Institute of Actuaries of Australia

An Investigation of Life Insurer Efficiency in Canada

Prepared by William Wise & Sachi Purcal

Presented to the Institute of Actuaries of Australia
4th Financial Services Forum 19-20 May 2008
Melbourne, Australia

© **William Wise**
School of Actuarial Studies
University of New South Wales[1 2]

Sachi Purcal
School of Actuarial Studies
University of New South Wales[3]

April 2008

The Institute of Actuaries of Australia
Level 7 Challis House 4 Martin Place
Sydney NSW Australia 2000
Telephone: +61 2 9233 3466 Facsimile: +61 2 9233 3446
Email: actuaries@actuaries.asn.au Website: www.actuaries.asn.au

[1] Sydney, 2052, Australia. E-mail: bill1612002@hotmail.com.
[2] Corresponding author
[3] Sydney, 2052, Australia. Telephone: +61 (2) 9385 3566. Fax: +61 (2) 9385 1883.
E-mail: s.purcal@unsw.edu.au.

Abstract

This paper explores the effect of the profit and cost efficiency of Canadian life insurers on their return on equity (ROE). We take the data submitted by these insurers to the Office of the Superintendent of Financial Institutions (OSFI) for 2000 through 2004 and determine 1) the extent of the profit and cost efficiency of the various Canada life insurers and 2) how this affects their ROE. We also explore how other factors such as company size, debt ratio and amount of new business written affect ROE. The values are determined using stochastic frontier analysis for both companies as a whole and separately for the various lines of business (LOBs) within the companies.

The results of the investigation show us that both the profit and cost efficiency is very important in determining the ROE of a life insurer as a whole and is much more so than the other factors explored. Indeed the average inefficiency of the insurers reduces their average ROE anywhere from 11% to 38% of its potential value depending upon the method of measurement used. It is found that in order to increase its ROE by even 1% (e.g. from 10% to 11%) by adjusting its size, debt ratio or amount of new business written is (virtually) impossible for a life insurer and the only reasonable way to do so is by improving its efficiency. In addition profit efficiency by LOB is seen, for the most part, to be important in determining the ROE of the LOB and is also more so than the other factors explored. There are some LOBs where the importance of profit efficiency is difficult to determine, mostly because of a lack of data.

Keywords: Life Insurance, Life Insurer Efficiency, Insurer Efficiency, Profit Efficiency, Cost Efficiency
JEL Classification Numbers: G22, H21, G28

An Investigation of Life Insurer Efficiency in Canada

1 Introduction

Life insurance is a very important segment of the Canadian economy and that of most developed countries. Therefore, as an insolvency can have a devastating effect on a country's economy, it is imperative that life insurers be viable and profitable.

The concept of efficiency concerns an insurer's ability to produce a given set of outputs (such as premiums and investment income) via the use of inputs such as administrative and sales staff and financial capital.[4]

So a key determinant of a life insurer's viability is its efficiency. However, even though many papers have been written on the efficiency of the various financial institutions[5], few have explored the effect of efficiency on the (financial) results of the entities in question and even fewer have considered life insurance in any way. Of the papers we have found that consider life insurer efficiency only one, Greene & Segal (2004), truly considers how life insurer efficiency affects their profits. There are three others that consider this effect to a lesser extent, but not to what is covered in this paper.

Greene & Segal (2004) is a study of life insurers in the United States that looks at the relation between efficiency (and other parameters) and the profit values of return on equity (ROE) and return on assets (ROA) for each company considered. This is considered both annually and on a cumulative basis over four years. The authors conclude that the mean of their estimate of life insurer inefficiency decreases the mean ROE of the industry from 12% to 8% on an annual basis which is clearly significant. The corresponding effect on ROA and earnings before tax in the industry is even greater as it is a decrease from 2% to 1% and of 54%, respectively.

The cumulative results are even more economically significant than the single year results. Here the effect of inefficiency on ROE at the mean of the inefficiency estimate is -5%, versus the industry ROE of 8% and the effect of inefficiency on ROA at the mean of the inefficiency estimate is -1.5%, versus the industry ROE of 1.2%.

This research goes beyond what has been done (for the most part) in the past and investigates the important phenomenon of how the efficiency of life insurers in Canada affects their profits. The research determines 1) the extent of the profit efficiency of the various Canada life insurers and 2) how this affects their ROE. We also explore how other factors such as company size, debt ratio and amount of new business written affect ROE. The values are determined using stochastic frontier analysis for both companies as a whole and separately for the various lines of business (LOBs) within the companies. As noted above this has not been done for life insurers in Canada and only Greene & Segal (2004) does it for any life insurance market.

In Section 2 we look at the past literature regarding life insurer efficiency and in Section 3 we outline the methodology used in this paper. Section 4 discusses the data used, Sections 5, 6 and 7 show the results of the profit and cost (in)efficiency investigations, Section 8 discusses these and in Section 9 we draw out conclusions.

---

[4] This statement is from Diacon et al.(2002). It also applies to the term "X-efficiency" (cross-efficiency) with respect to life insurance.

[5] Such as banks, thrifts, S&Ls, credit unions, and insurance companies.

2 Literature Review

2.1 Stochastic Frontier Analysis

Frontier analysis is the determination of the maximum output (i.e. the "frontier") that can be obtained using a set of inputs along with a comparison between this frontier and the outputs of specific entities using the same set of inputs.

Stochastic frontier analysis (SFA) was postulated as a way to avoid the problems encountered in the use of frontier analysis[6] by Aigner, Lovell & Schmidt (1977) and Meeusen & van Den Broeck (1977). Both papers advance the idea of an error term that is composed of two parts namely an inefficiency piece and a random piece. When utilizing SFA the form used is

$$y_i = f(x_i, \beta)\exp(v_i - u_i)$$

where $y_i = f(x_i, \beta)$ is the functional form of the efficient frontier, the y value is measured, the x_i values are the inputs and the β parameters are to be estimated. In addition exp v_i represents noise in measurement and exp u_i represents the inefficiency of the entity in question.

In addition both of the papers were the first to put forth a possible efficiency frontier for SFA(-type) models, namely $f(x_i, \beta)$. No other such frontier seems to have been put forth in the literature as being feasible.

2.2 Most Common Methods of Determining Efficiency

In the literature chiefly six methods, comprised of two nonparametric, three parametric and the Bayesian method have been used to explore efficiency of financial institutions. In the Bayesian approach one uses information, e.g. from economic theory, to estimate the parameters of the model. Then from the data one calculates the likelihood function $L(\boldsymbol{x} \mid \boldsymbol{\beta}, \sigma)$ ($\boldsymbol{x}$ represents the data points x_1, x_2 x_3,…). It is then (usually) possible to calculate a marginal pdf $p(\beta_k \mid \boldsymbol{x})$ for each element of $\boldsymbol{\beta}$ and thus calculate the probability that β_k lies in any particular interval.

One problem with the Bayesian approach is that it is necessary to choose a reasonable prior pdf without which the estimates with respect to each β_k may be useless or nonsensical. In addition the prior pdf will be chosen by the researcher so this can lead to inherent problems such as a bias or error in their beliefs.

The two nonparametric approaches, data envelopment analysis (DEA) and free disposal hull (FDH), do not specify a form for the underlying production relationship between inputs and outputs. For the linear programming technique DEA the set of frontier observations is such that no other (linear combination) of decision making units (DMUs) has at least as much (little) output (input) for a given set of inputs (outputs). FDH is a special case of DEA in that its production possibilities are only the vertices found using DEA and the FDH points interior to them.

The main problem with nonparametric approaches is that they basically assume that there is no random error. Another problem is that accounting rules distorting the measurement of inputs or

[6] Which uses the form $y_i = f(x_i, \beta)$, so this is the same form as is used by SFA (seen below) without the noise and inefficiency terms.

outputs are not accounted for by these methods as they assume that no such inaccuracies exist. Further deficiencies of the nonparametric methods include the facts that 1) the frontier is shaped by the data and 2) only the data of entities closest in type to that being measured are used in measuring the inefficiency of an entity.

The three parametric approaches, SFA, thick frontier analysis (TFA) and the distribution-free approach (DFA) specify a functional form for the efficiency frontier. The problem with the DFA is that it assumes that over time the efficiency of each firm exhibits little change and the "random errors average to zero".[7] Another problem is that a change in, for example technology or regulations that affects the efficiency of all of the firms considered, leads the DFA to measure the deviation of a particular firm's efficiency from the average frontier over time whereas it is probably more desirable to have a measure against the frontier at one particular point in time.

SFA allows for random error in the measurement of inefficiency that follows a symmetric distribution, usually the standard normal. The inefficiencies that a DMU exhibits are usually assumed to follow an asymmetric distribution (due to the fact that they are assumed to be non-negative) such as the half-normal, truncated normal or gamma. Therefore, given the observation of the error term as a whole, the inefficiency of the DMU is determined as the conditional mean of its distribution. TFA is similar except that it assumes that deviations from the predicted efficiency within the highest and lowest quartiles[8] of the observations represent random error and said deviations between these quartiles represent inefficiencies.

SFA is used in the paper so, as seen above, the form used is

$$y_i = f(x_i, \beta)\exp(v_i - u_i)$$

where $y_i = f(x_i, \beta)$ is the functional form of the efficient frontier, the y value is measured, the x_i values are the inputs, and the β parameters are to be estimated. In addition exp v_i represents noise in measurement and exp u_i represents the inefficiency of a DMU.

In reality when working with an SFA model it is more common to use the logarithmic form

$$\ln y_i = \ln f(x_i, \beta) + v_i - u_i$$

so that the efficient frontier is $\ln f(x_i, \beta)$ using the estimated β values.

Two methods of determining (in)efficiency that employ SFA are those that determine profit (in)efficiency and cost (in)efficiency. While most studies that we have seen have employed cost (in)efficiency some authors consider profit (in)efficiency to be a better measure to use. For example, Berger et al. (1993) write that "it is surprising that" profit efficiency has "been used so sparingly" given its advantages and Berger & Mester (2003) say that "(i)n studying firm performance, profit maximization is superior to cost minimization…" Therefore this paper will employ both profit and cost (in)efficiency with an emphasis on the former.

2.3 Papers Relating Life Insurer Efficiency To Profits To Some Degree

[7] Quote is from Berger & Humphrey (1997).
[8] It is possible to use other sets, e.g. quintiles.

As noted above a few of the papers sourced do relate the efficiency of a life insurer to its profits but only to a limited degree, i.e. they do not really investigate how (in)efficiency in life insurers affects profit performance.

Nini (2002) looks at profit efficiency of foreign and domestic insurance companies in the European Union. The paper estimates profit and cost efficiency within the five largest such insurance markets, namely Germany, Spain, France, Italy and the UK, for the years 1998 and 1999. To estimate the profit function a normalized quadratic function with a translog specification is used.[9]

A summary of the distribution of the profit loss due to inefficiency (per assets and per surplus) is presented. However this only shows a percentage loss of profits due to inefficiency, e.g. for Germany we can see that at the 25th percentile 2.6% of asset value is lost due to inefficiency while the corresponding values for the 50th and 75th percentiles are 1.8% and 1.4%. So this does not show how significant the losses are as if the profits are 50% of asset value then we can say that the loss is not as significant as if the average profit is only 5% of asset value whereupon the loss seems hugely significant. Presumably such results were generated but they are not displayed.

Berger, Cummins, Weiss & Zi (2000) takes a different tack on profit of insurers. They look at which product scope 1) joint production of both life and property-liability insurance or 2) specialist production of just one of these will generate "profit scope economies",[10] i.e. an increase in profits.

The authors' results include that only for large insurers will there be a statistically significant profit scope economy, i.e. being a joint insurance provider will be beneficial versus being a specialist provider. The authors also look at a thick frontier method wherein they use "the most X-efficient 50% of the firms in each size class." Then "(b)ased on the residuals from (their) main cost, revenue and profit functions, respectively" they state that they see "smaller cost and profit scope economies for X-efficient[11] insurers than for the full sample." So they use the concept of efficiency affecting profit scope economies but not profit explicitly.

Kellner & Mathewson (1983) determines an estimation of a set of first-order conditions for profit-maximizing output decisions by life insurance firms. To begin they assume that each firm sells a single product, a one-period nonpar insurance policy. They use this for the ease of both diagrammatic representations and economic interpretation. They then specify a single-output firm model and describe the industry equilibrium.

The principal contribution of the paper is to use a multi-product analogue of the profit-maximizing marginal conditions for the firm to estimate the production characteristics for life insurance and then to test the consistency of these parameter estimates with an industry equilibrium. This paper does show us a simple model that a firm could use to maximize its profits but it does not delve into how (in)efficiency affects profits.

2.4 Paper Relating Life Insurer Efficiency To Profits

The only paper we have found that truly looks at how efficiency affects life insurance profitability is Greene & Segal (2004). It uses the stochastic frontier method to suggest that cost inefficiency in the

[9] The results were also confirmed using a composite functional form.
[10] These are (partially) composed of "cost scope economies" and "revenue scope economies".
[11] Cost (profit) X-efficiency is used for the cost (profit) scope economies.

life insurance industry in the United States is substantial relative to earnings due to the idea that the life insurance industry is "mature and highly competitive."

The authors look at the relation between efficiency (and other parameters) and the profit values of ROE and ROA for each company considered both annually and on a four-year cumulative basis. This latter examination allows for the (partial) elimination of mere aberrations in an individual firm's output.

The results are that the effect of inefficiency on ROE at the mean of the inefficiency estimate is -4%, versus the industry ROE of 12% which is clearly economically significant. The effect of inefficiency on ROA at the mean of the inefficiency estimate is -1%, versus the industry ROE of 2% so this is even more economically significant.

For the cumulative results the results are that the effect of inefficiency on ROE at the mean of the inefficiency estimate is -5%, versus the industry ROE of 8% and the effect of inefficiency on ROA at the mean of the inefficiency estimate is -1.5%, versus the industry ROE of 1.2% so these results are even more economically significant than the single year results.

3 Methodology

As seen above, the concept of efficiency concerns an insurer's ability to produce a given set of outputs (such as premiums and investment income) via the use of inputs such as administrative and sales staff and financial capital. Frontier analysis, then, is the determination of the maximum output (i.e. the "frontier") that can be obtained using a set of inputs along with a comparison between this frontier and the outputs of specific entities using the same set of inputs.

In the Literature Review it was noted that when working with an SFA model it is more common to use the logarithmic form

$$\ln y_i = \ln f(x_i, \beta) + v_i - u_i$$

where $y_i = f(x_i, \beta)$ is the functional form of the efficient frontier, the y value is measured, the x_i values are the inputs, and the β parameters are to be estimated. In addition exp v_i represents noise in measurement and exp u_i represents the inefficiency of a DMU.

Now, to determine the functional form to use one needs enough parameters so that the profit (or cost) is approximated reasonably close to whatever the true function may be. It has been argued that since the translog function can be regarded as a second-order Taylor approximation to any arbitrary profit (or cost) function then if the data do not correspond to the demand functions derived from said translog function demand theory must be false. In addition the translog function is homogeneous of degree zero so no restriction is implied by using ratios of variables to a numeraire rather than the variables themselves.

Also, the translog functional form is by far the most common such form used in efficiency studies of financial institutions. Indeed upon exploring 47 such papers that use SFA; 41 use a translog functional form and one other uses a composite of a translog functional form with a normalized quadratic functional form. Therefore the translog functional form is well developed and integrated into in this area and it is well agreed that it is the most appropriate functional form to use.

Hence, the proposed basic functional form for both the profit and cost efficiency frontier is the translog function which is

$$\ln y = \beta_0 + \sum_1^N \beta_n \ln x_n + \frac{1}{2}\sum_1^N \sum_1^M \beta_{nm} \ln x_n \ln x_m .$$

Specifically for time-invariant profit (in)efficiency, following Berger & Mester (1997), this leads to the use of the formula[12]

$$\ln(\frac{\quad_i}{y_{Mi}(\ln A_i)} + \quad + 1) =$$

$$+ \sum \quad_n \ln(\frac{x_{ni}}{\ln A_i} + \quad_n + 1) + \sum \quad_m \ln(\frac{y_{mi}}{y_{Mi}} + \quad_m + 1) +$$

$$\frac{1}{2}\sum\sum \quad_{nk} \ln(\frac{x_{ni}}{\ln A_i} + \quad_n + 1)\ln(\frac{x_{ki}}{\ln A_i} + \quad_k + 1) + \frac{1}{2}\sum\sum \quad_{mj} \ln(\frac{y_{mi}}{y_{Mi}} + \quad_m + 1)\ln(\frac{y_{ji}}{y_{Mi}} + \quad_j + 1) +$$

$$\frac{1}{2}\sum\sum \quad_{nm} \ln(\frac{x_{ni}}{\ln A_i} + \quad_n + 1)\ln(\frac{y_{mi}}{y_{Mi}} + \quad_m + 1) + v_i + u_i \qquad (1)$$

where *i* is an index for the life insurance companies, Π_i is the profit generated by insurer *i*, A_i is the asset value of company *i*, the x_i values are the various output quantities produced by company *i*, the y_i values are the various input quantities used by company *i*, the θ values are such that the lowest value to take the natural log of is zero for each variable (set)[13], and the β parameters are to be estimated. In addition exp v_i represents noise in measurement and exp u_i represents the inefficiency of company *i*.

The equivalent formula is used for cost (in)efficiency except that

$$\ln(\frac{C_i}{y_{Mi}(\ln A_i)} + \quad + 1)$$

(where C_i, the cost incurred by insurer *i*) is the dependent variable.

The normalizations by $\ln A_i$ and y_{Mi} (the last input[14]) are designed to help control for heteroskedasticity and help reduce scale biases. They also impose linear homogeneity on the input quantities.

[12] Note that this paper uses panel data so the time subscript is suppressed here for ease of notation.
[13] So they are set to the opposite of the lowest value of each respective variable.
[14] In reality this can be any input.

To determine the profit inefficiency of a life insurer we use the idea that the most efficient insurer will have the highest profit. We follow Berger and Mester (1997) so that to determine profit inefficiency of company *i* we use

$$1-\frac{\Pi^{i}}{\Pi^{\max}}=1-\frac{\exp[\hat{f}(x^{i},y^{i},s^{i})]\hat{u}^{i}}{\exp[\hat{f}(x^{i},y^{i},s^{i})]\hat{u}^{\max}}=1-\frac{\hat{u}^{i}}{\hat{u}^{\max}} \qquad (2)$$

where *Π* is the profit values used in the LHS of equation (1); *f* is the functional form (here the translog function); *x*, *y* and *s* refer to inputs, outputs and exogenous variables[15] and max refers to the most efficient company.

So the profit inefficiency of company *i* is such that it is compared to the most efficient company if both are using the same sets, namely those of company *i,* of inputs, outputs exogenous variables with which to work.

A similar idea is used with respect to determining cost inefficiency except that the LHS of equation (2) is set to

$$1-\frac{\Pi^{\min}}{\Pi^{i}}$$

Following the method of Kumbhakar and Lovell (2000) to determine the cost inefficiency we set

$$\hat{u}_i^{*}=\frac{1}{T}\sum_{t}\{\ln(\frac{C_i}{y_{Mi}(\ln A_i)}+\ {}_{C}+1)-\hat{\beta}_0-\sum\hat{\beta}\ln(z)\}$$

for insurer *i*, where T is the number of panel data observations for company *i* and the $\sum\hat{}\ln(z)$ represents all of the summation terms in equation (1). So we are using the residuals from the estimate of the cost inefficiency equation and calculating the average residual for each company *i*.

We then set

$$\hat{u}_i=\min_i\{\hat{u}_i^{*}\}-\hat{u}_i^{*} \text{ and}$$

the cost inefficiency of each insurer *i* to[16]

$$CI_i=1-\exp(\hat{u}_i).$$

To determine the profit inefficiency the idea that the most efficient insurer will have the highest profits so

---

[15] The latter of which are only used when determining time-varying (in)efficiency.

[16] This is equivalent to the idea that the efficiency of each insurer is the ratio of the residual that the most efficient company would generate from the cost inefficiency function to the residual the insurer in question generates (a la Equation (2)).

$$\square u_i = \hat{u}_i^* - \max_i \{\hat{u}_i^*\}$$

and so the profit inefficiency of insurer *i* is

$$PI_i = 1 - \exp(\hat{u}_i) .$$

For time-varying cost (in)efficiency we explore both how u_i varies with time for each company *i* and how exogenous variables affect cost (in)efficiency. For the former we use the idea of Lee and Schmidt (1993) of setting

$$u_{it} = \quad {}_t u_i .$$

So the time-invariant translog model is enhanced by $\sum_i \sum_t D_t \quad {}_t u_i$ with D_t a dummy variable for time. Then

$$u_{it} = \max_i \{\square {}_t \square u_i\} - \square {}_t \square u_i .$$

For the exogenous variables we choose (the natural log of) asset size, debt ratio, percent of new business written by the company, average government ten year bond yields over the year and whether a company is domestic.[17] Using government yields is an legitimate variable to consider here as Section 608 of *Insurance Companies Act* states that "A foreign company shall, in relation to its insurance risks in Canada, maintain an adequate margin of assets in Canada over liabilities in Canada…."

Kumbhakar and Lovell (2000) states that using a two step process to determine the effect of exogenous variables on efficiency is only appropriate if they only affect the productivity process, but not efficiency. So to determine the effect of the exogenous variables on efficiency we follow Bhattacharyya et al. (1995) and use the same idea as with u_{it} on the exogenous variables. To do this we enhance the time-invariant translog model with the terms

$$\sum_i \sum_t D_t \qquad w_{it} \tag{3}$$

with *w* being the value of each of the exogenous variables under consideration[18] and β^w representing the β variables to be estimated for each *w*. Then the preliminary time-varying efficiency is determined as

$$u_{it}^* = 1 - \exp[-\sum_w (\max_i \{\hat{} \quad w_{it}\} - \hat{} \quad w_{it})]$$

where the *w* variables are the $\square u_i$ values as well as the value of each of the exogenous variables under consideration.[19]

---

[17] Distribution method is considered in several (many) insurer efficiency papers but in Canada there is no (legal) difference between agents and brokers (at least in the three largest provinces: BC, ON and QC). In addition ownership form is considered in several (many) insurer efficiency papers but in Canada very few life insurers are stock companies.

[18] Note that the (*w*) domestic variable is a dummy variable

Changing from time-invariant (in)efficiency to time-varying (in)efficiency should not change the overall (in)efficiency of a life insurer, so the u_{it}^* values are adjusted so that, for each company *i*, the average of the u_{it} values equals the time-invariant u_i values.

To determine the inputs and outputs used in the translog functions we consider that the data used consists of values from the Office of the Superintendent of Financial Institutions (OSFI) annual returns for 2000 through 2004.[20] These return values leading to the determination of profit for each company in each year are premiums, net investment income, other revenue, claims, annuity payments, other payments (which includes surrender values), policyholder dividends and experience rating refunds, (change in) policy liabilities, commissions, interest on policyholder amounts on deposit, interest in subordinated debt, other interest expense and general expenses and taxes (excluding income tax).[21]

So the choices of inputs and outputs to use in this paper come from these.[22] We operate on the premise that an output is something that a company strives to produce. Therefore the outputs chosen are premiums, net investment income and other revenue. For inputs it is clear that (change in) policy liabilities, commissions, interest on policyholder amounts on deposit, interest in subordinated debt, other interest expense and general expenses and taxes (excluding income tax) fit this as these items are clearly (paper) expenditures designed to keep a company viable. For policyholder dividends and experience rating refunds one could deem this to be an input or, just as easily, as negative output. For this paper this value is deemed to be an input as there is a timing issue with respect to the fact that the dividends (say) paid to a policyholder corresponding to a specific period do not necessarily correspond directly to the premiums received during this period and one can make an argument that the amount of dividends (say) can be thought of as "public relations."

On the other hand for claims, annuity payments and other payments it may be questionable as to whether these should be deemed inputs as even though there is a timing issue similar to that seen for dividends, whether the payment of these amounts can be thought of as "public relations" is doubtful. So this paper looks at both the case where these values are counted as inputs and where they are not.[23]

For the input numeraire a quantity that is both indicative of the amount of business that an insurer engages in and is a positive quantity for most of the company-year pairs in question should be used. Hence for the case where claims is used as an input claims is used as the input numeraire and for the case where claims is not used as an input commissions is so used.

It should be noted that the calculations are all done net of reinsurance (as we postulate that the reinsurance obtained by the company is a reflection of its efficiency with respect to profits and costs) and gross of income tax (as income tax is not necessarily controllable by the company).

---

[19] Note that the entire translog model is re-estimated here so all of the β parameters of the time-invariant translog model are re-estimated.

[20] See the Data section for more details.

[21] Transfers to (and from) other funds is also in the data but not used here.

[22] Previous studies of the efficiency of life insurance companies have used a plethora of different measures to at least proxy each company's inputs and outputs. This plethora is a result of differences of opinion between the authors as to what is the best measure for the task at hand. The author can provide a list and description of this plethora for several papers upon request.

[23] Note that interest on subordinated debt is not a value on the annual returns for the foreign owned companies, so it is excluded as an input.

After the profit and cost inefficiency values are determined for each insurer; the important idea of how the relevant inefficiencies and the variables of 1) the (average of the) year (parameter), 2) (natural log of) asset size, 3) debt ratio, 4) percent of new business written by the company, 5) average government bond yields over the year and 6) whether a company is domestic affect the ROE[24] of each insurer is also explored. To this end for profit inefficiency a regression is performed on the equation

$$ROE_i = {}_0 \quad {}_{ineffy}PI_i + \sum_{z=2000}^{2004} {}_z D_z + {}_{\ln asize} \ln A_i + {}_{drat}DRat_i + \beta_{pnew}PNew_i + \beta_{yields}Yields_i + \beta_{dom}D_{dom} \qquad (4)$$

where the D variables are dummy variables and the time subscripts are suppressed for ease of notation.

An equivalent regression is used for cost inefficiency.

To ensure that equation (4) does not exclude any relevant non-linear variables a Regression Equation Specification Error Test (RESET) test was performed. The RESET F parameter calculated was 0.981. Given that the relative F-statistic is about 2.30 at even 10% it is clear that no relevant non-linear variable was excluded.

In this paper the parameters are estimated using both generalized least squares (GLS) and maximum likelihood estimation (MLE).

The MLE formulas used follow Kumbhakar and Lovell (2000). We use the assumptions that

(i) v_{it} ~ iid N(0, σ_v^2),

(ii) u_i ~ iid N(0, σ_u^2) and

(iii) the v_{it} and u_i are independent of each other and of the regressors.

Then for the log-likelihood function for time-invariant (in)efficiency we use

$$\ln L = K + \frac{I(\ln \sigma_*^2)}{2} + \frac{1}{2}\sum_i \frac{u_{*i}^2}{\sigma_{*i}^2} - \frac{\sum_i [\varepsilon_i^T \varepsilon_i]}{2\sigma_v^2} - \frac{\sum T_i}{2}\ln\sigma_v^2 - \frac{I}{2}\ln\sigma_u^2 + \sum_i \ln[1 - \Phi(\frac{-u_{*i}}{\sigma_*})]$$

where K is a constant, I is the number of companies under consideration, T_i is the number of years under consideration for company i (with max$\{T_i\} = T$), ε is the vector of residuals,

$\sigma_{*i}^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_v^2 + T_i\sigma_u^2}$, $\sigma_*^2 = \frac{\sigma_u^2\sigma_v^2}{\sigma_v^2 + T\sigma_u^2}$, $\mu_{*i} = \frac{\sigma_u^2 \sum_i \varepsilon_{it}}{\sigma_v^2 + T_i\sigma_u^2}$ and Φ is the standard normal cdf.

[24] ROE is defined as profit/equity as shown in the OSFI returns.

Then for the (in)efficiency score we set

$$E(u_i \mid \varepsilon_i) = \mu_{*i} + \sigma_* [\frac{\phi(-\mu_{*i} / \sigma_*)}{1 - \Phi(-\mu_{*i} / \sigma_*)}]$$

so that $PI_i = 1 - \exp(\hat{u}_i)$ (as above).

In the past research into efficiency has only considered entities as a whole. This project uses the innovative approach of exploring the efficiency of the separate lines of business (LOBs) of the various life insurers. In the OSFI returns for 2000 through 2004 the financial results of each insurer are divided showing the financial results of the following ten LOBs separately:

1) Individual Life NonPar,
2) Individual Life Par,
3) Group Life NonPar,
4) Group Life Par,
5) Individual Annuities NonPar,
6) Individual Annuities Par,
7) Group Annuities NonPar,
8) Group Annuities Par,
9) Individual Accident & Sickness and
10) Group Accident & Sickness.

Using the inputs and outputs of each LOB of the life insurers both the profit and cost efficiency of each is determined and in addition each insurer's sum total efficiencies.

4 Data

The life insurers considered in this paper are those that are allowed to and do issue life insurance by the Office of the Superintendent of Financial Institutions (OSFI) so the several companies that are only allowed to service policies are excluded. In addition companies that only take reinsurance are excluded. So the study considers thirty-five domestically owned companies and thirty-one foreign owned companies.[25]

4.1 Data Sources

In this paper we take the panel data submitted by these insurers to OSFI for 2000 through 2004.[26] The specific OSFI returns that are used are as in Table 4.1 below:

[25] Note that the company numbers seen in this paper include all companies, so they range beyond sixty-six.
[26] See http://data.beyond2020.com/osfi/osfi_en.htm

TABLE 4.1

OSFI Returns Used in this Paper[27]

Period	Title	Return
2000-2004	Canadian Life Insurance Companies	OSFI-54
2000-2004	Foreign Life Insurance Companies	OSFI-55

These are all annual returns.

5 Profit (In)Efficiency Results

In this section we present GLS and MLE results for the several cases explored with respect to profit inefficiency. The cases are described in Table 5.1 below:

TABLE 5.1

Cases Explored Regarding Profit InEfficiency

	Include Claims, Annuity Pymts and Other Pymts as Inputs?	Numeraire	Exclude Specific Companies?
Base Case	Yes	Claims	No
Case II	No	Commissions	No
Case III	No	Commissions	Yes

In each case the effect on ROE of the various parameters are presented. In addition for some cases tables that show estimates of the translog parameters and profit inefficiencies by company[28] are shown.[29]

5.1 GLS Results

5.1.1 Time-Invariant Inefficiency

5.1.1.1 Base Case (Include claims, annuity payments and other payments as inputs and use claims as input numeraire)

The estimates of the parameters of the translog function are shown in Table 5.2 below:

[27] It should be noted that each of these returns consists of several (many) pages, much too many to be listed here.
[28] In some cases inefficiencies by company-year pair are also shown.
[29] These tables for all cases are available from the author.

TABLE 5.2

Estimates of Translog Parameters
Profit InEfficiency – GLS
Time-Invariant Base Case

Value(s) of which Ln is used[30]	Parameter Estimate	Standard Deviation	Values of which Ln is used	Parameter Estimate	Standard Deviation
premiums	167.346	320.514	or x com	1.459	2.961
net investment income	34.045	61.457	or x ipha	-7.206	24.742
other revenue	23.333	106.060	or x oie	-0.088	0.688
annuity pymts	-120.828	312.617	or x ge	0.047***	0.018
other pymts	-76.264	167.689	ap x op	-0.143***	0.046
change pol liabs	-87.476	309.809	ap x als	0.222**	0.104
dividends & errs	-18.039	311.635	ap x div	0.002	0.049
commissions	275.458	359.693	ap x com	-0.702	13.307
interest ph amts	841.997	925.581	ap x ipha	28.114	69.116
other interest exp	-1334.461	1187.529	ap x oie	1.358	3.820
general expenses	357.816	299.366	ap x ge	0.059***	0.014
prms x ii	-0.029	0.026	op x als	-0.282	0.320
prms x or	0.008	0.027	op x div	-0.101	0.092
prms x ap	0.384*	0.206	op x com	-14.784*	8.254
prms x op	-0.706***	0.253	op x ipha	40.493	38.533
prms x als	-2.006	2.829	op x oie	1.307	4.553
prms x div	0.392*	0.211	op x ge	0.258***	0.077
prms x com	-2.441	13.006	als x div	0.383	0.616
prms x ipha	-32.623	76.689	als x com	7.439	10.919
prms x oie	-0.283	1.698	als x ipha	14.225	69.695
prms x ge	0.049	0.261	als x oie	8.772	72.350
ii x or	0.005	0.007	als x ge	0.688***	0.063
ii x ap	0.061	0.043	div x com	17.168	46.833
ii x op	0.028	0.047	div x ipha	-21.580	38.748
ii x als	-0.455***	0.076	div x oie	0.776	2.645
ii x div	-0.107	0.077	div x ge	0.139	0.154
ii x com	-1.795	2.681	com x ipha	-74.128	72.784
ii x ipha	-4.726	14.385	com x oie	123.695	154.673
ii x oie	0.148	0.684	com x ge	-3.138	2.754
ii x ge	0.008	0.012	ipha x oie	127.136	117.279
or x aps	-0.216***	0.077	ipha x ge	-80.355	69.786
or x op	0.225**	0.091	oie x ge	-5.317	4.424
or x als	-0.293***	0.021	constant	-3464.996	4050.207
or x div	0.035	0.101			

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note: prms = premiums, ii = net investment income, or = other revenue, ap = annuity payments, op = other payments, als = change in policy liabilities, div = dividends and experience rating refunds, com = commissions, ipha = interest on policyholder amounts, oie = other interest expense and ge = general expenses

It should be noted that while some of these results are significant even to a (less than) 1% level, none of the estimates for the single parameters are. This is probably due to the fact that not all of the variables have the same numeraire. This also probably explains why interest on policyholder

[30] The constant (not its natural log) is used

amounts and general expenses have positive estimates (of course their lack of statistical significance really means that these parameters could just as easily be negative anyway).

The company by company time–invariant profit inefficiency results are shown in Table 5.3 below:

TABLE 5.3

Company Profit InEfficiency – GLS
Time-Invariant Base Case

Company	Profit Inefficiency	Company	Profit Inefficiency	Company	Profit Inefficiency
53	0.000%	107	5.234%	41	5.614%
35	1.976%	52	5.249%	8	5.657%
51	2.537%	72	5.298%	42	5.834%
106	2.811%	21	5.307%	78	5.848%
5	2.983%	61	5.312%	25	5.886%
82	3.113%	20	5.316%	15	5.907%
85	3.178%	49	5.336%	28	5.976%
44	3.356%	102	5.353%	98	6.026%
39	3.566%	90	5.355%	4	6.099%
16	4.123%	79	5.359%	17	6.188%
18	4.315%	22	5.392%	26	6.462%
29	4.468%	69	5.398%	96	6.482%
89	4.484%	77	5.400%	32	6.658%
73	4.622%	36	5.405%	3	6.764%
62	4.679%	19	5.412%	38	6.914%
33	4.813%	95	5.429%	1	7.091%
74	4.852%	6	5.438%	11	7.156%
40	4.987%	91	5.491%	104	7.172%
13	5.027%	27	5.572%	34	7.617%
43	5.043%	37	5.597%	71	35.676%
59	5.046%	58	5.607%	56	53.238%
30	5.091%				

In calculating the efficiency values it should be noted that two companies were calculated to be much more efficient than the rest, so they were excluded as outliers. If the (second) most efficient of these is included in the analysis then the average inefficiency of the other companies is (24.17%) 71.05%; a result that is most likely not valid.[31]

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-invariant inefficiency is 6.32%. This ranges from 1.98% to 53.24% (recall that one company has zero inefficiency by definition).

[31] It should be noted, then, that leaving either of these companies in the analysis will increase the effect of inefficiency on ROE and so increase the importance of inefficiency with respect to a company's profits.

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.4 below:

TABLE 5.4

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.355***	0.060
2001	-0.003	0.018
2002	-0.019	0.023
2003	-0.021	0.038
2004	-0.014	0.045
Ln Asset Size	-0.003	0.002
Debt Ratio	-0.034	0.080
%New Bus	-0.016*	0.009
Yields	-0.015	0.033
Domestic	0.089***	0.007
Constant	0.228	0.203

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**67.4%**
Only Parameters of Variables a Company Can Control	**87.0%**

*** = significant to a 1% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

So, when comparing the importance of profit inefficiency toward ROE versus the other variables of 1) the (average of the) year (parameter), 2) (natural log of) asset size, 3) debt ratio, 4) percent of new business written by the company, 5) average government bond yields over the year and 6) whether a company is domestic we see that the profit inefficiency parameter is 67.4% of the total value of the parameters.[32] Given that it is only one of seven such variables and of the largest magnitude we can conclude it is (potentially) of great importance.

When excluding the variables that a company can not control namely the (average of the) year (parameter), government bond yields and whether a company is domestic (and note that all but the latter has no level of significance) we see that the profit inefficiency parameter is 87.0% of the total value of the parameters so we can conclude it is (potentially) of very great importance.

The profit inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.355 with a significance of (less than) 1%. So every added percentage of profit inefficiency

[32] This (and similar) calculation(s) uses the absolute value of each variable.

decreases the ROE of these companies by 0.355%. As the average profit inefficiency is 6.32%, this leads to an average decrease of (.0632)(.355) = 2.24% versus an average company-year ROE of 12.76%.[33] So profit inefficiency cuts insurer ROE by 15.0% of its potential value.

When considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 16.9% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. The individual company-year results for this are shown in Table A.1 of the Appendix. From this we can see that 3.3% of the considered decreases in ROE are greater than 50% of their potential value, 17.0% are greater than 25% and 62.7% are greater than 10%. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on a life insurer is great.

It is interesting to note that when profit is put in place of profit inefficiency in this regression equation, the parameter estimate of β_{profit} is zero. Of course this stands to reason given the equation. In addition the other parameter estimates are close to those when using profit inefficiency with similar standard deviations and significance levels. The results of this regression are shown in Table A.2 of the Appendix. So this shows that one can not equate profit (in)efficiency with profit, so profit (in)efficiency is indeed a concept to consider on its own (merit).

5.1.1.2 Case II (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire)

In calculating the efficiency values in this case it should be noted that one company was excluded as an outlier because otherwise the average profit inefficiency of the other companies would be 83.16%; a result that is most likely not valid. In addition two other companies were excluded as outliers as they had company-year values that were much different than the rest.

The company by company time–invariant profit inefficiency results are shown in the Table A.3 of the Appendix.

As with the Base Case when a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are outlier company-year values but here there are only two. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-invariant inefficiency is 46.15%. This ranges from 23.22% to 77.02% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.5 below:

[33] This value is the average of the company-year pairs under consideration.

TABLE 5.5

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Case II

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	0.006	0.041
2001	0.005	0.010
2002	-0.008	0.010
2003	-0.005fs	0.010
2004		
Ln Asset Size	0.000	0.002
Debt Ratio	-0.070	0.083
%New Bus	-0.024**	0.009
Yields	-0.003	0.008
Domestic	0.086	0.008
Constant	0.096***	0.053

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**3.0%**
Only Parameters of Variables a Company Can Control	**3.1%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Here it is very important to note that the estimate of β_{ineffy} has no statistical significance whatsoever[34] and the standard deviation of the estimate is huge in comparison. This is due to the fact that there is little disparity[35] among the inefficiency scores of the companies, due to the great efficiency of Company 82[36] and so profit inefficiency has no explanatory power with respect to ROE. In addition few of the other parameters have any level of significance (especially when compared to the Base Case).

To try to alleviate this problem regressions were performed first excluding Company 82, then both Company 82 and Company 106 but the estimate of β_{ineffy} still had no significance.[37] So the results from these runs would not be informative. When excluding all of Companies 82, 106 and 60[38] the result becomes informative as the estimate of β_{ineffy} has a small level of significance. This is due to the fact that the inefficiency scores of the insurers now have enough disparity to allow this to happen.

[34] The significance level is 88.7%.
[35] When the scores are considered relative to one another
[36] Note that this result is legitimate as it comes from an average of the results of several individual years and for Company 82 the individual year results are not so that they could be excluded as outliers.
[37] In both runs the estimate of the β_{ineffy} parameter was negative.
[38] This is the equivalent to the case where these companies did not exist in the first place.

5.1.1.3 Case III (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire. Also excluding Companies 82, 106 & 60)

The company by company time–invariant profit inefficiency results are shown in the Table A.4 of the Appendix.

As with Case II when a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are two outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-invariant inefficiency is 29.93%. This ranges from 16.38% to 63.36% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.6 below:

TABLE 5.6

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Case III

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.282***	0.041
2001	0.003	0.010
2002	-0.008	0.010
2003	-0.004	0.010
2004		
Ln Asset Size	-0.002	0.002
Debt Ratio	-0.030	0.082
%New Bus	-0.022**	0.009
Yields	0.000	0.009
Domestic	0.082***	0.008
Constant	0.203***	0.057

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**66.6%**
Only Parameters of Variables a Company Can Control	**83.9%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was “dropped” by the statistical package as being “collinear”.

The results here have a bit better significance than in Case II and the profit inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.282 with a significance of (less than) 1%. So every added percentage of profit inefficiency decreases the ROE of these companies by 0.282%. As the average profit inefficiency is 29.93%, this leads to an average decrease of (.2993)(.282) = 8.44% versus an average company-year ROE of 13.40%. So profit inefficiency cuts insurer ROE by 38.6% of its potential value.

It is interesting to note that, as in the Base Case, when profit is put in place of profit inefficiency in this regression equation, the parameter estimate of β_{profit} is zero. Of course this stands to reason given the equation. In addition the other parameter estimates are close to those when using profit inefficiency with similar standard deviations and significance levels. So this shows that one can not equate profit (in)efficiency with profit, so profit (in)efficiency is indeed a concept to consider on its own (merit).

5.1.2 Time-Varying Inefficiency

5.1.2.1 Base Case (Include claims, annuity payments and other payments as inputs and use claims as input numeraire)

In calculating the efficiency values it should be noted that the same two companies as in the time-invariant Base Case were excluded as outliers as they were calculated to be much more efficient than the rest.

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-varying inefficiency is 6.32%. This ranges from 0.91% to 9.36% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.7 below:

TABLE 5.7

Effect on ROE
Profit InEfficiency – GLS
Time-Varying Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.265***	0.080
2001	-0.006	0.018
2002	-0.017	0.023
2003	-0.022	0.037
2004	-0.016	0.044
Ln Asset Size	-0.003	0.002
Debt Ratio	-0.036	0.080
%New Bus	-0.016*	0.009
Yields	-0.015	0.032
Domestic	0.087***	0.007
Constant	0.221	0.196

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**60.7%**
Only Parameters of Variables a Company Can Control	**82.8%**

*** = significant to a 1% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

The profit inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.265 with a significance of 1%.[39] So every added percentage of profit inefficiency decreases the ROE of these companies by 0.265%. As the average profit inefficiency is 6.32%, this leads to an average decrease of (.0632)(.265) = 1.67% versus an average company-year ROE of 12.76%. So profit inefficiency cuts insurer ROE by 11.6% of its potential value.

5.1.2.2 Case II (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire)[40]

In calculating the efficiency values it should be noted that the same companies as in the time-varying Base Case were excluded as outliers.

As with the Base Case when a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered

[39] When the u_{it} variables are not averaged (as described in Section 3) the β_{ineffy} parameter estimate is -0.290 with a significance of 1.2%. So in this case profit (in)efficiency would have a greater effect on ROE.
[40] Note that the yields exogenous variable is not included in Equation 3 as applied to Case II and Case III (for profit-efficiency) as otherwise yields would have an unrealistically large effect on the efficiency values.

that there are outlier company-year values but here there are only two. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-varying inefficiency is 46.10%. This ranges from 14.17% to 120.70%[41] (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.8 below:

TABLE 5.8

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Case II

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	0.005	0.038
2001	0.005	0.010
2002	-0.008	0.010
2003	-0.005	0.010
2004		
Ln Asset Size	0.000	0.002
Debt Ratio	-0.074	0.083
%New Bus	-0.024**	0.009
Yields	-0.003	0.009
Domestic	0.087	0.008
Constant	0.101***	0.054

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**3.0%**
Only Parameters of Variables a Company Can Control	**3.1%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Here it is very important to note that the estimate of β_{ineffy} has no statistical significance whatsoever[42] and the standard deviation of the estimate is huge in comparison. This is due to the fact that there is little disparity among the inefficiency scores of the companies, due to the great efficiency of Company 82 and so profit inefficiency has no explanatory power with respect to ROE. In addition few of the other parameters have any level of significance.

[41] This seemingly anomalous result is due to the averaging effect.
[42] The significance level is 90.4%

To try to alleviate this problem runs were done first excluding Company 82, then both Company 82 and Company 106 but the estimate of β_{ineffy} still had no significance.[43] So the results from these runs would not be informative. When excluding all of Companies 82, 106 and 60 the result become informative as the estimate of β_{ineffy} has a small level of statistical significance. This is due to the fact that the inefficiency scores of the insurers now have enough disparity to allow this to happen.

5.1.2.3 Case III (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire. Also excluding Companies 82, 106 & 60)

As with Case II when a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are two outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-invariant inefficiency is 29.89%. This ranges from 14.84% to 115.94% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.9 below:

TABLE 5.9

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Case III

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.175***	0.049
2001	0.037	0.054
2002	0.091	0.131
2003	0.042	0.074
2004	0.118	0.158
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.047	0.083
%New Bus	-0.026***	0.009
Yields	0.086	0.117
Domestic	0.082***	0.008
Constant	-0.352	0.698

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**35.9%**
Only Parameters of Variables a Company Can Control	**70.4%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

[43] In both runs the estimate of the β_{ineffy} parameter was positive but with no statistical significance.

The results here have quite a bit better significance than in Case II and the profit inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.175 with a significance of (less than) 1%. So every added percentage of profit inefficiency decreases the ROE of these companies by 0.175%. As the average profit inefficiency is 29.89%, this leads to an average decrease of (.2989)(.175) = 5.24% versus an average company-year ROE of 13.44%. So profit inefficiency cuts insurer ROE by 28.0% of its potential value.

5.2 MLE Results

5.2.1 Time-Invariant Inefficiency

5.2.1.1 Base Case (Include claims, annuity payments and other payments as inputs and use claims as input numeraire)

The highest log-likelihood came from starting with the GLS translog parameter estimates less 0.0015. The MLE estimates of the parameters of the translog function are mostly reasonably close to those of the GLS estimates, although there are some quite large differences.

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-invariant inefficiency is 14.84%. This ranges from 6.93% to 54.70%.

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.10 below:

TABLE 5.10

Effect on ROE
Profit InEfficiency – MLE
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.153***	0.033
2001	-0.008	0.017
2002	-0.018	0.023
2003	-0.025	0.038
2004	-0.015	0.045
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.043	0.081
%New Bus	-0.026***	0.009
Yields	-0.017	0.033
Domestic	0.088***	0.007
Constant	0.226	0.201

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**44.4%**
Only Parameters of Variables a Company Can Control	**68.7%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

The profit inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.153 with a significance of (less than) 1%. So every added percentage of profit inefficiency decreases the ROE of these companies by 0.153%. As the average profit inefficiency is 14.84%, this leads to an average decrease of (.1484)(.153) = 2.27% versus an average company-year ROE of 12.76%. So profit inefficiency cuts insurer ROE by 15.1% of its potential value. This result (along with those regarding the other parameters) is similar to those when using GLS.

6 Cost InEfficiency Results

In this section we present GLS results for the several cases explored with respect to cost inefficiency. The cases are described in Table 6.1 below:

TABLE 6.1

Cases Explored Regarding Cost InEfficiency

	Include Claims, Annuity Pymts and Other Pymts as Inputs?	**Numeraire**	**Exclude Specific Companies?**
Base Case	Yes	Claims	No
Case II	No	Commissions	No
Case III	No	Commissions	Yes
Case IV	Yes	Commissions	No
Case V	Yes	Commissions	Yes

Both time-invariant and time-varying cost inefficiency is considered except for Case III where only time-invariant cost inefficiency and Case V where only time-varying cost inefficiency is considered (for reasons described below). In each case the effect on ROE of the various parameters are presented. In addition for some cases tables that show estimates of the translog parameters and cost inefficiencies by company[44] are shown.[45]

6.1 GLS Results

6.1.1 Time-Invariant Inefficiency

6.1.1.1 Base Case (Include claims, annuity payments and other payments as inputs and use claims as input numeraire)

The company by company time–invariant cost inefficiency results are shown in Table A.5 of the Appendix.

In calculating the efficiency values it should be noted that two companies had individual company-year results that were much different than the rest so they were excluded as outliers.

When a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-invariant inefficiency is 6.31%. This ranges from 0.50% to 14.86% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.1 below:

[44] In some cases inefficiencies by company-year pair are also shown.
[45] These tables for all cases are available from the author.

TABLE 6.1

Effect on ROE
Cost InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	-0.373**	0.160
2001	-0.013	0.015
2002	-0.029	0.019
2003	-0.043	0.030
2004	-0.033	0.036
Ln Asset Size	-0.005***	0.002
Debt Ratio	0.033	0.074
%New Bus	-0.020**	0.009
Yields	-0.036	0.026
Domestic	0.090***	0.007
Constant	0.381	0.161

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**63.6%**
Only Parameters of Variables a Company Can Control	**86.4%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

So, when comparing the importance of cost inefficiency toward ROE versus the other variables of 1) the (average of the) year (parameter), 2) (natural log of) asset size, 3) debt ratio, 4) percent of new business written by the company, 5) average government bond yields over the year and 6) whether a company is domestic we see that the cost inefficiency parameter is 63.6% of the total value of the parameters. Given that it is only one of seven such variables and of the largest magnitude we can conclude it is (potentially) of great importance.

When excluding the variables that a company can not control namely the (average of the) year (parameter), government bond yields and whether a company is domestic (and note that all but the latter are not statistically significant) we see that the cost inefficiency parameter is 86.4% of the total so we can conclude it is (potentially) of very great importance.

The cost inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.373 with a significance of 2%. So every added percentage of cost inefficiency decreases the ROE of these companies by 0.373%. As the average cost inefficiency is 6.31%, this leads to an average decrease of (.0631)(.373) = 2.36% versus an average company-year ROE of 12.68%. So cost inefficiency cuts insurer ROE by 15.7% of its potential value.

When considering each company-year pair we see that the average drop in ROE from its potential value due to cost inefficiency is 20.0% if we confine the consideration to company-year pairs that have a positive ROE both before and after the drop due to cost inefficiency. It can be seen that 4.7% of the considered decreases in ROE are greater than 50% of their potential value, 26.1% are greater than 25% and 73.5% are greater than 10%. Given that even a 10% drop in ROE can be considered important we see that the effect of cost inefficiency on a life insurer is great.

6.1.1.2 Case II (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire)

As with the Base Case when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are outlier company-year values except that here there are only two. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-invariant inefficiency is 15.96%. This ranges from 8.67% to 25.93% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 6.2 below:

TABLE 6.2

Effect on ROE
Cost InEfficiency – GLS
Time-Invariant Case II

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	.300	0.244
2001	.046	.032
2002	.056	.043
2003	.104	.076
2004	.134	.091
Ln Asset Size	.002	.002
Debt Ratio	-.098	.080
%New Bus	-.019	.009
Yields	.097	.067
Domestic	.081***	.007
Constant	-.557	.399

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**44.1%**
Only Parameters of Variables a Company Can Control	**71.8%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Here it is very important to note that the estimate of β_{ineffy} has no statistical significance whatsoever[46] and the standard deviation of the estimate is huge in comparison. This is due to the fact that there is little disparity among the inefficiency scores of the companies, due to the efficiency of Company 71[47] and so cost inefficiency has no explanatory power with respect to ROE. In addition few of the other parameters have any level of significance.

To try to alleviate this problem runs were done first excluding Company 71 but the estimate of β_{ineffy} still had no statistical significance.[48] So the results from this run would not be informative. When excluding both Companies 71 and 17 the result become informative as the estimate of β_{ineffy} has a small level of significance. This is due to the fact that the inefficiency scores of the insurers now have enough disparity to allow this to happen.

6.1.1.3 Case III (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire. Also excluding Companies 71 & 17)

As with Case II when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are two outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-invariant inefficiency is 6.89%. This ranges from 2.21% to 16.41% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 6.3 below:

[46] The significance level is 21.8%
[47] Note that this result is legitimate as it comes from an average of the results of several individual years and for Company 71 the individual year results are not so that they could be excluded as outliers.
[48] In this run the estimate of the β_{ineffy} parameter was negative.

TABLE 6.3

Effect on ROE – GLS
Cost InEfficiency – GLS
Time-Invariant Case III

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	0.552***	0.203
2001	0.096	0.079
2002	0.128	0.110
2003	0.234	0.196
2004	0.292	.235
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.096	0.079
%New Bus	-0.020**	0.009
Yields	0.213	0.174
Domestic	0.072***	0.008
Constant	-1.200	1.031

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**48.4%**
Only Parameters of Variables a Company Can Control	**82.6%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

So the results here have quite a bit better significance than in Case III, however here we see that the cost inefficiency of these companies seems to have a positive effect on their ROE. Now, this result comes about when one excludes claims, annuity payments and other payments as inputs. To test whether this will hold up to scrutiny we try the same regression including claims, annuity payments and other payments as inputs.

6.1.1.4 Case IV (Include claims, annuity payments and other payments as inputs and use commissions as input numeraire)

As with the Base Case when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-invariant inefficiency is 6.60%. This ranges from 1.90% to 9.23% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.4 below:

TABLE 6.4

Effect on ROE
Cost InEfficiency – GLS
Time-Invariant Case IV

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	-.501*	0.271
2001	-.018	.012
2002	-.033	.013
2003	-.058***	.018
2004	-.053**	.021
Ln Asset Size	.000	.002
Debt Ratio	-.067	.083
%New Bus	-.024**	.009
Yields	-.052***	.015
Domestic	.083***	.008
Constant	.423***	.098

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**65.3%**
Only Parameters of Variables a Company Can Control	**84.7%**

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

So here we have a β_{ineffy} that seems to be in the correct direction and also has statistical significance. In addition the results here good significance, even better than the Base Case. These facts would indicate that excluding the claims, annuity payments and other payments as inputs is not correct, at least for the Canadian life insurer data.

The cost inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.501 with a significance of 6.5%. So every added percentage of cost inefficiency decreases the ROE of these companies by 0.501%. As the average cost inefficiency is 6.60%, this leads to an average decrease of (.0660)(.501) = 3.31% versus an average company/year ROE of 12.61%. So cost inefficiency cuts insurer ROE by 20.8% of its potential value.

6.1.2 Time-Varying Inefficiency

6.1.2.1 Base Case (Include claims, annuity payments and other payments as inputs and use claims as input numeraire)

The estimates of the parameters of the translog function are shown in Table A.6 of the Appendix.

It should be noted that many of the results are significant even to a (less than) 1% level, and several of these are estimates for the single parameters. Interestingly, despite the difference in numeraires, only the dividends & errs single parameter is significant and in the apparently wrong direction.

In calculating the efficiency values it should be noted that the same two companies as in the time-invariant case were excluded as outliers as they had individual company-year results that were much different than the rest.

When a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-varying inefficiency is 6.31%. This ranges from 0.16% to 22.80% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.5 below:

TABLE 6.5

Effect on ROE
Cost InEfficiency – GLS
Time-Varying Base Case

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	-0.305*	0.160
2001	-0.010	0.015
2002	-0.030	0.019
2003	-0.040	0.032
2004	-0.032	0.037
Ln Asset Size	-0.006***	0.002
Debt Ratio	0.023	0.073
%New Bus	-0.021**	0.009
Yields	-0.036	0.027
Domestic	0.091***	0.007
Constant	0.374**	0.167

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**60.1%**
Only Parameters of Variables a Company Can Control	**86.3%**

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

The cost inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.305 with a significance of 6%.[49] So every added percentage of cost inefficiency decreases the ROE of these companies by 0.305%. As the average cost inefficiency is 6.31%, this leads to an average decrease of (.0631)(.305) = 1.93% versus an average company-year ROE of 12.68%. So cost inefficiency cuts insurer ROE by 13.2% of its potential value.

6.1.2.2 Case II (Exclude claims, annuity payments and other payments as inputs and use commissions as input numeraire)

As with the Base Case when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are outlier company-year values except that here there are only two. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the two outliers the average company-year time-varying inefficiency is 15.96%. This ranges from 8.67% to 25.93% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.6 below:

[49] When the u_{it} variables are not averaged (as described in Section 3) the β_{ineffy} parameter estimate is -0.632 with a significance of only 23.52%. So in this case cost (in)efficiency may have a greater effect on ROE.

TABLE 6.6

Effect on ROE
Cost InEfficiency – GLS
Time-Varying Case II

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	0.361***	0.135
2001	0.004	0.009
2002	-0.010	0.009
2003	-0.005	0.009
2004		
Ln Asset Size	0.001	0.002
Debt Ratio	-0.103	0.082
%New Bus	-0.023**	0.009
Yields	-0.007	0.008
Domestic	0.090***	0.007
Constant	0.045	0.049

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**61.0%**
Only Parameters of Variables a Company Can Control	**73.9%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

However here we see that the cost inefficiency of these companies seems to have a positive effect on their ROE. Now, this result comes about when one excludes claims, annuity payments and other payments as inputs. To test whether this will hold up to scrutiny we try the same regression including claims, annuity payments and other payments as inputs.

6.1.2.3 Case IV (Include claims, annuity payments and other payments as inputs and use commissions as input numeraire)

As with the Base Case when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-varying inefficiency is 6.60%. This ranges from 1.02% to 10.40% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.7 below:

TABLE 6.7

Effect on ROE
Cost InEfficiency – GLS
Time-Invariant Case IV

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	-0.253	0.260
2001	-0.016	0.013
2002	-0.031**	0.014
2003	-0.053***	0.020
2004	-0.049**	0.023
Ln Asset Size	0.000	0.002
Debt Ratio	-0.070	0.083
%New Bus	-0.022**	0.010
Yields	-0.048***	0.016
Domestic	0.086***	0.008
Constant	0.381***	0.101

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**48.9%**
Only Parameters of Variables a Company Can Control	**73.2%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Here it is very important to note that the estimate of β_{ineffy} has no statistical significance whatsoever[50] and the standard deviation of the estimate is huge in comparison. This is due to the fact that there is little disparity among the inefficiency scores of the companies, due to the efficiency of Company 73[51] and so cost inefficiency has no explanatory power with respect to ROE.

To try to alleviate this problem a regression was performed excluding Company 73 whereupon the result become informative as the estimate of β_{ineffy} has a small level of significance. This is due to the fact that the inefficiency scores of the insurers now have enough disparity to allow this to happen.

6.1.2.4 Case V (Include claims, annuity payments and other payments as inputs and use commissions as input numeraire. Also excluding Company 73)

As with Case IV when a regression is done using ROE as the independent variable and cost inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered

[50] The significance level is 33.1%
[51] Note that this result is legitimate as it comes from an average of the results of several individual years and for Company 73 the individual year results are not so that they could be excluded as outliers.

that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-varying inefficiency is 4.68%. This ranges from 1.14% to 9.35% (recall that one company has zero inefficiency by definition).

The effect of cost efficiency as well as the various parameters on life insurer ROE is shown in Table 6.8 below:

TABLE 6.8

Effect on ROE
Cost InEfficiency – GLS
Time-Varying Case V

Variable	Parameter Estimate	Standard Deviation
Cost Inefficiency	-0.386*	0.228
2001	-0.018	0.011
2002	-0.031**	0.013
2003	-0.050***	0.018
2004	-0.050**	0.021
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.056	0.081
%New Bus	-0.029***	0.009
Yields	-0.048***	0.015
Domestic	0.088***	0.007
Constant	0.393***	0.094

Cost Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**59.9%**
Only Parameters of Variables a Company Can Control	**81.9%**

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

So here we have a β_{ineffy} that seems to be in the correct direction and also has statistical significance. In addition the results here good significance, even better than the Base Case. These facts would indicate that excluding the claims, annuity payments and other payments as inputs is not correct, at least for the Canadian life insurer data.

The cost inefficiency of these companies has a negative effect on their ROE. The β_{ineffy} parameter is -0.386 with a significance of 9%. So every added percentage of cost inefficiency decreases the ROE of these companies by 0.386%. As the average cost inefficiency is 4.68%, this leads to an average decrease of (.0468)(.386) = 1.81% versus an average company/year ROE of 12.44%. So cost inefficiency cuts insurer ROE by 12.7% of its potential value.

7. Line of Business Results

The profit efficiency of the various companies with respect to the LOBs of the OSFI54 and OSFI55 returns were calculated for the Base Case using GLS. One feature of these results is that it is difficult to get levels of significance for the β_{ineffy} parameter of less than 10%. This is mostly due to the smaller number of observations available for each LOB. However, the results are still useful.

The companies considered for each LOB are those that a (substantial) non-zero value ascribed to that LOB within the OSFI returns in one of the return values leading to the determination of profit for each company in each year.

7.1 Individual Life NonPar

In calculating the efficiency values it should be noted that one company was calculated to be much more efficient than the rest, so it was excluded as an outlier as including it in the analysis leads to an average inefficiency of the other companies is 22.89%; a result that is most likely not valid. In addition one other company had individual company-year results that were much different than the rest so it was also excluded as an outlier.

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are ten outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the ten outliers the average company-year time-invariant inefficiency is 3.66%. This ranges from 0.31% to 10.76% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.1 below:

TABLE 7.1

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-39.941	28.599
2001	0.613	1.720
2002	-0.630	1.557
2003	2.308	1.612
2004		
Ln Asset Size	-0.862**	0.380
Debt Ratio	37.357***	8.823
%New Bus	-4.970**	2.121
Yields	2.509*	1.420
Domestic	5.539***	1.602
Constant	-3.542	8.257

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**43.2%**
Only Parameters of Variables a Company Can Control	**48.0%**

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Note that the level of significance for the β_{ineffy} parameter estimate is 16.3% and given that most of the other parameter estimates have good levels of significance [52] the results here seem credible.

When comparing the importance of profit inefficiency toward ROE versus the other variables of 1) the (average of the) year (parameter), 2) (natural log of) asset size, 3) debt ratio, 4) percent of new business written by the company, 5) average government bond yields over the year and 6) whether a company is domestic we see that the profit inefficiency parameter is 43.2% of the total value of the parameters. Given that it is only one of seven such variables and of the largest magnitude we can conclude it is (potentially) of great importance.

When excluding the variables that a company can not control namely the (average of the) year (parameter), government bond yields and whether a company is domestic (and note that all but the latter has no level of significance) we see that the profit inefficiency parameter is 48.0% of the total value of the parameters so we can conclude it is (potentially) of great importance.

[52] The year 2003 parameter level is 15.2%

The profit inefficiency of these companies seems to have a negative effect on their ROE. The β_{ineffy} parameter is -39.94 with a significance of 16%. This large value of significance along with the fact that the company-year ROE values fluctuate a lot means that it is best to use a company-year analysis of the results.

When using the β_{ineffy} parameter estimate of -39.94 and considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 45.3% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. It can be seen that 46.3% of the considered decreases in ROE are greater than 50% of their potential value, 54.4% are greater than 25% and 61.8% are greater than 10%. Even when using a β_{ineffy} parameter estimate of -9.985 (i.e. one quarter of the original estimate) we see that the average drop in ROE from its potential value due to profit inefficiency is still 32.6% and it can be seen that 34.2% of the considered decreases in ROE are greater than 50% of their potential value, 45.0% are greater than 25% and 50.3% are greater than 10%. This latter value is close to the corresponding for the entire company value of 62.7%, so it seems reasonable. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on this LOB of a life insurer is great.

7.2 Individual Life Par

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there is one outlier company-year value. This influences the results unduly so the results are considered only excluding this outlier.

When excluding the outlier the average company-year time-invariant inefficiency is 9.02%. This ranges from 4.95% to 29.29% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.2 below:

TABLE 7.2

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-286.736	202.107
2001	11.231	14.686
2002	2.481	14.491
2003	47.818***	15.704
2004		
Ln Asset Size	-9.810***	3.015
Debt Ratio	234.807***	74.592
%New Bus	-18.273	31.991
Yields	7.669	12.598
Domestic	12.576	14.217
Constant	56.038	76.729

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**48.6%**
Only Parameters of Variables a Company Can Control	**52.2%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

The profit inefficiency of these companies seems to have a negative effect on their ROE. The β_{ineffy} parameter is -286.74 with a significance of 15.6%. This large value of significance along with the fact that the company-year ROE values fluctuate a lot means that it is best to use a company-year analysis of the results.

When using the β_{ineffy} parameter estimate of -286.74 and considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 52.1% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. It can be seen that 84.6% of the considered decreases in ROE are greater than 10% of their potential value. Even when using a β_{ineffy} parameter estimate of -71.684 (i.e. one quarter of the original estimate) we see that the average drop in ROE from its potential value due to profit inefficiency is still 35.8% and it can be seen that 63.2% of the considered decreases in ROE are greater than 10% of their potential value. This latter value is close to the corresponding for the entire company value of 62.7%, so it seems reasonable. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on this LOB of a life insurer is great.

7.3 Group Life NonPar

In calculating the efficiency values it should be noted that one company had individual company-year results that were much different than the rest so it was also excluded as an outlier.

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are twelve outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the twelve outliers the average company-year time-invariant inefficiency is 2.33%. This ranges from 1.22% to 4.30% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.3 below:

TABLE 7.3

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	50.851	73.837
2001	4.990	4.393
2002	7.106	6.148
2003	12.756	10.946
2004	14.901	13.139
Ln Asset Size	-0.886***	0.158
Debt Ratio	12.024***	3.751
%New Bus	1.135*	0.586
Yields	11.087	9.720
Domestic	0.766*	0.414
Constant	-57.887	57.450

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**59.9%**
Only Parameters of Variables a Company Can Control	**78.4%**

*** = significant to a 1% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Note that the level of significance for the β_{ineffy} parameter estimate is 49.1%. Even after using the technique of excluding the two most efficient companies the level of significance for the β_{ineffy} parameter is higher (even though the β_{ineffy} parameter estimate is negative in both cases). So it appears that the data will not give us any usable results with respect to ROE for this LOB. This is most likely due to the closeness of the efficiency scores which only range from 1.22% to 4.30%.

7.4 Group Life Par

There are only nine Canadian life insurers issuing business for this LOB so no investigation was performed on the data.

7.5 Individual Annuity NonPar

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are twenty-one outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the twenty-one outliers the average company-year time-invariant inefficiency is 3.10%. This ranges from 1.91% to 6.28% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.4 below:

TABLE 7.4

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-3079.913	2065.831
2001	-2.388	20.611
2002	-2.951	21.097
2003	-5.240	28.106
2004		
Ln Asset Size	2.445	4.765
Debt Ratio	58.973	132.036
%New Bus	-11.078	21.082
Yields	-4.577	20.431
Domestic	91.850	57.480
Constant	2.719	132.742

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**94.7%**
Only Parameters of Variables a Company Can Control	**97.7%**

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

The profit inefficiency of these companies seems to have a negative effect on their ROE. The β_{ineffy} parameter is -3079.91 with a significance of 13.6%. This large value of significance along with the fact that the company-year ROE values fluctuate a lot means that it is best to use a company-year analysis of the results.

When using the β_{ineffy} parameter estimate of -3079.91 and considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 83.0% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. It can be seen that 69.9% of the considered decreases in ROE are greater than 10% of their potential value. Even when using a β_{ineffy} parameter estimate of -5.000 we see that the average drop in ROE from its potential value due to profit inefficiency is still 56.6% and it can be seen that 77.8% of the considered decreases in ROE are greater than 10% of their potential value. This latter value is close to the corresponding for the entire company value of 62.7%, so it seems reasonable. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on this LOB of a life insurer is great.

7.6 Individual Annuity Par

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are nine outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the nine outliers the average company-year time-invariant inefficiency is 2.87%. This ranges from 1.77% to 4.95% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.5 below:

TABLE 7.5

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-27.465	17.220
2001	-0.086	0.295
2002	-0.128	0.305
2003	0.133	0.323
2004		
Ln Asset Size	-0.145***	0.049
Debt Ratio	1.018	1.491
%New Bus	0.135	0.334
Yields	0.107	0.276
Domestic	-0.209	0.374
Constant	1.994	1.586

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**94.1%**
Only Parameters of Variables a Company Can Control	**95.5%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was “dropped” by the statistical package as being “collinear”.

Note that the level of significance for the β_{ineffy} parameter estimate is 11.1%.

The profit inefficiency of these companies seems to have a negative effect on their ROE. The β_{ineffy} parameter is -27.46 with a significance of 11%. This large value of significance along with the fact that the company-year ROE values fluctuate a lot means that it is best to use a company-year analysis of the results.

When using the β_{ineffy} parameter estimate of -27.47 and considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 64.1% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. It can be seen that 85.4% of the considered decreases in ROE are greater than 10% of their potential value. Even when using a β_{ineffy} parameter estimate of -6.87 (i.e. one quarter of the original estimate) we see that the average drop in ROE from its potential value due to profit inefficiency is still 52.7% and it can be seen that 65.9% of the considered decreases in ROE are greater than 10% of their potential value. This latter value is close to the corresponding for the entire company value of 62.7%, so it seems reasonable. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on this LOB of a life insurer is great.

7.7 Group Annuity NonPar

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are eighteen outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the eighteen outliers the average company-year time-invariant inefficiency is 3.45%. This ranges from 0.44% to 5.81% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.6 below:

TABLE 7.6

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	3096.172	3745.882
2001	3.067	164.950
2002	120.231	156.958
2003	33.522	165.102
2004		
Ln Asset Size	7.467	19.109
Debt Ratio	-269.590	784.896
%New Bus	-348.822***	16.198
Yields	11.056	135.305
Domestic	281.538	192.185
Constant	-254.707	751.739

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**76.1%**
Only Parameters of Variables a Company Can Control	**83.2%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Note that the level of significance for the β_{ineffy} parameter estimate is 40.8%. Even after using the technique of excluding the most efficient company the level of significance for the β_{ineffy} parameter is higher. In addition the level of significance of the other parameter estimates are also higher. So it appears that the data will not give us any usable results with respect to ROE for this LOB. This is most likely due to fact that there are only 102 company-year observations left after eliminating all of the outliers.

7.8 Group Annuity Par

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are three outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the three outliers the average company-year time-invariant inefficiency is 1.30%. This ranges from 0.04% to 6.15% (recall that one company has zero inefficiency by definition).

There are only twelve Canadian life insurers issuing business for this LOB and after eliminating the outliers with respect to a regression using ROE as the independent variable there are only eleven such companies left. As a result the parameter estimates have levels of significance of 87.7% and up. So no investigation was performed on these results.

7.9 Individual Accident & Sickness

In calculating the efficiency values it should be noted that two companies had individual company-year results that were much different than the rest so they were excluded as outliers.

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are four outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the four outliers the average company-year time-invariant inefficiency is 38.39%. This ranges from 29.41% to 43.30% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 7.7 below:

TABLE 7.7

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-33.117	82.132
2001	-0.755	18.808
2002	-1.227	18.549
2003	-2.620	20.140
2004		
Ln Asset Size	0.120	2.137
Debt Ratio	167.182	117.265
%New Bus	-31.584	27.021
Yields	13.109	16.014
Domestic	0.606	16.991
Constant	-48.429	90.044

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**13.4%**
Only Parameters of Variables a Company Can Control	**14.3%**

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Note that the level of significance for the β_{ineffy} parameter estimate is 68.7%. When using the technique of excluding the most efficient company (Company 62) the level of significance for the β_{ineffy} parameter is much lower.

The effect of profit efficiency as well as the various parameters on life insurer ROE after excluding Company 62 is shown in Table 7.8 below:

TABLE 7.8

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Excluding Company 62

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-76.401	54.973
2001	2.001	19.286
2002	1.052	18.927
2003	-4.178	21.020
2004		
Ln Asset Size	-0.190	2.097
Debt Ratio	172.490	117.090
%New Bus	-33.217	27.879
Yields	15.117	16.701
Domestic	-3.524	16.596
Constant	-56.752	92.455

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**25.2%**
Only Parameters of Variables a Company Can Control	**27.1%**

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Now the level of significance for the β_{ineffy} parameter estimate is 16.5% and in addition the level of significance of the other parameter estimates are lower.

The profit inefficiency of these companies seems to have a negative effect on their ROE. The β_{ineffy} parameter is -76.40 with a significance of 17%. This large value of significance along with the fact that the company-year ROE values fluctuate a lot means that it is best to use a company-year analysis of the results.

When using the β_{ineffy} parameter estimate of -76.40 and considering each company-year we see that the average drop in ROE from its potential value due to profit inefficiency is 44.3% when we confine the consideration to company-years that have a positive ROE both before and after the drop due to profit inefficiency. It can be seen that 73.6% of the considered decreases in ROE are greater than 10% of their potential value. Even when using a β_{ineffy} parameter estimate of -19.10 (i.e. one quarter of the original estimate) we see that the average drop in ROE from its potential value due to profit inefficiency is still 30.4% and it can be seen that 51.7% of the considered decreases in ROE are greater than 10% of their potential value. This latter value is close to the corresponding for the entire company value of 62.7%, so it seems reasonable. Given that even a 10% drop in ROE can be considered important we see that the effect of profit inefficiency on this LOB of a life insurer is great.

7.10 Group Accident & Sickness

When a regression is done using ROE as the independent variable and profit inefficiency, (natural log of) asset size, debt ratio etcetera as the dependent variables it is discovered that there are six outlier company-year values. These influence the results unduly so the results are considered only excluding these outliers.

When excluding the six outliers the average company-year time-invariant inefficiency is 21.94%. This ranges from 4.35% to 36.37% (recall that one company has zero inefficiency by definition).

The effect of profit efficiency as well as the various parameters on life insurer ROE leads to the level of significance for the β_{ineffy} parameter estimate being 99.7% and poor statistical significance for the other parameter estimates. When using the technique of excluding the two most efficient companies the level of significance for the β_{ineffy} parameter is still only 30.6% and the level of statistical significance of the other parameters is not much better than previously. This is most likely due to the fact that twenty-one of the forty-two companies left have efficiency scores in the range of 3.48% to 4.99%. So it seems that no credible analysis of the results can be performed.

8 Discussion

For the analyses where claims, annuity payments and other payments are included as inputs (the Base Case and Case IV[53]) the average inefficiency of the life insurers ranges from 6.31% to 6.60% This is true for both profit and cost inefficiency as well as the change from time-invariance to time-varying inefficiency. In all of these analyses the majority of life insurers cluster around the average value and only a few deviate it from any degree.

For the LOB results, which are as a result of a profit efficiency calculation for the Base Case, five of the seven non-A&S average efficiency values range from 2.33% to 3.66%. The two A&S average efficiency scores are much higher. This suggests a fundamental difference between non-A&S and A&S business. In all of the LOBs, except for Group Annuity Par, the majority of life insurers cluster around the average value and only a few deviate it from any degree.

There is a contrast between this and the analyses where claims, annuity payments and other payments are excluded as inputs (Case II[54]) in that here the average profit inefficiency of the life insurers is around 46% while the average cost inefficiency of the life insurers is around 16%. The fact that there is such a range when compared to the Base Case and Case IV may indicate further that excluding claims, annuity payments and other payments as inputs is not correct, at least for Canadian life insurer data. Here also in all of these analyses the majority of life insurers cluster around the average value and only a few deviate it from any degree.

The clustering exhibited indicates that most life insurers in Canada have achieved the same level of profit or cost efficiency with only a few being either much more or much less efficient. This is true for both companies as a whole and for the LOBs.

[53] Note that Case V is not considered for this in that it was created simply to give the inefficiency scores some disparity.
[54] Note that Case III is not considered for this in that it was created simply to give the inefficiency scores some disparity.

Now, when considering how the various exogenous variables influence the ROE of the life insurers the trend is clear. In each case the inefficiency of the insurers has by far the greatest influence of the variables considered as it has more than 59% of the total influence of the variables in all but two of the cases where β_{ineffy} has statistical significance.[55] [56] Given that inefficiency is one of seven variables considered this is a notable result. This is even more evident when considering only the variables that an insurer can control. Here the inefficiency of the insurers has by the far the greatest influence of the variables considered as it has more than 70% of the total influence of the variables where β_{ineffy} has statistical significance and eight of ten of these values are greater than 80%. Given here that inefficiency is one of four variables considered this is also notable.

For the non-A&S LOB results the inefficiency of the insurers also has by far the greatest influence of the variables considered as it has more than 43% of the total influence of the variables and when considering only the variables that an insurer can control the inefficiency of the insurers has more than 48% of the total influence of the variables and four of six of these values are greater than 75%. For Individual A&S[57] the corresponding values are 25% and 27%, once again suggesting a fundamental difference between non-A&S and A&S business.

The influence of the inefficiency of the life insurers is shown when one explores the possible ways one can change its ROE via the exogenous variables considered. The effect of an insurer changing either its size, debt ratio or percent of new business written will be discussed in the following sub-sections. In addition we can consider the government bond yields here.

8.1 Profit Inefficiency GLS Time-Invariant Base Case

From Section 5.1.1.1 the effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.4 below:

TABLE 5.4

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.355***	0.060
2001	-0.003	0.018
2002	-0.019	0.023
2003	-0.021	0.038
2004	-0.014	0.045
Ln Asset Size	-0.003	0.002
Debt Ratio	-0.034	0.080
%New Bus	-0.016*	0.009
Yields	-0.015	0.033
Domestic	0.089***	0.007
Constant	0.228	0.203

Profit Inefficiency Parameter % of Total Value of Parameters

[55] As seen in the “Effect on ROE Tables” of Sections 5 and 6.
[56] In the two cases the influences were 48.4% and 35.9%.
[57] Such a calculation was not performed for Group A&S.

Including Average of Year Estimates	**67.4%**
Only Parameters of Variables a Company Can Control	**87.0%**

*** = significant to a 1% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Recall the average decrease of ROE caused by insurer profit inefficiency is 2.24% and consider the variables that a life insurer can control. First consider (the natural log of) asset size where the parameter is -.003, so to increase ROE by even 1% (e.g. from 10% to 11%) an insurer has to change its natural log of asset size value by -3.207[58] which is decreasing its asset size by 96.0%[59], clearly impossible. Here even if one uses the value at the end of the 95% confidence interval, -.007, to change ROE by even 1% an insurer has to change its natural log of asset size value by -1.37 which is decreasing its asset size by 74.6%, still clearly impossible.

Considering the debt ratio, we see that the relevant average is 2.555%[60] and the maximum value here is 43.016%. The parameter estimate is -.034 so we find that to increase ROE by even 1% (e.g. from 10% to 11%) an insurer has to change its debt ratio by 29.5% which, even at the maximum company-year value, is a decrease of 68.5% of its current value. So to change ROE by even a little it is necessary to change the business by a huge amount. Here even if one uses the value at the end of the 95% confidence interval (with the largest absolute value), -.191, to change ROE by even 1% an insurer has to change its debt ratio by 5.2% which even at the maximum company-year value, is a decrease of 12.1% of its current value (obviously quite difficult to do) and at the average company-year value of 2.555% is not possible.[61] To increase ROE by the average change generated by profit inefficiency, 2.24%, an insurer has to change its debt ratio by 11.7% which at the maximum company-year value is a decrease of 27.2% of its current value, so very difficult to do.

Considering the percentage of new business written by the insurer, we see that the relevant average is 35.43%. The parameter is -.016, so to increase ROE by even 1% an insurer has to decrease its percent of new business written by 62.4% (i.e. to a value less than zero) which is impossible. Here even if one uses the value at the end of the 95% confidence interval, -.034, to change ROE by even 1% an insurer has to change its percent of new business written by 29.2% which at the average company-year value of 35.43% is decreasing its percent of new business written 82.5% of its current value, which is very difficult to do. To increase ROE by the average change generated by profit inefficiency, 2.24%, an insurer has to change its percent of new business written by 65.6% which at the average company-year value is not possible.

The above results are summarized in Table 8.1 below:

[58] This equals .01/(-.0031186). Equivalent calculations with respect to the other cases are similar.
[59] This equals 1-exp(-3.20657). Equivalent calculations with respect to the other cases are similar.
[60] This is the average of the company-year debt ratios of those leading to the parameter estimates of Table 5.4.
[61] In the other direction using the value at the end of the 95% confidence interval, .124, necessitates increasing debt ratio by 317%, also clearly impossible.

TABLE 8.1

**Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Profit Inefficiency
GLS - Time-Invariant Base Case**

		Increase ROE by 1%	Increase ROE by Amt Due to InEfficiency
Asset Size	Using Parameter Estimate	96.0%	
	Using end of 95% CI Value	74.6%	
Debt Ratio Max	Using Parameter Estimate	68.5%	
	Using end of 95% CI Value	12.1%	27.2%
Debt Ratio Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	Impossible	
%New Bus Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	82.5%	Impossible

Even with respect to government bond yields using the parameter estimate of -.015 we see that these yields have to change by 0.677% for an insurer to be able to increase it ROE by 1%. Given that the yields changed by an average of 0.270% over the five years under consideration it is clear that an insurer should not base its hopes on this.

So we have seen that profit inefficiency has decreased the ROE of life insurers by an average of 2.24% which is a drop of 15.0% of the average potential ROE. In addition 17.0% of the company-year ROE values are decreased by more than 25% of their potential value and 62.7% are decreased by more than 10% of its potential value. So clearly profit inefficiency is a very important influence on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the 2.24%) a life insurer has to either change one of the aspects of its business that it can control (other than profit efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its profit efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average profit inefficiency for this case is 6.3%) that decreasing profit inefficiency by 2.8% (the amount necessary to increase ROE by 1%) is possible.

8.2 Profit Inefficiency GLS Time-Invariant Case III[62]

From Section 5.1.1.3 the effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.6 below:

[62] Recall that Case II resulted in profit inefficiency being non-explanatory.

TABLE 5.6

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Case III

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.282***	0.041
2001	0.003	0.010
2002	-0.008	0.010
2003	-0.004	0.010
2004		
Ln Asset Size	-0.002	0.002
Debt Ratio	-0.030	0.082
%New Bus	-0.022**	0.009
Yields	0.000	0.009
Domestic	0.082***	0.008
Constant	0.203***	0.057

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**66.6%**
Only Parameters of Variables a Company Can Control	**83.9%**

*** = significant to a 1% level
** = significant to a 5% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was “dropped” by the statistical package as being “collinear”.

Here recall the average decrease of ROE caused by insurer profit inefficiency is 8.44%. The results necessary to change ROE by 1% (e.g. from 10% to 11%) and by the average change in ROE due to inefficiency in this case are summarized in Table 8.2 below:

TABLE 8.2

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Profit Inefficiency
GLS - Time-Invariant Case III

		Increase ROE by 1%	Increase ROE by Amt Due to InEfficiency
Asset Size	Using Parameter Estimate	99.1%	
	Using end of 95% CI Value	78.9%	
Debt Ratio Max	Using Parameter Estimate	78.1%	
	Using end of 95% CI Value	12.2%	Impossible
Debt Ratio Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	Impossible	
%New Bus Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	68.5%	Impossible

Again, even with respect to government bond yields using the parameter estimate of .00033 we see that these yields have to change by 30.23% for an insurer to be able to increase it ROE by 1% which is not going to occur.

So we have seen that profit inefficiency has decreased the ROE of life insurers by an average of 8.44% which is a drop of 38.6% of the average potential ROE. So clearly profit inefficiency is a very important influence on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the 8.44%) a life insurer has to either change one of the aspects of its business that it can control (other than profit efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its profit efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average profit inefficiency for this case is 29.9%) that decreasing profit inefficiency by 3.5% (the amount necessary to increase ROE by 1%) is possible.

8.3 Profit Inefficiency GLS Time-Varying Base Case and Case III[62]

Here recall (Sections 5.1.2.1 and 5.1.2.3) the average decrease of ROE caused by insurer profit inefficiency is 1.67% for the Base Case and 5.24% for Case III. The results necessary to change ROE by 1% (e.g. from 10% to 11%) and by the average change in ROE due to inefficiency for these cases are summarized in Tables 8.3 and 8.4 below:

TABLE 8.3

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Profit Inefficiency
GLS – Time-Varying Base Case

		Increase ROE by 1%	**Increase ROE by Amt Due to InEfficiency**
Asset Size	Using Parameter Estimate	97.2%	
	Using end of 95% CI Value	75.9%	
Debt Ratio Max	Using Parameter Estimate	65.1%	
	Using end of 95% CI Value	12.0%	20.1%
Debt Ratio Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	Impossible	
%New Bus Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	81.6%	Impossible

TABLE 8.4

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Profit Inefficiency
GLS – Time-Varying Case III

		Increase ROE by 1%	Increase ROE by Amt Due to InEfficiency
Asset Size	Using Parameter Estimate	99.99%	
	Using end of 95% CI Value	83.7%	
Debt Ratio Max	Using Parameter Estimate	49.6%	
	Using end of 95% CI Value	11.1%	58.0%
Debt Ratio Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	Impossible	
%New Bus Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	63.5%	Impossible

Again, even with respect to government bond yields using the parameter estimate of -.015 (.086) for the Base Case (Case III) we see that these yields have to change by 0.676% (0.116%) for an insurer to be able to increase it ROE by 1%. Given that the yields changed by an average of 0.270% over the five years under consideration it is clear that an insurer should not base its hopes on this at least for the Base Case. For Case III to change its ROE by 5.24%, the yield change has to be 0.607%, so it is clearly much easier to use profit inefficiency to increase its ROE.

So we have seen that profit inefficiency has decreased the ROE of life insurers by an average of 1.67% (5.24%) for the Base Case (Case III) which is a drop of 11.6% (28.0%) of the average potential ROE. So clearly profit inefficiency is a very important influence on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the 1.67% or 5.24%) a life insurer has to either change one of the aspects of its business that it can control (other than profit efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its profit efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average profit inefficiency for these cases are 6.3% and 29.9%) that decreasing profit inefficiency by 3.8% for the Base Case or 5.7% for Case III (the amount necessary to increase ROE by 1%) is possible.

8.4 Profit Inefficiency MLE Time-Invariant Base Case

From Section 5.2.1.1 the effect of profit efficiency as well as the various parameters on life insurer ROE is shown in Table 5.10 below:

TABLE 5.10

Effect on ROE
Profit InEfficiency – MLE
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-0.153***	0.033
2001	-0.008	0.017
2002	-0.018	0.023
2003	-0.025	0.038
2004	-0.015	0.045
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.043	0.081
%New Bus	-0.026***	0.009
Yields	-0.017	0.033
Domestic	0.088***	0.007
Constant	0.226	0.201

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**44.4%**
Only Parameters of Variables a Company Can Control	**68.7%**

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

Recall the average decrease of ROE caused by insurer profit inefficiency is 2.27%. The results necessary to change ROE by 1% (e.g. from 10% to 11%) and by the average change in ROE due to inefficiency for this cases are summarized in Table 8.5 below:

TABLE 8.5

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Profit Inefficiency
MLE - Time-Invariant Base Case

		Increase ROE by 1%	Increase ROE by Amt Due to InEfficiency
Asset Size	Using Parameter Estimate	99.95%	
	Using end of 95% CI Value	85.1%	
Debt Ratio Max	Using Parameter Estimate	54.5%	
	Using end of 95% CI Value	11.5%	26.8%
Debt Ratio Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	Impossible	
%New Bus Ave	Using Parameter Estimate	Impossible	
	Using end of 95% CI Value	64.8%	Impossible

Even with respect to government bond yields using the parameter estimate of -.017 we see that these yields have to change by 0.578% for an insurer to be able to increase it ROE by 1%. Given that the yields changed by an average of 0.270% over the five years under consideration it is clear that an insurer should not base its hopes on this.

So we have seen that profit inefficiency has decreased the ROE of life insurers by an average of 2.27% which is a drop of 15.1% of the average potential ROE. So clearly profit inefficiency is a very important influence on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the 2.24%) a life insurer has to either change one of the aspects of its business that it can control (other than profit efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its profit efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average profit inefficiency for this case is 14.9%) that decreasing profit inefficiency by 6.5% (the amount necessary to increase ROE by 1%) is possible.

8.5 Cost Inefficiency GLS

For the time-invariant cost inefficiency studies recall (Sections 6.1.1.1 and 6.1.1.4) the average decrease of ROE caused by insurer cost inefficiency is 2.36% for the Base Case and 3.31% for Case IV. The results necessary to change ROE by 1% (e.g. from 10% to 11%) and by the average change in ROE due to inefficiency for these cases are summarized in Table 8.6 below:

TABLE 8.6

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Cost Inefficiency
GLS – Time-Invariant Base Case (Case IV)

		Increase ROE by 1%	**Increase ROE by Amt Due to InEfficiency**
Asset Size	Using Parameter Estimate	83.8% (100%)	
	Using end of 95% CI Value	67.3% (92.1%)	
Debt Ratio Max	Using Parameter Estimate	70.9% (34.9%)	
	Using end of 95% CI Value	13.1% (10.2%)	30.9% (33.7%)
Debt Ratio Ave	Using Parameter Estimate	Impossible (Imp)	
	Using end of 95% CI Value	Impossible (Imp)	
%New Bus Ave	Using Parameter Estimate	Impossible (Imp)	
	Using end of 95% CI Value	78.2% (67.5%)	Impossible (Impossible)

For the time-varying cost inefficiency studies recall (Sections 6.1.2.1 and 6.1.2.4) the average decrease of ROE caused by insurer cost inefficiency is 1.93% for the Base Case and 1.81% for Case V. The results necessary to change ROE by 1% (e.g. from 10% to 11%) and by the average change in ROE due to inefficiency for these cases are summarized in Table 8.7 below:

TABLE 8.7

Necessary Changes (as % of Current Value)
to Increase ROE by 1% (e.g. from 10% to 11%)
or by Average Change of ROE Due to Cost Inefficiency
GLS – Time-Varying Base Case (Case V)

		Increase ROE by 1%	Increase ROE by Amt Due to InEfficiency
Asset Size	Using Parameter Estimate	83.1% (100%)	
	Using end of 95% CI Value	66.8% (88.6%)	
Debt Ratio Max	Using Parameter Estimate	103.2% (41.4%)	
	Using end of 95% CI Value	14.0% (10.8%)	27.0% (19.5%)
Debt Ratio Ave	Using Parameter Estimate	Impossible (Imp)	
	Using end of 95% CI Value	Impossible (Imp)	
%New Bus Ave	Using Parameter Estimate	Impossible (Imp)	
	Using end of 95% CI Value	78.7% (62.2%)	Impossible (Impossible)

Again, even with respect to government bond yields using the various parameter estimates we see that these yields have to change by anywhere from 0.194% to 0.281% for an insurer to be able to increase it ROE by 1%. So while an insurer could hope for this to occur, it seems to be a much better idea to use a change in cost efficiency to achieve this goal.

So we have seen that cost inefficiency has decreased the ROE of life insurers by an average of anywhere from 12.7% to 20.8% of the average potential ROE. In addition for the time-invariant Base Case 26.1% of the company-year ROE values are decreased by more than 25% of their potential value and 73.5% are decreased by more than 10% of its potential value. So clearly cost inefficiency is a very important influence on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the 1.81% or 3.31%) a life insurer has to either change one of the aspects of its business that it can control (other than cost efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its cost efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average cost inefficiency for these cases are 6.31%, 6.60%, 6.31% and 4.68%)[63] that decreasing cost inefficiency by 2.7%, 2.0%, 3.3% or 2.6% (the amount necessary to increase ROE by 1%) is possible.

8.6 LOB Profit Inefficiency Time-Invariant Base Case

From Section 7.1 the effect of profit efficiency as well as the various parameters on life insurer ROE for the Individual Life NonPar LOB is shown in Table 7.1 below:

[63] For the time-invariant Base Case and Case IV and the time-varying Base Case and Case V, resp.

TABLE 7.1

Effect on ROE
Profit InEfficiency – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit Inefficiency	-39.941	28.599
2001	0.613	1.720
2002	-0.630	1.557
2003	2.308	1.612
2004		
Ln Asset Size	-0.862**	0.380
Debt Ratio	37.357***	8.823
%New Bus	-4.970**	2.121
Yields	2.509*	1.420
Domestic	5.539***	1.602
Constant	-3.542	8.257

Profit Inefficiency Parameter % of Total Value of Parameters	
Including Average of Year Estimates	**43.2%**
Only Parameters of Variables a Company Can Control	**48.0%**

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.
Note that the 2004 variable was "dropped" by the statistical package as being "collinear".

Recall the average decrease of ROE caused by insurer profit inefficiency when considering the individual company-year values is 32.6% and consider the variables that a life insurer can control. First consider (the natural log of) asset size where the parameter is -0.862, so to increase ROE by 10% (a value that over half of the individual company-year changes are) an insurer has to change its natural log of asset size value by -0.116 which is decreasing the asset size allocated to this LOB by 11.0%. This is difficult to do given that the asset sizes are allocated to the LOBs based on the face values written in each LOB.[64] Here even if one uses the value at the end of the 95% confidence interval, -1.607, to change ROE by 10% an insurer has to change its natural log of asset size value by -0.062 which is decreasing the asset size by 6.0%, still difficult. The corresponding decreases necessary to result in a 32.6% increase in ROE are 31.5% and 18.4%.

Considering the debt ratio, we see that the relevant average is 2.684.[65] The parameter estimate is 37.35 so we find that to increase ROE by 10% an insurer has to change its debt ratio by 0.267% which, at the average company-year value, is an increase of 10.0% of its current value. Here even if one uses the value at the end of the 95% confidence interval, 54.65, to change ROE by 10% an insurer has to change its debt ratio by 5.2% which at the average company-year value, is an increase of 6.8% of its current value. The corresponding increases necessary to result in a 32.6% increase in

[64] More precisely the allocation is by Value-at-Risk.
[65] For the LOBs the overall debt ratio of the company is used.

ROE are 32.5% and 22.2% of the current average value. One should also note that only nine of twenty-seven domestic and none of the foreign-owned companies have any individual company-year debt ratios here that are non-zero. So not only is affecting ROE by changing the debt ratio not particularly easy to do, it seems to be open to only a limited number of these insurers.

Considering the percentage of new business written by the insurer, we see that the relevant average is 21.61%. The parameter is -4.97, so to increase ROE by 10% an insurer has to decrease its percent of new business written by 2.0% which is a decrease of 9.1% of the current value. Here even if one uses the value at the end of the 95% confidence interval, -9.13, to change ROE by 10% an insurer has to change its percent of new business written by 1.1% which at the average company-year value of 21.61% is decreasing its percent of new business written 5.0% of its current value. To increase ROE by the average change generated by profit inefficiency, 32.6%, an insurer has to change its percent of new business written by 3.57% which at the average company-year is a decrease of 16.2% of the current value. So it appears that to increase the ROE of this LOB, the insurer has to decrease the amount of business it writes quite substantially which may not fit into a company's philosophy.

The above results are summarized in Table 8.8 below:

TABLE 8.8

Necessary Changes (as % of Current Value)
to Increase ROE by 10%
or by Average Change of ROE Due to Profit Inefficiency
GLS - Time-Invariant Base Case

		Increase ROE by 10%	**Increase ROE by Amt Due to InEfficiency**
Asset Size	Using Parameter Estimate	11.0%	31.5%
	Using end of 95% CI Value	6.0%	18.4%
Debt Ratio Ave	Using Parameter Estimate	10.0%	32.5%
	Using end of 95% CI Value	6.8%	22.2%
%New Bus Ave	Using Parameter Estimate	9.1%	29.7%
	Using end of 95% CI Value	5.0%	16.2%

So we have seen that profit inefficiency has decreased the ROE of life insurers by an average of 32.6% and 50.3% are decreased by more than 10% of its potential value. So clearly profit inefficiency is a very important influence on the ROE of this LOB for the life insurers in Canada.

Now, to change ROE by 10% (never mind the 32.6%) a life insurer has to either change one of the aspects of its business that it can control (other than profit efficiency) quite radically so as to be at least difficult to do. Therefore the best and easiest way to influence its ROE for this LOB is through changing its profit efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear (as the average profit inefficiency for this case is 3.66%) that decreasing profit inefficiency by 0.25% (the amount necessary to increase ROE by 10%) is much easier.

9 Conclusions

We have seen that inefficiency has decreased the ROE of life insurers by an amount that is between 11% and 38% of the potential ROE. In addition large percentages of the company/year ROE values are decreased by more than 25% and 10% of their current value. So clearly profit and cost inefficiency are very important influences on the ROE of life insurers in Canada.

Now, to change ROE by even 1% (never mind the average of any case considered) a life insurer has to either change one of the aspects of its business that it can control (other than efficiency) extremely radically (so as to be virtually impossible) or finds that it is impossible to do. Therefore the best, easiest and quite possibly only way to influence its ROE is through changing its efficiency. Given that this (in)efficiency study compares companies such that the efficiency scores are determined when identical sets of inputs, outputs and exogenous variables are used (as seen in equation (2)) it seems quite clear that decreasing inefficiency by the amount necessary to increase ROE by 1% is possible.

A key benefit of this research is that it adds to the 1) information concerning the important area of expenses and efficiency in the life insurance industry and 2) the knowledge of how to regulate life insurance and determine warning signs concerning the viability of insurers. Efficiency is considered to be a more accurate and encompassing feature of a company to consider than (items similar to) expense ratios. Indeed, "the economic efficiency approach is superior to conventional measurement techniques such as the analysis of expense ratios and net income because it sums the firm's performance in a single statistic that takes into account differences among firms in product and input mix in a sophisticated multidimensional framework." [66] So the concept of efficiency can be an improvement of existing methods as it will enable the determination of insurers future profitability and/or viability in a way that is more accurate than simply using expenses or expense ratios.

An example of this is the purpose of Section 3c) of Canada's *Winding-up and Restructuring Act (1985)* (R. S., 1985, c. W-11)[67] which states that a "company is deemed insolvent if it exhibits a statement showing its inability to meet its liabilities." As expenses are such a liability efficiency can also be used in this area to gain a greater understanding of life insurer viability.

Another example of this is the purpose of Section 136 of Australia's *Life Insurance Act (1995)* (Cwlth No. 4). Paragraphs d) and e) of this Section list as grounds for a show cause notice 1) an expense to premium ratio that is too high and 2) the use of an inequitable expense apportionment (method). So, with respect to these items the use of efficiency rather than expenses or expense ratios as a measure will be more accurate and encompassing. In addition paragraph a) of Section 136 lists the inability of a life company to meet its liabilities.[68] As expenses are such a liability efficiency can also be used in this area to gain a greater understanding of life insurer viability.

Another potential outcome is that it may be possible to more definitively determine the best inputs and outputs to use for future studies regarding life insurer efficiency.

This research can also be used as a basis for regulation of insurers with respect to increase in volume. As it can be an especially dangerous if a life insurer expands too quickly and difficult to know how fast is too fast this can be an important tool in this area. Similar remarks can be made for product development.

---

[66] Quote is from Carr et al. (1999).

[67] It may be that the *Insurance Companies Act* (1991 c.47) is more relevant here but I have not determined that yet.

[68] The descriptions of the paragraphs of Section 136 here are brief paraphrases.

This research will also help insurers learn which areas to concentrate on when making management decisions regarding expenses, efficiency, and similar concepts.

Bowie et al. (1996) points out "that difficulty with the computational tool is not a good reason to dismiss the model." So one can infer from this that if one includes efficiency in an analysis of life insurance that, even though it may be more difficult to work with than simply using expense ratios (say), one is creating and/or using a better way to analyse life insurance. Therefore this can be deemed both desirable and necessary.

APPENDIX

TABLE A.1

Profit InEfficiency - GLS - Effect on ROE
Time-Invariant Base Case
Individual Company-Year Values

	Average	16.85%						
Company	Year	Percent ROE Decrease	Company	Year	Percent ROE Decrease	Company	Year	Percent ROE Decrease
1	2002	---	32	2000	0.41%	62	2000	6.14%
1	2003	5.14%	32	2001	15.49%	62	2001	4.29%
1	2004	7.06%	32	2002	17.60%	62	2002	---
3	2000	43.37%	32	2003	13.40%	62	2003	6.50%
3	2001	16.46%	32	2004	15.77%	62	2004	18.57%
3	2002	24.08%	33	2000	7.62%	69	2000	4.37%
3	2003	10.88%	33	2001	6.77%	69	2001	---
3	2004	13.51%	33	2002	6.74%	69	2002	36.92%
4	2000	19.37%	33	2003	5.81%	69	2003	9.58%
4	2001	12.82%	33	2004	4.92%	69	2004	7.91%
4	2002	17.01%	34	2000	14.64%	71	2001	---
4	2003	19.76%	34	2001	37.97%	71	2002	---
4	2004	17.43%	34	2002	6.90%	71	2003	---
5	2002	---	34	2003	11.10%	71	2004	---
5	2003	5.71%	34	2004	10.24%	72	2000	---
5	2004	2.48%	35	2000	5.52%	72	2001	35.58%
6	2000	2.26%	35	2001	4.93%	72	2002	---
6	2001	8.04%	35	2002	9.92%	72	2003	---
6	2002	11.14%	35	2003	4.84%	72	2004	---
6	2003	9.29%	35	2004	5.44%	73	2000	7.48%
6	2004	7.68%	36	2000	---	73	2001	5.58%
8	2000	11.68%	36	2001	13.49%	73	2002	7.47%
8	2001	19.62%	36	2002	5.56%	73	2003	5.72%
8	2002	15.06%	36	2003	2.86%	73	2004	7.54%
8	2003	---	36	2004	8.41%	74	2000	15.64%
8	2004	---	37	2000	5.01%	74	2001	58.87%
11	2000	16.36%	37	2001	6.80%	74	2002	7.97%
11	2001	30.95%	37	2002	7.87%	74	2003	26.69%
11	2002	9.58%	37	2003	8.09%	74	2004	6.73%
11	2003	10.54%	37	2004	8.27%	77	2000	18.31%
11	2004	8.08%	38	2000	20.55%	77	2001	---
13	2000	7.41%	38	2001	11.73%	77	2002	10.22%
13	2001	8.28%	38	2002	11.69%	77	2003	5.49%
13	2002	14.41%	38	2003	17.48%	77	2004	8.20%
13	2003	13.16%	38	2004	14.94%	78	2000	17.01%
15	2000	10.16%	39	2000	20.29%	78	2001	---
15	2001	9.49%	39	2001	5.23%	78	2002	---
15	2002	9.39%	39	2002	3.41%	78	2003	---
15	2003	11.09%	39	2003	5.01%	78	2004	12.68%
15	2004	12.58%	39	2004	49.46%	79	2000	11.28%
16	2000	18.41%	40	2000	11.84%	79	2001	11.31%
16	2001	8.44%	40	2001	15.12%	79	2002	8.14%
16	2002	19.00%	40	2002	47.25%	79	2003	7.50%
16	2003	19.05%	40	2003	10.48%	79	2004	21.49%
16	2004	7.69%	40	2004	10.62%	82	2000	11.87%

17	2000	32.79%	41	2000	27.69%	82	2001	14.39%
17	2001	7.72%	41	2001	20.41%	82	2002	11.61%
17	2002	6.02%	41	2002	20.67%	82	2003	13.44%
17	2003	7.85%	41	2003	20.67%	82	2004	10.67%
17	2004	9.12%	41	2004	21.01%	85	2000	---
18	2000	---	42	2000	21.04%	85	2001	11.09%
18	2001	8.79%	42	2001	34.20%	85	2002	24.80%
18	2002	28.43%	42	2002	17.14%	85	2003	32.19%
18	2003	32.83%	42	2003	16.17%	85	2004	92.98%
18	2004	12.90%	42	2004	26.30%	89	2000	---
19	2000	5.19%	43	2000	3.88%	89	2001	11.25%
19	2001	11.05%	43	2001	5.82%	89	2002	57.00%
19	2002	16.38%	43	2002	9.11%	89	2003	30.22%
19	2003	23.36%	43	2003	6.57%	89	2004	20.52%
19	2004	18.32%	43	2004	6.83%	90	2000	26.12%
20	2000	7.20%	44	2000	20.53%	90	2001	15.46%
20	2001	7.18%	44	2001	1.60%	90	2002	26.42%
20	2002	6.69%	44	2002	1.68%	90	2003	17.15%
20	2003	17.23%	44	2003	3.16%	90	2004	22.13%
20	2004	11.11%	44	2004	12.78%	91	2000	---
21	2000	9.46%	49	2000	23.02%	91	2001	---
21	2001	9.00%	49	2001	12.79%	91	2002	12.10%
21	2002	10.51%	49	2002	36.46%	91	2003	12.61%
21	2003	9.63%	49	2003	15.66%	91	2004	24.67%
21	2004	7.96%	49	2004	45.01%	95	2000	65.17%
22	2000	11.14%	51	2000	8.00%	95	2001	59.72%
22	2001	13.55%	51	2001	4.94%	95	2002	42.13%
22	2002	11.63%	51	2002	5.39%	95	2003	---
22	2003	30.99%	51	2003	6.43%	95	2004	---
22	2004	28.62%	51	2004	3.40%	96	2000	17.51%
25	2000	5.95%	52	2000	9.85%	96	2001	16.92%
25	2001	6.98%	52	2001	10.73%	96	2002	14.99%
25	2002	19.26%	52	2002	20.40%	96	2003	25.09%
25	2003	---	52	2003	7.07%	96	2004	20.48%
25	2004	11.23%	52	2004	8.71%	98	2000	18.89%
26	2000	13.81%	53	2000	---	98	2001	25.06%
26	2001	14.91%	53	2001	---	98	2002	19.78%
26	2002	86.64%	53	2002	---	98	2003	17.70%
26	2003	18.39%	53	2003	---	98	2004	27.80%
26	2004	18.66%	53	2004	---	102	2000	23.17%
27	2000	9.24%	56	2000	62.40%	102	2001	37.21%
27	2001	7.01%	56	2001	---	102	2002	24.13%
27	2002	10.65%	56	2002	---	102	2003	---
27	2003	6.27%	56	2003	---	102	2004	11.48%
27	2004	7.44%	56	2004	38.20%	104	2000	41.91%
28	2000	16.42%	58	2000	14.15%	104	2001	32.64%
28	2001	23.09%	58	2001	6.16%	104	2002	---
28	2002	18.34%	58	2002	8.51%	104	2003	98.47%
28	2003	16.25%	58	2003	13.41%	104	2004	1.09%
28	2004	20.22%	58	2004	4.21%	106	2000	29.55%
29	2001	17.73%	59	2000	---	106	2001	14.08%
29	2002	10.39%	59	2001	---	106	2002	42.98%
29	2003	8.95%	59	2002	35.94%	106	2003	21.79%
29	2004	7.62%	59	2003	18.53%	106	2004	38.39%
30	2000	5.31%	59	2004	27.41%	107	2000	18.29%
30	2001	8.82%	61	2000	2.26%	107	2001	19.88%
30	2002	27.62%	61	2001	---	107	2002	8.90%

30	2003	26.32%	61	2002	24.75%	107	2003	83.88%
			61	2003	---	107	2004	18.54%
			61	2004	21.12%			

TABLE A.2

Effect on ROE (using Profit) – GLS
Time-Invariant Base Case

Variable	Parameter Estimate	Standard Deviation
Profit	0.000	0.000
2001	-0.003	0.018
2002	-0.012	0.023
2003	-0.014	0.038
2004	-0.003	0.046
Ln Asset Size	-0.001	0.002
Debt Ratio	-0.016	0.101
%New Bus	-0.024***	0.009
Yields	-0.007	0.033
Domestic	0.091***	0.007
Constant	0.135	0.202

*** = significant to a 1% level

Note that 2000 is the base year so the year variables represent the change due to operating in that year versus 2000.

TABLE A.3

Company Profit InEfficiency – GLS
Time-Invariant Case II

Company	Profit Inefficiency	Company	Profit Inefficiency	Company	Profit Inefficiency
82	0.000%	33	47.438%	25	47.639%
106	23.220%	90	47.438%	21	47.652%
60	24.987%	28	47.440%	15	47.686%
49	33.984%	34	47.450%	51	47.690%
77	37.534%	22	47.491%	20	47.741%
6	42.663%	43	47.497%	35	47.758%
62	43.718%	98	47.515%	27	47.759%
94	44.673%	91	47.518%	3	47.782%
85	45.057%	96	47.519%	8	47.898%
44	46.246%	39	47.523%	38	47.900%
59	46.802%	26	47.526%	89	47.950%
5	46.915%	79	47.527%	1	48.002%
69	47.021%	17	47.535%	61	48.019%
19	47.125%	4	47.561%	53	48.205%
30	47.196%	107	47.579%	104	48.295%
13	47.207%	32	47.580%	40	48.718%
37	47.208%	74	47.581%	102	48.815%
11	47.226%	58	47.583%	95	49.295%
41	47.342%	42	47.601%	29	49.400%
52	47.374%	36	47.612%	78	62.107%
18	47.376%	16	47.622%	71	77.021%

TABLE A.4

Company Profit InEfficiency – GLS
Time-Invariant Case III

Company	Profit Inefficiency	Company	Profit Inefficiency	Company	Profit Inefficiency
49	0.000%	26	30.094%	27	30.389%
6	16.378%	32	30.096%	61	30.419%
62	24.165%	98	30.129%	38	30.424%
85	26.100%	52	30.148%	21	30.488%
79	26.501%	43	30.155%	91	30.543%
59	27.943%	77	30.159%	39	30.583%
94	28.146%	4	30.169%	89	30.597%
90	28.985%	33	30.187%	13	30.610%
5	29.245%	35	30.191%	40	30.629%
44	29.546%	74	30.206%	107	30.698%
95	29.636%	15	30.235%	1	30.715%
30	29.752%	58	30.238%	8	30.737%
37	29.954%	36	30.270%	102	30.941%
22	29.954%	34	30.284%	53	30.973%
19	29.987%	16	30.286%	69	31.088%
11	30.017%	20	30.296%	96	31.437%
42	30.021%	25	30.306%	29	32.031%
28	30.042%	104	30.326%	17	32.620%
41	30.074%	51	30.327%	78	41.508%
18	30.089%	3	30.331%	71	63.355%

TABLE A.5

Company Cost InEfficiency – GLS
Time-Invariant Base Case

Company	Cost Inefficiency	Company	Cost Inefficiency	Company	Cost Inefficiency
29	0.000%	41	6.145%	17	6.628%
39	0.496%	36	6.176%	33	6.669%
59	4.781%	4	6.258%	32	6.670%
44	5.106%	20	6.267%	107	6.704%
53	5.121%	37	6.279%	78	6.705%
95	5.240%	90	6.290%	96	6.720%
5	5.347%	11	6.295%	35	6.818%
106	5.352%	89	6.306%	38	6.894%
21	5.357%	73	6.322%	27	6.976%
13	5.397%	49	6.326%	22	7.027%
85	5.467%	25	6.328%	30	7.057%
72	5.653%	8	6.378%	40	7.117%
69	5.684%	43	6.403%	94	7.122%
26	5.688%	74	6.434%	34	7.127%
98	5.754%	6	6.435%	28	7.175%
52	5.797%	58	6.467%	56	7.205%
61	5.892%	18	6.482%	104	7.401%
42	5.894%	62	6.527%	15	7.744%
51	5.996%	91	6.573%	102	8.041%
77	6.000%	19	6.580%	82	9.415%
3	6.005%	16	6.601%	60	14.859%
79	6.100%				

TABLE A.6

Estimates of Translog Parameters
Cost InEfficiency – GLS
Time-Varying Base Case

Value(s) of which Ln is used[69]	Parameter Estimate	Standard Deviation	Values of which Ln is used	Parameter Estimate	Standard Deviation
premiums	-59.159	81.738	op x oie	0.055	0.865
investment income	126.013***	18.706	op x ge	-0.109***	0.010
other revenue	-53.719	34.751	als x div	0.463***	0.124
annuity pymts	-1050.931***	99.047	als x com	1.132	1.400
other pymts	-713.024***	52.891	als x ipha	318.403***	24.143
change pol liabs	-1356.738***	103.528	als x oie	23.488	18.556
dividends & errs	901.104***	77.260	als x ge	-0.565***	0.011
commissions	-868.512***	116.416	div x com	-26.373**	11.378
interest ph amts	-3601.953***	337.003	div x ipha	-174.446***	10.875
other interest exp	-517.920	391.517	div x oie	0.178	0.435
general expenses	110.152	104.196	div x ge	0.072**	0.033
prms x ii	0.006	0.004	com x ipha	220.769***	26.571
prms x or	0.003	0.003	com x oie	9.424	42.798
prms x ap	-0.066**	0.026	com x ge	-1.225***	0.355
prms x op	0.151***	0.036	ipha x oie	74.508*	40.421
prms x als	-0.809	0.503	ipha x ge	-22.543	24.366
prms x div	-0.192***	0.041	oie x ge	-2.694**	1.270
prms x com	-8.775***	2.082	uihat1b	-1.273***	0.192
prms x ipha	27.487	19.371	uihat2b	-1.095***	0.193
prms x oie	0.072	0.268	uihat3b	-1.269***	0.192
prms x ge	-0.163***	0.042	uihat4b	-0.852***	0.187
ii x or	-0.001	0.001	uihat5b	-1.008***	0.215
ii x ap	-0.005	0.005	uihat1as	-0.003***	0.001
ii x op	-0.021***	0.007	uihat2as	-0.001	0.001
ii x als	0.444***	0.015	uihat3as	-0.002*	0.001
ii x div	0.056***	0.012	uihat4as	-0.002**	0.001
ii x com	2.209***	0.363	uihat5as	-0.002**	0.001
ii x ipha	-33.339***	4.337	uihat1dr	0.000	0.017
ii x oie	-0.046	0.228	uihat2dr	-0.009	0.016
ii x ge	-0.026***	0.002	uihat3dr	-0.012	0.016
or x aps	0.024***	0.007	uihat4dr	0.003	0.014
or x op	-0.033***	0.010	uihat5dr	-0.019	0.015
or x als	-0.264***	0.007	uihat1pn	0.001	0.004
or x div	0.030	0.020	uihat2pn	0.003	0.003
or x com	1.554***	0.419	uihat3pn	0.006*	0.004
or x ipha	10.810	8.135	uihat4pn	-0.002	0.003
or x oie	-0.177	0.196	uihat5pn	0.005***	0.002
or x ge	0.000	0.003	uihat1d	0.000	0.002
ap x op	0.062***	0.006	uihat2d	-0.001	0.002
ap x als	-0.633***	0.011	uihat3d	-0.001	0.002
ap x div	0.017	0.012	uihat4d	0.000	0.002
ap x com	-0.451	1.636	uihat5d	-0.002	0.002
ap x ipha	248.060***	23.105	uihat1y	-0.002	0.004
ap x oie	1.730***	0.672	uihat2y	-0.003	0.004

[69] For neither the "uihatnx" variables nor the constant is the natural log used.

ap x ge	0.092***	0.002	uihat3y	-0.005	0.005
op x als	-0.236***	0.023	uihat4y	0.001	0.005
op x div	-0.033	0.023	uihat5y	-0.001	0.005
op x com	2.214**	0.999	constant	14868.780***	1446.573
op x ipha	164.224***	12.371			

*** = significant to a 1% level
** = significant to a 5% level
* = significant to a 10% level

Note: prms = premiums, ii = net investment income, or = other revenue, ap = annuity payments, op = other payments, als = change in policy liabilities, div = dividends and experience rating refunds, com = commissions, ipha = interest on policyholder amounts, oie = other interest expense, ge = general expenses and uihatnx are the *w* variables of equation (3)

References

Aigner, D. J., Lovell, C. A. K. & Schmidt, P. (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics* **6**, 21-37

Barros, C. P., Barroso, N. & Borges, M. R. (2005), "Measuring Efficiency in the Life Insurance Industry with a Stochastic Frontier Model", Presented at the 28th International Congress of Actuaries, Paris, France held May 28 – June 2, 2006

Berger, A. N. & DeYoung , R. (1997), "Problem loans and cost efficiency in commercial banks", *Journal of Banking and Finance* **21**, 849-870

Berger, A. N., Hancock, D. & Humphrey, D. B. (1993), "Bank efficiency derived from the profit function", *Journal of Banking & Finance* **17,** 317-347

Berger, A. N. & Humphrey, D. B. (1997), "Efficiency of Financial Institutions: International Survey and Directions for Future Research", *European Journal of Operational Research* **98,** 175-212

Berger, A. N. & Mester, L. J. (1997), "Inside the black box: What explains differences in the efficiencies of financial institutions?", *Journal of Banking & Finance* **21,** 895-947

Berger, A. N. & Mester, L. J. (2003), "Explaining the dramatic changes in performance of US banks: technological change, deregulation, and dynamic changes in competition", *Journal of Financial Intermediation* **12,** 57-95

Bernier, G. & Sedzro, K. (2003), "An Intertemporal Analysis of Efficiency Using DEA : The Case of the Canadian Life Insurance Industry Prior to 2000", Presented at the American Risk and Insurance Association 2003 Annual Meeting, Denver, CO held August 10 – 13, 2003

Bhattacharyya, A., Kumbhakar, S. C., & Bhattacharyya, A. (1995), "Ownership Structure and Cost Efficiency: A Study of Publicly Owned Passenger-Bus transportation Companies in India", *The Journal of Productivity Analysis* **6,** 47-61

Boonyasai, T., Grace, M. F. & Skipper, Jr., H. D. (2002), "The Effect of Liberalization and Deregulation on Life Insurer Efficiency", Center for Risk Management and Insurance Research, Georgia State University, Atlanta, GA, Working Paper No. 02-2

Bowie, D. C., Cairns, A. J. G., Macdonald, A. S. & Speed C. A. (1996), "Models, useful models, and reality", *The Actuary* (Institute of Actuaries, UK) **7**, 27-28

Cant, M. A. & French, D. A. (1993), "Margin on Services Reporting: The Financial Implications", *Transactions of the Institute of Actuaries* **1993**, 437-549

Carr, R. M., Cummins, J. D. & Regan, L. (1999), "Efficiency and competitiveness in the US life insurance industry: corporate, product, and distribution strategies" in "*Changes in the Life Insurance Industry: Efficiency, Technology and Risk Management"*, Cummins, J. D. & Santomero, A. M. (eds.), Kluwer Academic Publishers (1999), Norwell (suburb of Boston), MA

Chadwick, C. & Cappelli, P. (1999), "Strategy, Human Resource Management, and the Performance of Life Insurance Firms" in "*Changes in the Life Insurance Industry: Efficiency, Technology and Risk Management"*, Cummins, J. D. & Santomero, A. M. (eds.), Kluwer Academic Publishers (1999), Norwell (suburb of Boston), MA

Cummins, J. D. (1999), "Efficiency in the US life insurance industry: Are insurers minimizing costs and maximizing revenues?" in "*Changes in the Life Insurance Industry: Efficiency, Technology and Risk Management"*, Cummins, J. D. & Santomero, A. M. (eds.), Kluwer Academic Publishers (1999), Norwell (suburb of Boston), MA

Cummins, J. D., Tennyson, S., & Weiss, M. A. (1999), "Consolidation and efficiency in the US life insurance industry", *Journal of Banking & Finance* **23**, 325-357

Cummins, J. D., & Weiss, M. A. (2000), "Analyzing Firm Performance in the Insurance Industry Using Frontier Efficiency and Productivity Methods" in *"Handbook of Insurance"*, G. Dionne (ed.), Kluwer Academic Publishers, Norwell (suburb of Boston), MA

Cummins, J. D., Weiss, M. A. & Zi, H. (2003), "Economies of Scope in Financial Services: A DEA Bootstrapping Analysis of the US Insurance Industry", Presented at the 4th International Symposium on DEA, Birmingham, UK held Sep 4-6, 2004

Cummins, J. D. & Zi, H. (1998), "Comparison of Frontier Efficiency Models: An Application to the U. S. Life Insurance Industry" *Journal of Productivity Analysis* **10**, 131-152

Deaton, A. & Muellbauer, J. (1980), *"Economics and Consumer Behaviour"* Cambridge University Press, Cambridge, UK

DeYoung, R. & Nolle, D. (1996), "Foreign owned banks in the US: Earning market share or buying it?", *Journal of Money, Credit, and Banking* **28**, 622-636

Diacon, S. R., Starkey, K., & O'Brien, C. (2002), "Size and Efficiency in European Long-term Insurance Companies: An International Comparison", *The Geneva Papers on Risk and Insurance* **27**, 444-466

Elysiani, E., Mehdian, S. M. & Rezvanian, R. (1994), "An empirical test of association between production and financial performance", *Applied Financial Economics* **4**, 55-59

Grace, M. F. & Timme, S. G. (1992), "An Examination of Cost Economies in the United States Life Insurance Industry", *Journal of Risk and Insurance* **59**, 72-103

Greene, W. H. & Segal, D. (2004), "Profitability and Efficiency in the U.S. Life Insurance Industry", *Journal of Productivity Analysis* **21**, 229-247

Hao, J. C. (2003), "X-Efficiency in the Taiwan Life Insurance Industry", Presented at the American Risk and Insurance Association 2003 Annual Meeting, Denver, CO held August 10 – 13, 2003

Hao, J. C. (2005), "Comparison of Efficiency Estimation Models – The Case in Taiwan's Life Insurance Industry", Presented at the of the World Risk and Insurance Economics Congress Inaugural Meeting, Salt Lake City, UT held August 7 – 11, 2005

Hardwick, P., Adams, M. B., & Zou, H. (2003), "Corporate Governance and Cost Efficiency in the United Kingdom Life Insurance Industry", European Business Management School, Swansea, UK, Working Paper No. EBMS/2003/1

Hardwick, P. (1997), "Measuring cost efficiency in the UK life insurance industry", *Applied Financial Economics* **7**, 37-44

Hasan, I. & Hunter, W. C. (1996), "Efficiency of Japanese multinational banks in the United States", *Research in Finance* **14**, 157-173

Hitt, L. M. (1999), "The impact of information technology management practices on the performance of life insurance companies" in "*Changes in the Life Insurance Industry: Efficiency, Technology and Risk Management"*, Cummins, J. D. & Santomero, A. M. (eds.), Kluwer Academic Publishers (1999), Norwell (suburb of Boston), MA

Hussels, S. & Ward D. (2002), "Cost Efficiency and Total Factor Productivity in the European Life Insurance Industry: The Development of the German Life Insurance Industry Over the Years 1991-2002", University of Bradford School of Management, Bradford, UK, Working Paper No. 04/05

Insurance Companies Act (1991, c.47) - Department of Justice Canada

Khaled, M., Adams, M. B. & Pickford, M. (2001), "Estimates of Scale and Scope Economies in the New Zealand Life Insurance Industry", *The Manchester School* **69**, 327-349

Kim, Y.-D. (2002), "WTO Negotiations, Financial Crisis, and Efficiency and Productivity in the Korean Insurance Market", College of Business and Economics, Soongsil University, Seoul, ROK

Kumbhakar, S. C. & Lovell, C. A. K. (2000), *"Stochastic Frontier Analysis"* Cambridge University Press, Cambridge, UK

Lee, Y. H. & Schmidt, P. (1993), "A Production Frontier Model with Flexible Temporal Variation in Technical Inefficiency" in "*The Measurement of Productive Efficiency: Techniques and Applications"*, Fried, H. O., Lovell, C. A. K. & Schmidt, S. S. (eds.), Oxford University Press (1993), New York, NY

Letza, S., Hardwick, P. & Kowalski, T. (2001), "Efficiency in the UK life insurance industry", *Journal of Financial Services Marketing* **6**, 40-49

Leverty, T., Lin Y. & Zhou H. (2004), "Firm Performance in the Chinese Insurance Industry", Georgia State University, Atlanta, GA, Working Paper No. 04-10

Life Insurance Act (Australia) 1995: Act No. 4 as amended, Prepared by the Office of Legislative Drafting and Publishing, Attorney-General's Department, Canberra, ACT

Meador, J. W., Ryan, Jr., H. E. & Schellhorn, C. D. (1997), "Product Focus versus Diversification: Estimates of X-Efficiency for the US Life Insurance Industry", Financial Institutions Center, The Wharton School, University of Pennsylvania, Philadelphia, PA, Working Paper No. 97-16

Meeusen, W. & van Den Broeck, J. (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review* **18**, 435-444

Nini, G. P. (2002), "An Efficiency Analysis of Foreign and Domestic Insurance Companies in the European Union", Chapter 2 of "Current Events in Insurance: Three Essays on Capital, Learning and Geography" - A Dissertation in Insurance and Risk Management for the Graduate Group in Managerial Science and Applied Economics, Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Pritchett, S. T. (1974), "Operating Expenses and Prices for Thirty Insurers: Economies of Size for Ordinary Life Insurance", *Nebraska Journal of Economics and Business* **13**, 19-31

Rai, A. (1996), "Cost Efficiency of International Insurance Firms", *Journal of Financial Services Research* **10**, 213-233

Ryan, Jr., H. E. & Schellhorn, C. D. (2000), "Life Insurer Cost Efficiency Before and After Implementation of the NAIC Risk-Based Capital Standards", *Journal of Insurance Regulation* **18**, 362-382

Schaffnit, C., Rosen, D. & Paradi, J. C. (1997), "Best practice analysis of bank branches: An application of DEA in a large Canadian bank", *European Journal of Operational Research* **98**, 270-290

Winding-up and Restructuring Act (1985) (R. S., 1985, c. W-11) Department of Justice Canada