Southern Business Review

Volume 22 | Issue 2 Article 4

October 1996

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INTRODUCTION

A number of studies have examined economies of scale in the property-liability insurance industry (see Geheen, 1986 for a survey). Since output is used as the measure of scale within this literature, the proper specification and measurement of insurer output is crucial in investigating economies of scale. However, no general consensus regarding the appropriate measurement of insurer output has emerged in the literature.[1] The lack of agreement is reflected in the diversity of the output measures used in past studies. For example, previous researchers have employed premiums written (Cummins and VanDerhei, 1979; Barrese and Nelson, 1992), premiums earned (Johnson, Flanigan and Weisbart, 1981), claims paid (Doherty, 1981; Skogh, 1982), and losses incurred (Cummins and Weiss, 1993) as measures of insurance output.

Each of these alternative measures has serious shortcomings when used as a proxy for the quantity of services provided by an insurance firm. The use of premiums (written or earned) is equivalent to measuring output by total sales revenue, a measure that depends upon the firm's pricing policy. If product prices vary systematically with insurer size, then the use of premium income as a proxy for output can result in biased estimation of the relationship between costs and the scale of production. Claims payments serve as a proxy for the risk bearing services provided by the insurer, but claims paid or incurred do not adequately represent other services such as loss settlement services and intermediation services that are also provided as part of the insurer's output.

Since the choice of output measure can influence the empirical results concerning economies of scale, the proper measurement of output remains a critical unsettled issue in insurance cost research. In a survey of the insurance cost literature, Geehan concluded that "the determination of an appropriate measure of output constitutes the single most important problem for research in this area," (1986, p. 139).

This paper directly addresses the unresolved issue of output measurement by employing a "revenue-restricted" cost function in the estimation of costs in the property-liability insurance industry. Theoretically, the revenue-restricted cost function is derived by minimizing the cost of producing a specified level of *total revenue*, given technology and input and output prices (Shephard, 1974). Since the revenue-restricted cost function employs total revenue rather than output as a measure of overall scale, its application to the insurance industry offers a theoretically correct method of sidestepping the controversy surrounding the measurement of insurance output. Although this approach avoids the need to measure insurance output, the use of a revenue-restricted cost function does require appropriate measures of product price. Fortunately, the available proxies for insurance price are much less controversial than are the available proxies for insurance output. Shaffer (1994) has estimated a revenue-restricted cost function for a sample of large commercial banks.

Recent studies of insurer costs have explicitly recognized the multiproduct character of the typical insurance firm (Cummins and Weiss, 1993; Hanweck and Hogan, 1996). The revenue-restricted cost function offers an additional advantage for the study of scale economies in the context of multiproduct production. The usual measure of overall economies of scale is based on the summation of the partial elasticities of cost with respect to each of the separate outputs, implying that the production of all outputs is expanded in the same proportion as firm scale increases. If the optimal output mix changes as firms grow in size (the expansion path in output space is nonlinear), then this measure may understate the actual cost economies associated with larger scale. Since the revenue-restricted cost function assumes that firms choose an optimal mix of both outputs and inputs at any given scale, the approach taken in the present paper avoids this source of potential estimation bias. A potential drawback of the present approach, however, is the inability to estimate economies of scope since output quantities are not included in the analysis.

The paper is organized as follows: review of the results of previous property-liability insurance cost studies regarding economies of scale; presentation of the revenue-restricted cost function; discussion of the model and data used in the empirical analysis; presentation of the results; and conclusion.

PREVIOUS STUDIES

Previous cost studies of the property-liability insurance industry have reported conflicting evidence regarding the presence of economies of scale. The majority of these studies have estimated a single product cost function having the Cobb-Douglas functional form. Allen (1974), Cummins (1977), Cummins and VanDerhei (1979), and Johnson, Flanigan and Weisbart (1981) used a premiums-based measure as the proxy for output in their analyses. Allen found evidence of economies of scale for small-sized insurers, but not for medium- and large-sized insurers. In contrast, Johnson, Flanigan and Weisbart reported significant diseconomies of scale for small- and medium-sized insurers and significant economies of scale for large insurers. Cummins found no evidence of economies of scale in his study, while Cummins and VanDerhei reported moderate scale economies among insurers in their sample.

Doherty (1981) and Skogh (1982) use a claims-based measure as the proxy for output in their studies of insurer costs. Doherty finds evidence of significant economies of scale in the Canadian property-liability insurance industry. Similarly, Skogh detects strong economies of scale in the Swedish property-liability insurance industry. Although Doherty and Skogh argue that a claims-based measure is theoretically superior to a premiums-based measure of insurance output, they also estimated economies of scale using a premiums-based output measure. Both authors found that the use of premiums as the proxy for output resulted in smaller estimates of scale economies.

More recently, Barrese and Nelson (1992) also employed alternative measures of output in their cost study. When premiums were used as the output proxy, they found no evidence of economies of scale. In contrast, they found significant economies of scale when losses were used as the proxy for output. Cummins and Weiss (1993) estimated a multiproduct cost function for property-liability insurers. Their results suggest that economies of scale exist for small- and medium-sized firms, while diseconomies of scale prevail for large firms. Using a premiums based measure of insurer output, Hanweck and Hogan (1996) also estimated a multiproduct cost function for property-liability insurers. They found significant economies of scale for small firms and diseconomies of scale for the largest firms in the industry. In view of the mixed evidence on economies of scale in the property-liability insurance industry, further empirical study seems warranted.[2]

THE REVENUE-RESTRICTED COST FUNCTION

The standard cost function provides a theoretical framework for previous insurance cost studies. This cost function is derived by minimizing the cost of producing a specified output mix, given the input prices. Formally, the standard cost function, C(q, w), is derived from the solution to the problem

$$C(q,w) \equiv \min_x w \cdot x \quad \text{subject to} \quad T(q,x) = 0 \tag{1}$$

where q is a vector of outputs, w is a vector of input prices, x is a vector of inputs, and $T(q, x)$ is the transformation function that characterizes the firm's technology. Thus, this cost function describes the minimum expenditure required to produce a given output mix at given input prices. Since the optimization is conditional on the output vector q, the standard cost function is known as the "output-restricted" form of the cost function.

The alternative "revenue-restricted" form of the cost function gives the minimum expenditure required to produce a given level of total revenue at given output and input prices (Shephard, 1974; Brown and Chachere, 1986). This form of the cost function is defined by the solution to the problem

$$C(R,p,w) \equiv \min_{x,q} w \cdot x \quad \text{subject to} \quad p \cdot q - R = 0 \quad \text{and} \quad T(q,x) = 0 \tag{2}$$

where R denotes total revenue and p is a vector of output prices. Conceptually, the revenue-restricted cost function can be obtained in a two-stage procedure. In the first stage, the standard cost function is obtained. In the second stage, the revenue-restricted cost function is obtained as the solution to the problem

$$C(R,p,w) \equiv \min_q C(q,p,w) \quad \text{subject to} \quad p \cdot q - R = 0\,. \tag{3}$$

Thus, the revenue-restricted cost function describes the cost of the optimal (cost-minimizing) output mix that is capable of generating a pre-specified level of revenue.[3] The revenue-restricted cost function provides a more general framework than the standard cost function for the estimation of multiproduct economies of scale. If the optimal output mix changes as firm size increases (the output expansion path is nonlinear), then the standard cost approach that measures multiproduct economies of scale along a ray in output space (implicitly assuming a linear output expansion path) will understate the cost economies associated with larger scale. Since the revenue-restricted cost function explicitly accounts for changes in the output mix as firm size increases, it avoids this potential source of bias in the estimation scale economies.

The revenue-restricted cost function $C(R, p, w)$ satisfies certain monotonicity and homogeneity conditions (Shephard, 1974). Like the standard cost function, the revenue-restricted cost function is an increasing function of input prices as well as homogeneous of degree one in the input prices. In addition, the revenue restricted cost function is increasing in total revenue, decreasing in output prices, and homogeneous of degree zero in revenue and the output prices.

EMPIRICAL MODEL AND DATA

The authors utilize a translog functional form in the estimation of the revenue-restricted cost function, $C(R, p, w)$. The translog function is a standard flexible functional form that can be interpreted as a first-order approximation to a general revenue-restricted cost function. This form of the cost function does not restrict the cost function to constant elasticity of scale. The model includes six output prices and one input price as well as dummy variables for organizational form, distribution system, and year. The cost function can be written as:

$$\ln C = \alpha_0 + \alpha_R \ln R + \sum \alpha_i \ln p_i + \alpha_w \ln w + \frac{1}{2}\beta_{RR}(\ln R)^2 + \sum_{i=1}^{6} \beta_{Ri} \ln R \ln p_i + \frac{1}{2}\sum \sum \beta_{ij} \ln p_i \ln p_j + \frac{1}{2}\beta_{ww}(\ln w)^2 + \gamma_{Rw} \ln R \ln w + \sum \gamma_{iw} \ln p_i \ln w + \sum \delta_k D_k + \varepsilon \tag{4}$$

where ln is a logarithmic transformation, $\beta_{ij} - \beta_{ji} (I \neq j)$ by the assumption of symmetry, and where:

C	-	total costs (underwriting expenses incurred; loss adjustment expenses incurred; or underwriting plus loss adjustment expenses incurred)
R	-	net premiums written
p_1	-	price of Homeowners insurance
p_2	-	price of Commercial Multiple Peril insurance
p_3	=	price of Workers' Compensation insurance
p_4	=	price of Auto Liability insurance
p_5	=	price of Auto Physical Damage insurance
p_6	=	price of Other Liability insurance
w	=	price of labor
D_1	=	1 for stock companies and 0 otherwise
D_2	=	1 for independent agency companies and 0 otherwise
D_3	=	1 for exclusive agency companies and 0 otherwise
D_4	=	1 for year 1989 and 0 otherwise
D_5	=	1 for year 1990 and 0 otherwise
D_6	=	1 for year 1991 and 0 otherwise
ϵ	-	an error term

A stock-mutual dummy variable was included to account for possible differences in cost structures resulting from differences in the severity of the standard agency conflict between owners and managers. Two additional dummy variables were included to allow for possible cost differences attributable to alternative marketing systems. The first is specified to account for distribution through the independent agency system, while the second is introduced to account for utilization of exclusive agency marketing systems. The remaining companies in the sample are salaried representative companies and other direct sales companies such as mail order. The year dummy variables were included to reflect temporal effects that were common to all insurers and to take account of yearly effects that may be present because costs and prices were recorded as nominal values.

The theoretical requirement that the revenue-restricted cost function is homogeneous of degree zero in revenue and the output prices requires the following parameter restrictions:[4]

$$\alpha_R + \sum \alpha_i = 0 \tag{5}$$

$$\gamma_{Rw} + \sum \gamma_{iw} = 0 \tag{6}$$

$$\beta_{Rj} + \sum \beta_{ij} = 0 \qquad \text{for each } j \tag{7}$$

$$\beta_{RR} + \sum \beta_{Ri} = 0. \tag{8}$$

An appropriate local measure of economies of scale is the elasticity of cost with respect to revenue, $S \equiv \partial \ln C / \partial \ln R$. This elasticity measures the proportional increase in total cost that accompanies a proportional increase in total revenue, keeping prices, organizational form, and distribution system unchanged. It is important to emphasize that this elasticity of cost with respect to scale implicitly accounts for the effect of a change in insurer size on the optimal output mix. Thus, this measure is appropriate for accurately predicting changes in cost that accompany changes in insurer size, regardless of how changes in size affect the product mix.[5] A value of S less (greater) than one implies the existence of economies (diseconomies) of scale. A flexible functional form such as the translog function does not impose any a priori restriction on the elasticities of the function. For the translog cost function in equation (4), the scale elasticity is given by

$$S = \alpha_R + \beta_{RR} \ln R + \sum \beta_{Ri} \ln p_i + \gamma_{Rw} \ln w \tag{9}$$

Since the scale elasticity is a function of revenue (as well as the output and input prices), the value of S at different firm sizes is estimated.

Many previous researchers have implemented empirical tests of economies of scale in insurance by estimating a cost function in which total premium revenue serves as the output measure. The theory of the revenue-restricted cost function suggests that the estimating equation used by these researchers is misspecified since the output prices are not included in the analysis. The authors' results can be seen as correcting this omission.

The data used in this study are obtained from the National Association of Insurance Commissioners data tapes of annual reports of property-liability insurers for the years 1988 through 1991. The estimation of a revenue-restricted cost function requires information on the output prices. The output price is unobserved when an insurer chooses not to produce a particular product.[6] Consequently, a subset of companies was selected for which premiums written was positive in each of six major insurance lines: homeowners, commercial multiple peril, workers' compensation, auto liability, auto physical damage, and other liability. Companies that had no business in any one of these six lines were excluded from the sample since the approach used in this paper requires measures of output price. The accuracy of the data for each variable was examined and some firms were dropped from the sample because of inconsistencies in the recorded data. Records with unusual values were also eliminated from the sample. The resulting sample comprises a total of 886 observations for the four year period. The companies in this sample receive over 80 percent of their total revenue from business in these six major lines. The mean value of annual net premiums written by firms in the sample is approximately $300 million, while the median value is approximately $72 million.

Total costs, C, are specified as underwriting expenses incurred plus loss adjustment expenses incurred. Prices for each insurance line are measured by earned premiums divided by incurred losses (revenue per dollar of coverage).[7] Larger values of this proxy indicate higher output prices. For each insurer, the price of labor is computed as the weighted average of the statewide annual salaries for property and casualty employees reported by the Bureau of Labor Statistics. The weights are the proportions of the insurer's total premiums accounted for by each state. The authors have not included the prices of financial or physical capital in the analysis due to data availability problems. The only available measure of the price of physical capital is based on the book value of buildings and equipment and is not an adequate proxy for the cost of physical capital since book values do not represent true rental costs.

All of the nondichotomous right-hand side variables were normalized to equal 1 at the median value of the sample. This normalization procedure is equivalent to taking the sample median as the point of approximation of the true cost function by the translog function.

EMPIRICAL RESULTS

The revenue-restricted cost function (4) was estimated by ordinary least squares with the homogeneity restrictions (5)-(8) imposed on the estimation. Table 1 presents the parameter estimates together with the corresponding t-statistics. All of the estimated linear coefficients of the output prices have the theoretically correct negative sign, and five of the six coefficients are significantly different from zero at the 1 percent confidence level. In addition, the linear coefficient of the wage variable is positive, as predicted by theory, and significant at the 1 percent level.[8]

The estimated scale elasticities are presented in Table 2. As a flexible functional form, the translog cost function allows the scale elasticity to depend on prices as well as the revenue level. The authors report estimates of the scale elasticity where output prices and the wage rate are held fixed at their median values and R is chosen to correspond to the 25, 50 and 75 percentile levels observed in the sample. These points can be interpreted as representative of "small," "medium," and "large" firms, respectively. In all three cases, the null hypothesis of constant returns to scale, $H_0{:}S = 1$, and is rejected at the one percent significance level. Since all of the estimated values of the scale elasticity are less than one, the estimated cost function displays statistically significant economies of scale for the three size groups observed in the sample. These results imply that even large insurers have not exploited the potential economies of scale that exist in the property-liability insurance industry. This result contrasts with that of Cummins and Weiss (1993) who find that the largest insurers are operating in the region of diseconomies of scale.

TABLE 1
PARAMETER ESTIMATES OF THE TRANSLOG REVENUE RESTRICTED COST FUNCTION

Parameter	Estimate	t-statistic	Parameter	Estimate	t-statistic
α_0	3.3165	115.1	β_{26}	-0.06548	-1.927
α_R	0.97452	236.0	β_{33}	-0.02371	-0.411
α_1	-0.19367	-5.663	β_{34}	0.06570	0.596
α_2	-0.08462	-3.351	β_{35}	-0.16244	-1.331
α_3	-0.15742	-6.042	β_{36}	0.03791	1.108
α_4	-0.26136	-6.333	β_{44}	0.40400	2.546
α_5	-0.26116	-6.959	β_{45}	-0.44312	-2.597
α_6	-0.01628	-1.201	β_{46}	0.13422	2.289
α_w	0.54249	5.597	β_{55}	0.72288	3.942
β_{RR}	-0.00363	-1.086	β_{56}	-0.10445	-1.591
β_{R1}	0.05135	2.640	β_{66}	-0.03706	-1.223
β_{R2}	0.02223	1.519	β_{ww}	-0.48393	-0.518
β_{R3}	-0.03410	-2.318	γ_{Rw}	0.17044	3.464
β_{R4}	-0.05318	-2.264	γ_{1w}	-0.08739	-0.284
β_{R5}	0.03840	1.703	γ_{2w}	-0.38557	-1.671
β_{R6}	-0.02107	-2.443	γ_{3w}	0.24498	0.996
β_{11}	-0.07239	-0.684	γ_{4w}	0.59404	1.646
β_{12}	-0.02027	-0.212	γ_{5w}	-0.49145	-1.267
β_{13}	0.11231	1.219	γ_{6w}	-0.04504	-0.318
β_{14}	-0.14443	-1.049	D_1	-0.02742	-1.965
β_{15}	0.01751	0.157	D_2	0.21155	10.11
β_{16}	0.05591	0.882	D_3	-0.02120	-0.639
β_{22}	0.10114	2.001	D_4	-0.10978	-4.910
β_{23}	0.00434	0.076	D_5	-0.10384	-4.044
β_{24}	0.03682	0.412	D_6	-0.05413	-2.779
β_{25}	-0.07878	-0.648			

TABLE 2
ESTIMATED SCALE ELASTICITIES, WHOLE SAMPLE

Percentile Evaluation Point	Estimated S	Standard Error	t-statistic $H_0: S = 1$
Total Expenses			
25%	0.9782	0.005985	-3.635
50%	0.9745	0.004129	-6.170
75%	0.9701	0.005001	-5.969
Underwriting Expenses			
25%	0.9720	0.008906	-3.139
50%	0.9679	0.006145	-5.226
75%	0.9630	0.007442	-4.971
Loss Adjustment Expenses			
25%	0.9936	0.008926	-0.712
50%	0.9969	0.006159	-0.499
75%	1.0008	0.007458	0.105

The estimate of the scale elasticity at the median insurer size (0.9745) is comparable to that obtained by Shaffer (1994) for large U.S. banks. Although the scale elasticity is near one, the implied scale effects can nevertheless result in substantial differences in average costs over a sufficiently wide range of insurer sizes.

The effect of the wage rate on the scale elasticity, $\partial S/\partial w = \gamma_{Rw}$, is positive and significant. Thus, higher wage firms have higher values of S, if all else is constant. For example, the estimated parameter value $\gamma_{Rw} = 0.1704$ implies that a wage rate that is 20 percent above the sample median increases the scale elasticity by $0.1704(\ln 1.20) = 0.0311$. The effects of the product prices on the scale elasticity, $\partial S/\partial p_i = \beta_{Ri}$, are also generally statistically significant. However, since the coefficients are small in absolute size and of mixed signs, the overall effect of product prices on S is minor. For example, product prices that are 20 percent above the sample median will serve to decrease the scale elasticity by $\Sigma^6_{i=1}\beta_{Ri} \bullet (\ln 1.2) = 0.00363(\ln 1.2) = 0.00065$. Thus, the effects of product prices on economies of scale can be safely ignored.

In order to investigate the source of the economies of scale, the authors also estimated a partial cost function in which underwriting expenses incurred and loss adjustment expenses incurred were used as dependent variables in separate regressions.[9] The results of the test of economies of scale in underwriting and in loss adjustment for the full sample are shown in Table 2. The results indicate that statistically significant economies of scale are present at all size levels in underwriting services but not in loss adjustment services. A partial explanation for the absence of economies of scale in loss adjustment expenses is that small insurers frequently purchase loss adjustment services from large firms that specialize in providing loss adjustment services to their subscribers. This arrangement affords smaller insurers the opportunity to realize cost savings arising from economies of scale in the provision of loss adjustment services.

The translog cost function can be interpreted as a local approximation to some "true" underlying cost function. However, a local approximation may not adequately represent the global behavior of insurer costs. In order to explore this possibility, the authors estimated separate cost functions for two subsets of the data. One subset consisted of "large" insurers with written premiums exceeding the median value in the sample as a whole, while the other subset consisted of "small" insurers with written premiums below the median. Thus, the median size in the small group corresponds to the 25 percentile point in the whole sample while the median size in the large group corresponds to the 75 percentile point in the whole sample. Table 3 reports the scale elasticities for the "small" and "large" firms with revenue and prices evaluated at the median for the respective subsamples.[10] The estimated cost function for the smaller firms displays statistically significant economies of scale for total cost as well as for underwriting and loss adjustment services. For larger insurers, statistically significant scale economies are present in the provision of underwriting services, but not in loss adjustment services or in total expenses. These results are broadly similar to those obtained by Cummins and Weiss (1993) who estimated standard multiproduct translog cost functions for three size groups. They found that economies of scale are present for small- and medium-sized insurers but that mild diseconomies of scale prevail for large insurers. The estimates in Table 3 imply that fitting the same translog cost function to data on both large and small insurers results in underestimates of economies of scale for small insurers and overestimates of economies of scale for large insurers.

TABLE 3
ESTIMATED SCALE ELASTICITIES, SMALL AND LARGE FIRMS

	Estimated S	Standard Error	t-statistic $H_0 : S = 1$
Total Expenses			
Small Firms	0.9365	0.01597	-3.976
Large Firms	0.9857	0.01035	-1.384
Underwriting Expenses			
Small Firms	0.9285	0.02863	-2.497
Large Firms	0.9750	0.01035	-2.418
Loss Adjustment Expenses			
Small Firms	0.9358	0.02159	-2.974
Large Firms	1.0182	0.01774	1.026

An important byproduct of this study is evidence concerning the effects on costs of differences in organizational form and marketing system. For the full sample of firms, the coefficient of the stock dummy variable is negative and significantly different from zero. This finding supports the notion that stock companies will be more cost efficient than mutual companies. The coefficient of the independent agency variable is significantly positive. Thus, companies that market through independent agents appear to have higher costs than companies that market their product through exclusive agents or on a non-commission basis, confirming the results of previous studies (Cummins and VanDerhei, 1979; Barrese and Nelson, 1992; Flanigan, Winkler and Johnson, 1993). The coefficient of the exclusive agency variable is negative but insignificant. Finally, the time dummies for the years 1989, 1990, and 1991 are all negative and significant, indicating a general downward trend in costs for all property-liability insurers. This trend may have been associated with technological advances as well as improvements in firm efficiency stimulated by a competitive market environment.

CONCLUSION

This paper has applied a revenue-restricted multiproduct cost function in the analysis of economies of scale in the property-liability insurance industry. The approach offers a theoretically correct method of sidestepping the controversy surrounding the measurement of insurance output. An important feature of the estimated cost structure is the existence of economies of scale for a wide range of company sizes, including the largest firms in this sample.

This analysis suggests that potential cost savings are associated with mergers among even large insurers. This incentive to attain greater scale augments the mounting pressure on property-liability insurers to consolidate in order to bolster their financial strength in the face of large natural catastrophes and environmental losses. Offsetting the efficiency consequences of merger activity are potential inefficiencies associated with increases in market power.

ENDNOTES

[1] For general discussions of output measurement see Geheen (1986), O'Brien (1991) and Cummins and Weiss (1993).

[2] Several recent studies have also examined scale economies for the property-liability insurance industry in Italy (Eisen, 1991), France (Fecher, Perelman, and Pesticau, 1991) and Canada (Suret, 1991).

[3] Note that a profit maximizing firm necessarily produces its chosen revenue level at least cost, so that the revenue-restricted cost function is implied by the assumption of profit maximization.

[4] The homogeneity restriction for input prices is ignored in the estimation since only one input price was included.

[5] In a multiproduct cost function approach, global economies of scale are usually assessed by assuming that all outputs are increased in the same proportion as firm size grows. The authors' approach avoids this restriction, and thus, is more useful for accurately predicting the actual effects of firm size on costs.

[6]It is not legitimate to use a zero price in place of the unobserved price. The correct price is the price that would be observed if the firm chose to sell the product.

[7] Braeutigam and Pauly (1986) and Doherty and Kang (1988) have used this measure of insurance price. It would be desirable to adjust the price measure to differentiate long-tail liability lines from short-tail property lines. A fund-generating coefficient (reserves divided by earned premiums) can be used for the price adjustment. However, the adjustment is not included in this study because the effects are expected to be minor.

[8]The linear coefficients of the output and input price variables correspond to the elasticities of cost with respect to price, evaluated at the median values of all variables in the sample.

[9]Note that estimating a partial cost function implies a specification error unless the cost function is strongly separable.

[10] A test of the restriction of identical cost functions for the two size groups was rejected at the 1% level.

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