Scale and Scope Economies in the Canadian Property and Casualty Insurance Industry

by Jean Marc Suret *

Abstract

This study investigates scale and scope economies in the Canadian property/casualty insurance. Use of the translog cost function allows the estimation of a U-shaped cost curve and of cost elasticities that vary with the size of the insurance company. The model is estimated on a sample of 180 companies over the period 1986 to 1988, and considers four outputs: property, automobile, civil liability, and other types of insurance. The factors of production are labour, rentals, and capital, but the cost of the latter is taken as a constant.

Using data for the years 1986 to 1988, we show that there exists significant economies of scale for insurance companies with assets between \$40 and \$100 million. However, the evidence in favour of the existence of economies of scale for smaller and larger firms are limited to one year in each case.

We do not observe systematic evidence of significant cost complementarities between insurance products, nor do we note significant economies of scope. No cost complementarities exist between the two main product lines of property/casualty and automobile. Furthermore, there is some evidence of diseconomies of scope. Diversification economies can only be obtained with liability and other product lines.

Our evidence of slight economies of scale and no economies of scope is compatible with observation that many insurance companies in Canada are small and undiversified.

1. Introduction

Because the regulation of the financial sector in Canada is currently under modification, the cost structure of the Canadian insurance industry is a timely research topic. As deregulation would strongly affect the insurance market structure, it is of particular interest to determine if this market appears to be a natural monopoly. If scale and scope economies

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exist, established firms would have a cost advantage as compared to smaller, undiversified, and newly-entering firms. If the decision to enter the market is not reversible without cost, such a market will not be contestable.

As noted by Bernstein and Geehan (1988), there is a need for more evidence on the structure of the production functions of life and property/casualty insurance services. In fact, little research has been done, except for some studies estimating measures of scale economies (and these studies often used incorrect output measures). There is virtually no evidence on the issues of scope economies and productivity growth.

The objective of this study is to improve our knowledge of the cost structure in the property/casualty insurance sector. Furthermore, we will attempt to solve the main problems of previous studies. These problems are:

- 1) the utilization of a single-product framework;
- 2) the measurement of output in the insurance industry;
- 3) the assumption of restrictive functional forms to represent the production technology;
- 4) the failure to assess the robustness of various measures of the presence of scale and scope economies;
- 5) the failure to compute standard errors of the estimates of the parameters that characterise the cost function.

This study relies on the methodological framework developed by Mester (1987) in the savings and loan industry. With respect to the first problem described above, we consider the multiproduct nature of the insurance company by using the theory developed by Baumol, Panzar, and Willig (1982).

We resolve the second problem mentioned above by using two different measures of output, premium income and claims. This permits us to check if the premium income measure of size used in earlier studies produces downward-biased estimates of economies of scale (Skogh: 1982).

This study uses a multiproduct translogarithmic cost function to address the third problem mentioned above. To the best of our knowledge, it is the first time that this type of function has been used in the property/casualty insurance sector.

To assess the robustness of our results and resolve the fourth problem, we replicate our study over each of three years from 1986 to 1988. We also evaluate the effect of the epsilon value used to replace null values in the data set when a logarithmic function is estimated.

Finally, standard errors are calculated for the main results, using Fuller's (1962) method to estimate the reliability of quantities derived from empirical production functions. This allows us to evaluate the significance level of coefficients on the variables representing the presence of scale and scope economies.

The first section of this paper discusses briefly several characteristics of economies of production, and summarizes previous studies on cost functions in the insurance industry. The second section presents the models and the estimation procedures. The data and the estimation problems encountered are presented and discussed in the third section, while the last section presents our results.

2. Economies of production

2.1. Scale and scope economies: concepts and definitions¹

For a single product firm, overall economies of scale are present at a production level y if the total production cost of a firm increases less rapidly than its entire output. More formally, the degree of scale economies at y is:

$$S = C(y)/yC'(y) = AC(y)/C'(y) = (\text{average cost}) / (\text{marginal cost}).$$

Returns to scale are increasing, constant, or decreasing as S is greater than, equal to, or less than unity.

In the multiproduct situation, the degree of scale economies defined over the entire product set at y is given by:

$$S_i(y) = C(y) / \sum_{i=1}^n y_i C_i(y)$$

where $C_i(y) \equiv \partial C(y) / \partial (y_i)$.

Returns to scale are increasing, constant, or decreasing as $S(y)$ is greater than, equal to, or less than unity. This concept of returns to scale relies on a proportional increase in all outputs. Specific economies of scale can also be calculated in the case where the quantities of a subset T of the N different outputs increase, holding other outputs constant.

But a multiproduct firm can also modify the relative proportions of the N outputs. There is also a possibility that cost savings may result from the simultaneous production of different outputs by a single firm, as contrasted to the production of each output in isolation by its own specialized firm. These are economies resulting from the scope of the firm's operation (BPW, p. 71). The degree of economies of scope (which measure the economies of joint production) at y relative to product set T is given by:

$$SC_T(y) = [C(y_T) + C(y_{N-T}) - C(y)] / C(y)$$

where y_T is the vector with a zero component instead of y_i for all $i \notin T$, and y_{N-T} is the vector with a zero component in place of y_i for all $i \in T$. Thus, the degree of economies of scope represents the relative increase in cost that would result from the division of the production of y into product lines T and $N-T$.

BPW (1982, p. 75) show that a sufficient condition for a multiproduct cost function to exhibit overall economies of scope at y^* is that the cost function must exhibit weak cost complementarities, between each output pair, at all y up to y^* . That is, $\partial^2 C(y) / \partial y_i \partial y_j \leq 0$, $i \neq j$. The cost complementarities imply that the marginal cost of producing any one product decreases with the increase in the quantities of all other products.

¹ The main parts of the definition are taken from Baumol, Panzar and Willig (1982) (BPW).

2.2. *Economies of production in the insurance industry*²

Up to now, studies of the cost functions of companies in the insurance industry have been essentially concerned with economies of scale. In the property/casualty sector, past research has reported conflicting results in every country in which empirical tests have been undertaken.

In the USA, Allen (1974) found increasing returns to scale which disappeared at premium volumes of \$60 million. Joskow (1973) found returns to scale to be weak or nonexistent except for mutual automobile insurance companies. Hammond, Melander, and Shilling (1967) found increasing returns to scale which disappeared at premium volumes of \$300 million. Johnson, Flanigan, and Weisbart (1982) observed decreasing returns to scale for small and medium-sized insurers. However, increasing returns to scale were noted for large insurers with earned premiums in excess of \$250 million in 1976. Cho (1988) addressed the issue of possible scale economies in workers' compensation insurance. Statistically significant scale economies were present for acquisition, field supervision, and collection expenses. Only weak evidence of size efficiency was noted for losses, loss adjustment expenses, and general expenses.

In France, Rosa (1974) observed scale economies for premium volumes between 100 and 1000 million francs. Outreville (1987) found increasing returns to scale, while Dubois (1988) observed constant returns to scale. Skogh (1982), using claims as the measure of output, detected economies of scale in the Swedish property/casualty insurance sector in 1977. Like Skogh, Doherty (1981) used claims as the measure of output in Canada to find evidence in favour of significant size efficiency. Although Outreville and Proulx (1984) noticed significant size efficiency in Canada as well, they also found that economies of scale seemed to disappear after the numerous mergers observed in this sector between 1978 and 1981.

No definitive conclusions can be drawn from these studies. Mester (1987)³ reports that most of the previous empirical cost studies have proxied the multiple outputs either by creating a composite commodity, by choosing one of the firm's outputs to represent all its outputs, or by treating the firm as a collection of separate production functions.⁴ Treating a vector of outputs as a single composite commodity implies holding constant the proportions of the various outputs. Only changes in outputs which vary by a homogeneous percentage can be considered. Furthermore, relative marginal costs of any two outputs are forced to be independent of input prices, and thus the cost function is separable in output. When separate cost functions are estimated for each output, it is assumed that the marginal cost of producing one output is independent of that of the another outputs. One could erroneously conclude that scale economies exist only when cost complementarities are present. Since prior studies do not separate the issues of economies of scale and economies of scope, their conclusions are not definitive on this point.

² For a complete review of previous research in this area, see Pestiau and Pirard (1990), Bernstein and Geehan (1988) and Finsinger and Pauly (1986). Clark (1988) summarizes studies of economies of scale and scope in deposit financial institutions.

³ Mester's conclusions are based on an analysis of empirical studies of banking firms, but her conclusions could also apply to empirical studies on the insurance sector's cost functions.

⁴ To the best of our knowledge, there is only one study treating both scale and scope economies in the insurance sector; however, it focuses on the life insurance industry (Kellner and Mathewson: 1983).

Another important limitation of previous studies concerns the measurement of output. Premium income is generally used to represent output, which can underestimate real economies of scale. The problems associated with the measurement of output of property/casualty insurance companies are discussed in the third section.

3. Estimation procedures

3.1. The cost function

Following Mester (1987), a translogarithmic cost function is estimated in this research. This flexible function imposes only restrictions consistent with the existence of a dual relationship between the cost and transformation functions. There were no restrictions on the first and second order derivatives. Production functions estimated in previous research on economies of scale in the insurance industry have often been of either the Cobb-Douglas or the constant elasticity of substitution forms. These production functions are not consistent with economies or diseconomies of scale and scope over all relevant output ranges, and results are thus biased from the outset when inflexible functional forms are adopted. The translog function permits the evaluation of the characteristics of the cost function, such as its separability or if it takes the Cobb-Douglas form. Furthermore, fewer parameters must be estimated when using the translog function as compared to other flexible forms (Caves, Christiansen and Tretheway, 1980). The main problem with the translog function is that cost must equal zero when the output level is equal to zero. However, the flexibility of this functional form has made it the currently most popular choice in multiproduct cost studies.

For n products (y_i) and m inputs (w_j), the translog function may be written:

$$\begin{aligned}
 \ln C = & \alpha_0 + \sum_{i=1}^n \alpha_i \ln Y_i + \sum_{j=1}^m \beta_j \ln w_j \\
 & + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \sigma_{ij} \ln y_i \ln y_j \\
 & + \frac{1}{2} \sum_{j=1}^m \sum_{k=1}^m \delta_{jk} \ln w_j \ln w_k \\
 (1) \quad & + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^m \tau_{ij} \ln y_i \ln w_j
 \end{aligned}$$

From Shepherd's Lemma, the derived demand functions are found by differentiating the translog cost function with respect to the input prices. The input share equations are given by:

$$\begin{aligned}
 S_j &= \partial \ln C / \partial \ln w_j \\
 (2) \quad S_j &= \beta_j + \sum_{i=1}^n \delta_{ij} \ln y_i + \sum_{k=1}^m \beta_{jk} \ln w_k
 \end{aligned}$$

The translog cost function must be homogeneous of degree one in input prices. This implies the following parameter restrictions:⁵

$$\sum_j \beta_j = 1 \quad \sum_i \delta_{ij} = \sum_j \beta_{jk} = \sum_k \beta_{jk} = 0$$

Furthermore, the second order coefficients must be symmetric. This implies

$$\sigma_{ij} = \sigma_{ji} \quad \delta_{jk} = \delta_{kj} \quad \alpha_{ij} = \alpha_{ji}$$

In our study, variables are:

- y_1 : Property insurance
- y_2 : Automobile insurance
- y_3 : Liability insurance
- w_1 : Unit cost of salaries
- w_2 : Unit rental cost

A dummy variable (FORM) is included to control for the organizational form, stock vs mutual.

We estimated the model without the input share equation, because we did not have sufficient data to estimate S_j . Omitting the input share equation is a common practice in current multiproduct cost studies (Gilligan, Smirlock, and Marshall: 1984; Goldstein, McNulty, and Verbrugge: 1987). Murray and White (1983) obtain similar results when including or excluding the input share equations.

3.2. Degrees of scale and scope economies

The estimation of the translog function is only the first step; the second step is to calculate the degrees of scale economies and scope economies present. We accomplished this by using the definitions of Panzar and Willig (1977) and BPW (1982), and the estimation techniques described by Murray and White (1983) and Kim (1987).

Panzar and Willig (1977) demonstrate that a local measure of overall economies of scale (SL) for a multiproduct firm is the scale elasticity:

$$(3) \quad SL = C(Y, W) / \sum_i y_i MC_i = 1 / \sum \frac{\partial \ln C}{\partial \ln y_i} = 1 / \sum \alpha_i$$

where MC is the marginal cost with respect of the i th output.

The cost elasticity of the i th output can be obtained from the translog function by:

$$(4) \quad \gamma_i = \alpha_i + \sum_j \sigma_{ij} \ln y_j + \sum_k \delta_{ik} \ln w_k$$

At the point estimate, if $y_i = w_k = 1$, overall economies of scale are reduced to:

$$(5) \quad SL = (\sum_i \alpha_i)^{-1}$$

This simplification requires a standardization of the data before estimating the model. Murray and White, as well as Kim, use this transformation.

BPW (1982) define product-specific scale economies SL_i for product i as:

$$(6) \quad SL_i = \frac{IC_i(Y, W)}{Y_i MC_i(Y, W)} = \frac{IC_i / C}{\gamma_i}$$

⁵ See Christensen, Jorgenson and Lau (1973).

where $IC_i(Y, W)$ is the incremental cost of the i th product, defined as the difference in cost incurred by the firm in producing the mean level of product i as opposed to zero production of product i , while the quantities of the other products are held constant.

Kim (1986) noted that the estimation of SL_i requires the calculation of the cost function at the zero output level. For most firms, this requires a long extrapolation of the cost function far outside the range of the sample output levels over which the cost functions is estimated. He proposed to use 10 percent of the mean output level as a reference point.⁶ Product-specific scale economies can then be derived from the translog coefficients as:

$$(7) \quad SL_i = \frac{\exp(\alpha_o) - \exp(\alpha_o + \alpha_i \ln \epsilon + 1/2 \sigma_{ii} (\ln \epsilon)^2)}{\alpha_i \exp(\alpha_o)}$$

where $\epsilon_i = 0.0001, 0.001, 0.01, 0.1$ or 0.15 .

The concept of product-specific scale economies can be extended to a subset of products. The degree of scale economies specific to the products y_i and y_j can be obtained at the point of approximation of the translog cost function by:

$$(8) \quad SL_{ij} = \frac{\exp(\alpha_o) - \exp(\alpha_o + \alpha_i \ln \epsilon + \alpha_j \ln \epsilon + 1/2 \sigma_{ii} (\ln \epsilon)^2 + 1/2 \sigma_{jj} (\ln \epsilon)^2)}{\exp(\alpha_o) (\alpha_i + \alpha_j)}$$

We have seen that the degree of overall economies of scope (SC) at y relative to product set T is given by:

$$(9) \quad SC_T = (C(y_T) - C(y_{N-T}) - C(y)) / C(y)$$

In the three-output case, SC can be derived from the coefficient of the translog function as:

$$(10) \quad \begin{aligned} SC = [& \exp(\alpha_o + \alpha_2 \ln \epsilon + \alpha_3 \ln \epsilon + 1/2 \sigma_{22} (\ln \epsilon)^2 + 1/2 \sigma_{33} (\ln \epsilon)^2) \\ & + \exp(\alpha_o + \alpha_1 \ln \epsilon + \alpha_3 \ln \epsilon + 1/2 \sigma_{11} (\ln \epsilon)^2 + 1/2 \sigma_{33} (\ln \epsilon)^2) \\ & + \exp(\alpha_o + \alpha_1 \ln \epsilon + \alpha_2 \ln \epsilon + 1/2 \sigma_{11} (\ln \epsilon)^2 + 1/2 \sigma_{22} (\ln \epsilon)^2) \\ & - \exp(\alpha_o)] / \exp(\alpha_o) \end{aligned}$$

Because cost complementarity among products is a sufficient condition for a multi-product cost function to exhibit overall economies of scope, we also calculated these cost complementarities. As already mentioned, the cost complementarities imply that the marginal cost of producing any one product decreases with increases in the quantity of all other products.

From the translog function, cost complementarities can be detected by calculating cross-marginal elasticities at the approximation point by:

$$(11) \quad C = \frac{\partial \ln MC_i}{Z \ln y_i} = \frac{1}{\alpha_i} (\delta_{ij} + \alpha_i (\alpha_j - \Delta_{ij}))$$

⁶ It can be shown that Kim's results are highly sensitive to the choice of this reference point. For example, the product-specific economies of scale coefficient is 1.007 when the reference points is 0.10, but is becomes .935 when this point rises to 0.15. The extremely large confidence intervals surrounding the computed value are noted by Clark (1988). We used 5 different reference points (from 0.0001 to 0.15) to assess the robustness of our results.

where $\Delta_{ij} = 1$ for $i = j$ and $\Delta_{ij} = 0$ for $i \neq j$. A negative cross-marginal elasticity implies a cost complementarity between two products. Following Murray and White (1983), we used an approximate test of this condition, which is:

$$(12) \quad \alpha_i \alpha_j + \sigma_{ij} < 0$$

Output combinations satisfying (12) benefit from cost complementarities.

Finally, we calculated product-specific scope economies. As mentioned above, such economies exist when the joint production of an output with the existing combination of other outputs is cheaper than its production separate from the other outputs. At the point of approximation of the translog cost function, SC_i are given by:

$$(13) \quad SC_i = [\exp(\alpha_o + \sum_{j \neq i} \alpha_j \ln \epsilon + 1/2 \sum_{j \neq i} \sum \sigma_{jj} (\ln \epsilon)^2) + \exp(\alpha_o + \alpha_i \ln \epsilon + 1/2 \sigma_{ii} (\ln \epsilon)^2) - \exp(\alpha_o)] / \exp(\alpha_o).$$

The estimation of a confidence interval around these statistics representing the degrees of SL and SC follows in the next section.

3.3. Confidence intervals

A weakness of previous studies is the failure to compute standard errors of the estimates of the parameters characterising the cost function. This calculation is complex, because it is necessary to estimate the standard deviations of statistics which are non-linear functions of the estimated parameters. Fuller (1962) showed that the variance covariance matrix of such variables ($Z_1, Z_2 \dots Z_n$) that are functions of the estimated parameters ($a_1, a_2 \dots a_r$) is given by $D\Sigma D'$, where:

$$D = \begin{bmatrix} \partial Z_1 / \partial a_1 & \partial Z_1 / \partial a_2 & \dots & \partial Z_1 / \partial a_r \\ \vdots & \vdots & & \vdots \\ \partial Z_i / \partial a_1 & \dots & & \partial Z_i / \partial a_r \end{bmatrix}$$

where the partial derivatives are evaluated at the point estimates of $(a_1 \dots a_r)$ and Σ is the variance-covariance matrix of the parameters. We used this methodology to calculate the standard deviations and significance levels of our estimated parameters. In this study, SL , SL_i , SC , $SC_i \dots$ are the Z_i and the cost function parameters are the a_j .

4. Data and estimation process

4.1. The problem of output measurement

A great deal of controversy and confusion surrounds the nature of the outputs provided by insurance firms (Bernstein and Geehan: 1988). The measure of output most often used in current studies is premium income (Joskow: 1973, Johnson, Flanigan and Weisbart: 1982, Cho: 1988). However, Skogh (1982) showed that this approach involves a serious bias: premium income adequately measures output only under constant returns to scale in a long run competitive equilibrium. As one of the goals of this study is to test for the existence of constant returns to scale, it would be inappropriate to measure output by premium income. Furthermore, Skogh points out an econometric problem which is linked with the measurement of output by premium income. A simultaneity bias results from a positive relationship

between the explanatory variable, premium income, and the dependant variable, administrative costs. Premium income is composed of claims plus administrative costs; thus, the estimated economies of scale will be less than the true economies if premium income is used as a measure of size. Bernstein and Geehan note that premium income is not a correct measure of output, because it does not capture the risk-pooling nature of insurance.

This study follows Skogh's (1982) recommendation⁷ to use claims as the measure of the volume of output. However, we also computed scale and scope economies indicators using net premium income as the measure of output. A comparison of the two sets of cost function and production economies indicators allows an empirical evaluation of the appropriateness of the two alternative measures of output.

4.2. Prices of input factors

Three input factors are considered in this study: they are labour, rentals, and capital. The cost of capital is assumed constant across firms, as it is generally admitted that firms from the same sector belong to the same risk class. Even if they differ by their financial leverage, they should have the same cost of capital since financial leverage should not affect the cost of capital (Miller: 1977).

Wages can fluctuate from one geographic area to another. We thus first determined in which region each sample company appeared to be undertaking most of its operating activity. In a second step, we attributed to each company the average wage cost in the service sector of the area, as published by Statistics Canada.

Rentals, or the depreciation of real estate investment, appears to be an expensive item. We estimated the average rental rate (per square foot) for the main cities in Canada from the annual market study of the real estate firm Royal LePage. This estimation technique for rental costs has already been used in Gilligan and Smirlock (1984), and in Benston, Hanweck, and Humphrey (1982) in the banking sector.

4.3. Output and cost measurement

Premium income, claims, and expenses were collected from the Report of the Superintendent of Financial Institutions: *Abstract of Property and Casualty Insurance Companies* (The Report), for the years 1986 to 1988.

We considered the three main products of the property casualty insurance industry: automobile, property casualty and liability. These three lines of products represent more than 80% of insurance industry activity. Other insurance lines were grouped in a residual class to allow for a comprehensive model specification.

All Canadian insurance companies classified in the property/casualty sector in the Federal Report were included in the sample. Insurance companies that do not operate in one of the main insurance sectors, or which had negative or null expenses, were excluded from the sample. We defined three subsamples based on the level of total assets. Small firms were those having assets lower than \$ 40 million (\$ 30 million in 1986), large firms

⁷ However, Cho (1988), in a more recent study, writes that the use of claims is subject to serious criticism and does not constitute the right measure of output. Insurance product should also include auxiliary services; moreover, the amount of claims paid should be more preferably treated as a cost. He suggests using premium income.

were those having assets in excess of \$ 100 million (\$ 80 million in 1986), and medium-sized firms were between these two limits. Each group contains from 50 to 70 companies, depending on the year.

The main variables were defined as follows. Net claims include adjustment expenses. Property insurance (claims and premiums) includes personal and commercial insurance lines, and automobile insurance includes personal, liability, and other automobile insurance products. Total costs are composed of commissions and overhead expenses. When premium income is used as the measure of output, total costs include claims and relative expenses, and net premium income (i. e. direct premium income plus reinsurance assumed minus reinsurance added) is used as the measure of output.

When one line of insurance is not offered by a firm, a null value appears in the data set.⁸ As $\ln(0)$ is not defined, we replaced each null value by 0.1 and also tested the model using different values. Since null values appear essentially in the liability and the other insurance products categories, grouping these two lines together would be another way to solve this problem. However, we do not observe any significant effects of these various specifications on the coefficient values and significance levels. Nevertheless, the replacement of the liability and the other insurance products categories with a combined category entails important consequences in terms of the measurement of scale and scope economies.

4.4. Estimation process

Step one: Estimation of the cost function

Equation 1 is linear in its unknown parameter and thus OLS estimation can be used. The translog cost function was therefore estimated by using the REG procedure of SAS software, for the total sample and for each subsample, and for each of the years 1986, 1987, and 1988. The presence of influential variables, multicollinearity, and heteroskedasticity were tested by using the methodologies presented in Besley, Kuh, and Welch (1980). Prior normalization of the variables seems to be crucial in order to obtain a correct specification of the model. Without this transformation, variance inflation tests reveal a strong multicollinearity problem.

Step two: Estimation of the degrees of scale and scope economies

Using equations (5), (7), (8), (12) and (13), we calculated the degrees of scale and scope economies by product, by product pair, and by product group, for each year and for each group of firms. These equations require an approximation of the zero production level and, as mentioned above, calculations were replicated with the null values ϵ of 0.0001, 0.001, 0.01, 0.1, and 0.15. As shown in Kim (1986), the scale and scope coefficients seem to be highly sensitive to the value of ϵ . Furthermore, for a given ϵ , the choice of ϵ_0 also affects the value and the sign of the coefficients representing scale and scope economies. In fact, the sign and the magnitude of the coefficients representing scale and scope economies appear to be essentially a function of the value used to replace the null values in the data set when estimating the equations (5) to (13).

⁸ The value used in place of 0 in the data set for estimating the cost function is denoted ϵ_0 . ϵ is the value used to approximate zero production in equations (5) through (12).

This can explain in part the conflicting results offered by previous studies. As a result, it is extremely important to define confidence intervals around the indicators representing the presence of scale and scope economies.

Step three: Calculation of confidence interval

Fuller's (1962) approach was used to calculate the standard deviation of the main parameter estimates. These standard errors allow us to test the following hypotheses:

- The overall scale economies coefficient is significantly different from 1.
- The overall scope economies coefficient is significantly different from 0.
- Significant cost complementarities exist between products i and j .

These tests were replicated with different replacement values for null production. The conclusions drawn from these statistical tests do not seem to be affected by the choice of ϵ_0 and ϵ , even though this choice affects the value of the parameters. No definitive conclusion can be drawn, relative to the presence of scale and scope economies when a trans-logarithmic cost function is used, without performing statistical tests on the degrees of scale and scope economies represented by the estimation of the model.

5. Results

4.1. Estimation of the cost function

Table 1 shows the coefficients of the cost function estimated for 1986 using total costs and both measures of output. Since the results are very similar in terms of the signs and significance levels of the coefficients, we can conclude that the choice of the output measure seems to be unimportant to estimate the cost function.

Most of the coefficients are statistically significant and carry their expected sign. The control variable FORM was never significant, so the reported results exclude this variable. The coefficients of the level 1 terms are positive and statistically significant, except for the rental costs. Positive coefficients are as would be expected as they indicate a positive relationship between cost and output. The insignificant coefficient associated with the second input (rental cost) could be due to a less intensive use of this input when the unit rental cost is high.

The coefficients of the squared terms are positive and statistically significant. This implies that no linear form could be adapted to the description of the functional cost relationship. As economies of scale should not be constant, we use groups of firms of the remainder of this study.

The coefficients of the cross-product terms are generally significantly negative. This is a necessary (but not sufficient) condition for cost complementarities, which in turn is a sufficient condition for scope economies. The significance level of these terms implies that the cost process cannot be represented by separate cost functions.

Table 1
Coefficients of the translogarithmic cost functions,
by measure of output in 1986

	Claims as output Coefficients	T value	Premium income as output Coefficients	T value
Intercept	-1.139302	-12.287	-0.437913*	-8.830
ln(Y1)	0.400357*	10.016	0.401407*	12.644
ln(Y2)	0.317072*	9.436	0.383908*	17.606
ln(Y3)	0.083084	2.670	0.091417*	4.577
ln(Y4)	0.074193*	4.328	0.064343*	6.303
ln(W1)	1.025848*	5.670	0.992985*	9.430
ln(W2)	-0.025848	-0.143	0.007015	0.067
ln(Y1)*ln(Y1)	0.044590*	8.809	0.064334*	7.419
ln(Y1)*ln(Y2)	-0.009749*	-2.328	-0.044823*	-4.418
ln(Y1)*ln(Y3)	-0.001689	-0.322	-0.012534*	-1.545
ln(Y1)*ln(Y4)	-0.005487	-1.260	-0.010584*	-1.276
ln(Y2)*ln(Y2)	0.025840*	6.402	0.037391*	9.597
ln(Y2)*ln(Y3)	-0.009710	-1.467	-0.016097*	-2.271
ln(Y2)*ln(Y4)	-0.013312*	-2.478	-0.013516*	-3.008
ln(Y3)*ln(Y3)	0.012410*	2.650	0.012699*	3.189
ln(Y3)*ln(Y4)	-0.001281	-0.321	-0.003007	-0.645
ln(Y4)*ln(Y4)	0.011732*	3.203	0.008113*	3.514
ln(W1)*ln(W1)	-6.464700	-1.516	-1.700385	-0.609
ln(W2)*ln(W2)	-0.173845	-0.289	-0.310092*	-0.956
ln(W1)*ln(W2)	6.638545	1.442	2.010478	0.673
ln(Y1)*ln(W1)	0.434029	1.079	-0.184548	-0.382
ln(Y1)*ln(W2)	-0.170425*	-2.962	0.020597	0.245
ln(Y2)*ln(W1)	-0.495290	-1.122	0.105347	0.268
ln(Y2)*ln(W2)	0.034625	0.554	-0.043546*	-0.731
ln(Y3)*ln(W1)	0.784798	1.539	0.176069	0.547
ln(Y3)*ln(W2)	-0.060114	-1.158	-0.055893*	-1.376
ln(Y4)*ln(W1)	-0.481675	-1.770	-0.029508	-0.140
ln(Y4)*ln(W2)	-0.045947	-0.980	0.011482*	0.404
n:	161		178	
R-square:	0.9227		0.9696	
Adj. R-sqaure:	0.9091		0.9648	
Y1 = property		Y4 = other		
Y2 = automobile		W1 = salaries		
Y3 = liability		W2 = rental cost		

* significant at the 5 % level

Table 2 completes the description of the cost function for 1986, with a separate estimation of the function for each group of firms. The signs on the coefficients appear to be generally consistent with previous aggregated results, and are similar across groups. The

Table 2
Coefficients of the translogarithmic cost function,
by size group

	Small companies		Medium companies		Large companies	
	Coefficients	T values	Coefficients	T values	Coefficients	T values
Intercept	-1.658077	-5.520	-0.999158	-4.158	-0.363521	-2.222
ln(Y1)	0.444255*	5.214	0.365737*	4.364	-0.633920*	9.415
ln(Y2)	0.100751	1.229	0.358795*	3.196	0.361573*	5.169
ln(Y3)	0.010959	0.202	0.038929	0.548	0.023409	0.399
ln(Y4)	0.131841*	4.080	0.011039	0.260	0.076316	1.637
ln(W1)	0.586607	1.408	0.960759*	2.402	2.322359*	4.119
ln(W2)	0.413393	0.992	0.039241	0.098	-1.322359*	-2.345
ln(Y1)*ln(Y1)	0.052887*	2.972	0.049629*	3.864	0.051145*	3.514
ln(Y1)*ln(Y2)	-0.012245	-1.437	0.023288	0.618	-0.016759	-0.478
ln(Y1)*ln(Y3)	-0.017727	-1.488	0.004281	0.207	-0.064624	-1.147
ln(Y1)*ln(Y4)	-0.023958*	-2.141	0.000328	-0.033	-0.042306*	-1.263
ln(Y2)*ln(Y2)	0.008166	0.746	0.005271	-0.156	0.029547	5.643
ln(Y2)*ln(Y3)	0.016099	0.955	-0.001300	0.037	-0.064059	-1.472
ln(Y2)*ln(Y4)	-0.002539	-0.231	-0.013109	-0.396	0.013370	0.362
ln(Y3)*ln(Y3)	0.014412	1.108	0.008628	0.661	0.016522	1.114
ln(Y3)*ln(Y4)	-0.013936	-1.527	-0.006761	-0.795	0.002280	0.081
ln(Y4)*ln(Y4)	0.031962*	2.773	0.005401	0.509	-0.001048	-0.189
ln(W1)*ln(W1)	-4.719056	-0.429	4.143749	0.322	-10.746294	-1.544
ln(W2)*ln(W2)	1.186406	0.889	1.285232	0.925	-3.828883	-1.720
ln(W1)*ln(W2)	3.532651	0.298	-5.428981	-0.387	14.575177	2.313
ln(Y1)*ln(W1)	0.184363	0.254	0.679038	0.549	2.375461	1.176
ln(Y1)*ln(W2)	-0.248953	-1.891	0.078140	-0.481	0.122443	0.595
ln(Y2)*ln(W1)	0.151311	0.195	-0.172467	0.013	-1.021917	-0.602
ln(Y2)*ln(W2)	-0.191333	-1.146	0.140094	0.616	0.160139	0.776
ln(Y3)*ln(W1)	0.810499	0.935	-1.260370	-0.997	-1.698505	-0.831
ln(Y3)*ln(W2)	-0.257863*	-2.398	0.124765	0.982	-0.025051	-0.107
ln(Y4)*ln(W1)	-0.280346	-0.493	0.363841	0.424	-0.026885	-0.043
ln(Y4)*ln(W2)	0.167678	-1.509	-0.141695	-1.087	0.114416	1.466
n:	46		54		59	
R-square:	0.9221		0.8698		0.9273	
Adj. R-square:	0.8372		0.7656		0.8774	
Y1 = property			Y4 = other			
Y2 = automobile			W1 = salaries			
Y3 = liability			W2 = rental cost			

* significant at the 5% level

significance levels are lower because of the limited size of the sample, given the great number of coefficients to be estimated.

We obtained similar results for 1987 and 1988. These results are not reported here, since the presence of scale and scope economies is the main interest in this study.

Table 3
Economies of scale and economies of scope by size group
with claims as a measure of output
and standard errors of estimation
1986

	Small Companies	Medium Companies	Large Companies
Overall scale economies (standard error of estimation)	1.143 (0.152)	1.291 (0.113)*	0.931 (0.076)
Product-specific scale economies: SL_i			
1	1.380	1.391	1.158
2	1.526	1.584	1.465
3	1.763	1.659	0.429
4	1.758	1.000	2.142
Dual-product scale economies			
1 vs 2	1.072	1.087	0.879
1 vs 3	1.278	1.335	1.121
1 vs 4	1.287	1.364	1.095
2 vs 3	1.398	1.499	1.388
2 vs 4	1.409	1.550	1.385
3 vs 4	1.639	1.499	1.724
Overall scope economies (standard error of estimation)	0.054 (0.272)	0.076 (0.138)	-0.146 (0.153)
Dual-product scope economies			
1 vs 2, 3 and 4	-0.169	-0.109	-0.344*
2 vs 1, 3 and 4	-0.152	-0.114	-0.309*
3 vs 1, 2 and 4	0.054	0.145	0.095
4 vs 1, 2 and 3	0.067	0.187	-0.040
Cost complementarities (if negative) (standard error of estimation)			
1 vs 2	0.117* (0.048)	0.155* (0.036)	0.212* (0.023)
1 vs 3	0.032 (0.025)	0.019 (0.050)	-0.050 (0.022)
1 vs 4	0.024 (0.021)	0.004 (0.040)	0.006 (0.018)
2 vs 3	0.017 (0.048)	0.015 (0.046)	-0.056* (0.017)
2 vs 4	0.010 (0.024)	-0.009 (0.027)	-0.041 (0.013)
3 vs 4	0.005 (0.009)	-0.006 (0.028)*	-0.004 (0.010)

Table 4
Economies of scale and economies of scope by size group
with claims as a measure of output
and standard errors of estimation
1987

	Small Companies	Medium Companies	Large Companies
Overall scale economies (standard error of estimation)	1.786 (0.106)*	1.270 (0.095)*	0.976 (0.072)
Product-specific scale economies: <i>SL i</i>			
1	2.386	1.489	1.158
2	1.634	1.326	1.508
3	2.472	2.602	1.822
4	1.957	7.912	1.780
Dual-product scale economies			
1 vs 2	1.457	1.017	0.932
1 vs 3	2.328	1.482	1.083
1 vs 4	2.100	1.396	1.119
2 vs 3	1.618	1.317	1.364
2 vs 4	1.535	1.276	1.429
3 vs 4	2.004	1.830	1.703
Overall scope economies (standard error of estimation)	0.305 (0.219)	0.072 (0.171)	-0.108 (0.101)
Dual-product scope economies			
1 vs 2, 3 and 4	-0.002	-0.074	-0.256*
2 vs 1, 3 and 4	-0.016	-0.069	-0.228*
3 vs 1, 2 and 4	0.220	0.182	0.018
4 vs 1, 2 and 3	0.167	0.289	-0.066
Cost complementarities (if negative) (standard error of estimation)			
1 vs 2	0.194* (0.033)	0.079 (0.053)	0.051 (0.042)
1 vs 3	0.129 (0.027)*	0.057 (0.046)	0.075 (0.039)
1 vs 4	0.095 (0.025)*	-0.036 (0.039)	-0.018 (0.029)
2 vs 3	-0.087 (0.024)*	-0.005 (0.036)	0.007* (0.026)
2 vs 4	-0.035 (0.019)	0.018 (0.031)	0.025 (0.014)
3 vs 4	-0.058 (0.021)*	0.009 (0.017)*	0.012 (0.009)

Table 5
Economies of scale and economies of scope by size group
with claims as a measure of output
and standard errors of estimation
1988

	Small Companies	Medium Companies	Large Companies
Overall scale economies (standard error of estimation)	1.318 (0.145)*	1.473 (0.109)*	1.279 (0.088)*
Product-specific scale economies: <i>SL i</i>			
1	1.347	1.330	1.521
2	2.207	1.279	1.812
3	1.658	2.304	1.315
4	1.872	-5.498	2.005
Dual-product scale economies			
1 vs 2	1.185	1.167	1.239
1 vs 3	1.266	1.381	1.368
1 vs 4	1.289	1.320	1.383
2 vs 3	1.846	2.582	1.570
2 vs 4	1.921	2.256	1.594
3 vs 4	1.674	2.554	1.619
Overall scope economies (standard error of estimation)	0.109 (0.068)	0.023 (0.156)	0.171 (0.147)
Dual-product scope economies			
1 vs 2, 3 and 4	-0.126	-0.170	-0.147
2 vs 1, 3 and 4	-0.078	-0.171	-0.125
3 vs 1, 2 and 4	0.108	0.265	0.105
4 vs 1, 2 and 3	0.117	0.178	0.012
Cost complementarities (if negative) (standard error of estimation)			
1 vs 2	0.128* (0.028)	0.255* (0.059)	0.134* (0.021)
1 vs 3	0.012 (0.019)*	-0.007 (0.041)	-0.050 (0.027)
1 vs 4	-0.009 (0.019)	0.024 (0.031)	0.042 (0.024)
2 vs 3	0.034 (0.014)*	-0.081 (0.039)*	-0.003 (0.017)
2 vs 4	-0.009 (0.014)	-0.015 (0.032)	-0.001 (0.021)
3 vs 4	0.002 (0.003)	-0.025 (0.016)*	-0.010 (0.015)

4.2. *Economies of scale*

The two first lines of tables 3 to 5 show us the degree of overall scale economies, as calculated with equation (5), and the standard error of estimation of this coefficient. These results are presented for each year and for each group, along with significance tests. To calculate the significance of the estimated coefficients, t values at $\alpha = 0.05$ for 25 to 40 degrees of freedom were used. The degrees of freedom were given by the number of observations (anywhere from 51 to 66) minus the number of estimated parameters (26).

We observe statistically significant scale economies for each year for medium-sized companies. Scale economies are present for small firms in only 1987 and for large ones in only 1988. For these groups, no definitive conclusion can be drawn from these results because of the instability of the overall scale economies coefficient. We can conclude that there exist significant overall economies of scale only for medium-sized insurance companies.

Positive coefficients on the degrees of product-specific and dual-product economies of scale indicate that increasing one activity can generally be profitable for the firm. This is true only if this operation does not affect the other product lines. These coefficients are similar for each year.

5.3. *Economies of scope*

Tables 3 to 5 indicates that there are no overall economies of scope in the Canadian property/casualty insurance industry. The large size of the standard errors of estimation seems to explain the lack of significant scope economies. These large standard errors could not be avoided since it was necessary to estimate a very large number of parameters. The coefficient is negative in 1986 and 1987 for large firms. This could imply that large undiversified firms hold a cost advantage relative to multiproduct companies.

The cost complementarities tests confirm the absence of scope economies. Of particular interest is the cost complementarity between products 1 and 2 (property and automobile). This coefficient is positive and statistically significant for the three groups in 1986 and 1988. It becomes insignificant, although positive, in 1987 for medium and large firms. Such a result can be observed if the insurance market is characterised by economies of specialization. Single-product insurance companies appear to perform better than dual-product companies. Significant cost complementarities could be observed for large firms only in 1986 and for medium and small firms only in 1987. In each case, adding the third line of insurance, liability, leads to cost complementarities. The automatic link between property and liability insurance (particularly for housing insurance) could explain this result.

Dual-product scope economies are generally negative for the two main product lines. This indicates diseconomies of scope between property and automobile insurance. This is particularly true for large firms, for which the coefficients representing dual-product scope economies are significantly negative in 1986 and 1987.

5.4. *Economies of production and the choice of output measure*

Table 6 is analogous to Table 4, but the cost function is estimated with net premium income as the measure of output in Table 6. Total cost includes operating expenses, claims, and adjustment expenses. The results are similar to those presented in Table 4, except for the overall scope economies coefficient for large firms, which is significantly positive. This

Table 6
Economies of scale and economies of scope by size group
with net premium income as the measure of output
and standard errors of estimation
1987

	Small Companies	Medium Companies	Large Companies
Overall scale economies (standard error of estimation)	1.294 (0.261)	1.419 (0.217)	1.022 (0.035)
Product-specific scale economies : SL_i			
1	1.417	1.396	1.354
2	2.000	1.612	1.270
3	1.813	1.307	-0.981
4	2.054	1.884	1.906
Dual-product scale economies			
1 vs 2	1.302	1.155	0.957
1 vs 3	1.124	1.290	1.035
1 vs 4	1.578	1.374	1.282
2 vs 3	1.662	1.457	1.001
2 vs 4	-1.283	1.567	1.208
3 vs 4	2.132	1.423	0.474
Overall scope economies (standard error of estimation)	-0.183 (0.497)	0.260 (0.229)	0.210 (0.084)
Dual-product scope economies			
1 vs 2, 3 and 4	-0.194	0.005	-0.110
2 vs 1, 3 and 4	-0.000	-0.004	-0.112
3 vs 1, 2 and 4	-0.192	0.191	0.263
4 vs 1, 2 and 3	0.268	0.217	0.087
Cost complementarities (if negative) (standard error of estimation)			
1 vs 2	0.189 (0.067)	0.088 (0.050)	0.091 (0.035)
1 vs 3	0.103 (0.158)	0.089 (0.064)	-0.086 (0.031)
1 vs 4	-0.031 (0.150)	0.025 (0.023)	0.078 (0.019)
2 vs 3	-0.010 (0.065)	-0.052 (0.042)	-0.010 (0.028)
2 vs 4	-0.061 (0.038)	-0.046 (0.047)	0.000 (0.015)
3 vs 4	0.018 (0.055)	-0.027 (0.016)	-0.023 (0.012)

result is puzzling because the dual-product scope economies coefficients are negative for the two main product lines, and we observe only one significantly negative cost complementarity between lines 1 and 4. We obtain similar conclusions by comparing the two sets of results for 1986 and 1988.

One could conclude from these results that, when analyzing the cost function's characteristics, the correct evaluation of the significance level of the various measures of scale and scope economies is more relevant than the choice of the output measure.

6. Conclusion

The main objective of this research is the measure of economies of scope and economies of scale in the Canadian property/casualty insurance industry. Using data for the years 1986 to 1988, we show that there exists significant economies of scale for insurance companies with assets between \$ 40 and \$ 100 million. However, the evidence in favour of the existence of economies of scale for smaller and larger firms are limited to one year in each case.

We do not observe systematic evidence of significant cost complementarities between insurance products, nor do we note significant economies of scope. No cost complementarities exist between the two main product lines of property/casualty and automobile. Furthermore, there is some evidence of diseconomies of scope. Diversification economies can only be obtained with liability and other product lines.

Our study also has some important implications on a methodological level. In fact, we observe that, when analyzing the cost function's characteristics, the correct evaluation of the significance level of the various measures of scale and scope economies is more relevant than the choice of the input measure.

The lack of significance tests for the existence of scale and scope economies in previous studies preclude any comparison of our empirical results with those in the past research.

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