td>707</td>
<td>1140</td>
<td>765</td>
</tr>
<tr>
<td><strong>Z</strong></td>
<td>6.5137</td>
<td>-0.155831</td>
<td>4.34248</td>
<td>0.446715</td>
</tr>
<tr>
<td><strong>SIGN</strong></td>
<td>Reject $H_0$</td>
<td>$H_0$</td>
<td>Reject $H_0$</td>
<td>$H_0$</td>
</tr>
</tbody>
</table>
Table 2

Results of Mann-Whitney tests applied on domestic insurers 1998-1999

<table>
<thead>
<tr>
<th></th>
<th>CE</th>
<th>RE</th>
<th>SE</th>
<th>TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>935</td>
<td>735</td>
<td>304</td>
<td>823</td>
</tr>
<tr>
<td>Z</td>
<td>2.2127954</td>
<td>0.1350532</td>
<td>-4.342481</td>
<td>1.04925981</td>
</tr>
<tr>
<td>SIGN</td>
<td>H₀</td>
<td>H₀</td>
<td>Reject H₀</td>
<td>H₀</td>
</tr>
</tbody>
</table>
Table 3

Results of Mann-Whitney tests applied on foreign insurers 1997-1998

<table>
<thead>
<tr>
<th></th>
<th>CE</th>
<th>RE</th>
<th>SE</th>
<th>TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>496</td>
<td>211.5</td>
<td>775</td>
<td>524.5</td>
</tr>
<tr>
<td>Z</td>
<td>0.2182179</td>
<td>-3.787137</td>
<td>4.14613991</td>
<td>0.619457</td>
</tr>
<tr>
<td>SIGN</td>
<td>$H_0$</td>
<td>Reject $H_0$</td>
<td>Reject $H_0$</td>
<td>$H_0$</td>
</tr>
<tr>
<td></td>
<td>CE</td>
<td>RE</td>
<td>SE</td>
<td>TE</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><strong>U</strong></td>
<td>803.5</td>
<td>922</td>
<td>194</td>
<td>800</td>
</tr>
<tr>
<td><strong>Z</strong></td>
<td>4.547</td>
<td>6.216</td>
<td>-4.033</td>
<td>4.4981</td>
</tr>
<tr>
<td><strong>SIGN</strong></td>
<td>Reject $H_0$</td>
<td>Reject $H_0$</td>
<td>Reject $H_0$</td>
<td>Reject $H_0$</td>
</tr>
</tbody>
</table>
Table 5

Results of Mann-Whitney tests applied on domestic versus foreign insurers

<table>
<thead>
<tr>
<th></th>
<th>CE</th>
<th>RE</th>
<th>SE</th>
<th>TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGN</td>
<td>Reject Ho</td>
<td>Reject Ho</td>
<td>Reject Ho</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Z (1998)</td>
<td>3.84219</td>
<td>-5.8387</td>
<td>-0.37396</td>
<td>5.39233</td>
</tr>
<tr>
<td>SIGN</td>
<td>Reject Ho</td>
<td>Reject Ho</td>
<td>Ho</td>
<td>Reject Ho</td>
</tr>
<tr>
<td>Z(1999)</td>
<td>5.92915</td>
<td>7.10533</td>
<td>1.170147</td>
<td>5.307886</td>
</tr>
<tr>
<td>SIGN</td>
<td>Reject Ho</td>
<td>Reject Ho</td>
<td>Ho</td>
<td>Reject Ho</td>
</tr>
</tbody>
</table>
INTERPRETATION OF RESULTS

• Our results, for the 1997-1999 period (prior to the demutualization wave), suggest that:
  – as a group, domestic life insurers did not really experience significant efficiency changes, except perhaps in terms of SE (Tables 1 and 2);
  – as a group, and over the entire 3-year period, foreign life insurers did experience significant RE and SE frontier changes. Also, CE and TE frontiers changed significantly in 1999 over 1998 (Tables 3 and 4);
  – domestic versus foreign life insurers are two distinctive types of entities (or “programs”) since, year after year, they do not share the same CE, RE and TE frontiers. In 1998 &1999, the two groups did however share the same SE frontier (Table 5).
Limitations of Study

• General limitations of DEA apply.
  – DEA being an extreme point technique, measurement error (noise) can cause problems.

• Time period is short and only prior to demutualization wave.
  – Need to extend tracking window and compare pre and post demutualization periods more thoroughly;

• Additional work on the sources of efficiency changes for insurers operating in Canada is needed.
  – Measure the “Malmquist Productivity Index” in order to track down the changes.