

---

Financial  
Institutions  
Center

*The Coexistence of Multiple  
Distribution Systems for Financial  
Services: The Case of Property-  
Liability Insurance*

by  
Allen N. Berger  
J. David Cummins  
Mary A. Weiss

95-13

## THE WHARTON FINANCIAL INSTITUTIONS CENTER

The Wharton Financial Institutions Center provides a multi-disciplinary research approach to the problems and opportunities facing the financial services industry in its search for competitive excellence. The Center's research focuses on the issues related to managing risk at the firm level as well as ways to improve productivity and performance.

The Center fosters the development of a community of faculty, visiting scholars and Ph.D. candidates whose research interests complement and support the mission of the Center. The Center works closely with industry executives and practitioners to ensure that its research is informed by the operating realities and competitive demands facing industry participants as they pursue competitive excellence.

Copies of the working papers summarized here are available from the Center. If you would like to learn more about the Center or become a member of our research community, please let us know of your interest.

Anthony M. Santomero  
Director

*The Working Paper Series is made possible by a generous  
grant from the Alfred P. Sloan Foundation*

The Coexistence of Multiple Distribution Systems for Financial Services:  
The Case of Property-Liability Insurance <sup>1</sup>

Draft: March 31, 1995

Abstract: Property-liability insurance is distributed by independent agents, who represent several insurers, and exclusive agents, who represent only one insurer. The independent agency system is known to have higher costs than the exclusive agency system. The *market imperfections hypothesis* attributes the coexistence of the two systems to impediments to competition, while the *product quality hypothesis* holds that independent agents provide higher quality services. We measure both *profit efficiency* and *cost efficiency* for a sample of property-liability insurers and find strong support for the product quality hypothesis. The data are consistent with a higher quality of output for independent agency insurers that is rewarded with additional revenues.

---

<sup>1</sup>Allen N. Berger is at the Board of Governors of the Federal Reserve System, Washington, DC 20551, and the Wharton Financial Institutions Center, Philadelphia, PA 19104. J. David Cummins is at the Wharton School of the University of Pennsylvania, Philadelphia, PA 19104. Mary A. Weiss is at Temple University and the Wharton School of the University of Pennsylvania, Philadelphia, PA 19104.

The opinions expressed do not necessarily reflect those of the Board of Governors or its staff. The authors thank Dwight Jaffee and the other participants in the National Bureau of Economic Research Property-Liability Insurance Seminar for helpful comments. The authors acknowledge the capable research assistance of Jalal Akhavein.

# The Coexistence of Multiple Distribution Systems for Financial Services: The Case of Property-Liability Insurance

## **I. Introduction**

Economic theory predicts that in long-run competitive equilibrium, the price of a good or service will equal the minimum average costs associated with the most efficient production technology -- firms that have inefficient technologies and higher average costs will not survive. The coexistence over long periods of time of alternative technologies performing the same function thus poses an interesting economic puzzle. Prominent examples are alternative distribution systems for the same or similar financial service, such as full-service and discount brokers for performing securities trading, automatic teller machines (ATMs) and human tellers for distributing cash, and banks, savings and loans, and credit unions for delivering depository services.

This paper focuses on a particularly interesting case of financial services distribution, the property-liability insurance industry. Property-liability insurance is distributed by two different types of firms, those that distribute their product through independent agents, who represent more than one insurer, and direct writing insurers that distribute insurance through exclusive agents, who represent only one insurer. These systems have long interested researchers because independent agents have played an important role in insurance markets over many decades even though they are known to have higher costs (e.g., Joskow, 1973, Cummins and VanDerhei, 1979, and Pauly, Kleindorfer, and Kunreuther, 1986, Kim, Mayers, and Smith, 1994). The purpose of this paper is to analyze the reasons for the long-term coexistence of the independent agency and direct writing distribution systems.

Two primary hypotheses have been advanced to explain the coexistence of independent and exclusive agents. According to the *market imperfections hypothesis*, firms that use independent agents survive while providing essentially the same services as firms using exclusive agents because of market imperfections such as price regulation (Joskow, 1973, Cummins and VanDerhei, 1979, Weiss, 1990), slow diffusion of information in insurance markets (Berger, Kleindorfer, and Kunreuther, 1989), or search costs that permit inefficient firms to survive alongside efficient firms (Dahlby and West, 1986). Under the market imperfections hypothesis, efficient firms are expected to earn super-normal risk-adjusted profits, while inefficient firms will

earn risk-adjusted profits closer to normal levels. In contrast, according to the *product quality hypothesis*, the higher costs of independent agents represent unobserved differences in product quality or service intensity, such as providing additional customer assistance with claims settlement, offering a greater variety of product choices, and reducing policyholder search costs (Kim, Mayers, and Smith, 1994, Pauly, Kleindorfer, and Kunreuther 1986). This hypothesis predicts normal risk-adjusted profits for both independent and exclusive agency firms.

The product quality hypothesis implies that firms are sorted into product quality or service-intensity market niches, with customers who prefer higher quality paying more for the product. The higher prices received by the higher-quality providers cover their extra production costs, allowing these firms to survive in equilibrium. This rationale is broad enough to encompass agency-theoretic explanations for the existence of alternative technologies (e.g., Mayers and Smith, 1981, Kim, Mayers, and Smith, 1994). For example, principal-agent problems such as company/buyer incentive conflicts may be more important to some buyers or for some product variants, leading to the survival of distribution systems that deal efficiently with this type of incentive conflict. This simply broadens the definition of costs and quality to encompass agency costs and their resolution. Thus, independent agents may survive because they more effectively discipline insurers into paying legitimate claims promptly and fairly. Independent agents can credibly threaten to switch business to an alternate insurer because their contracts with insurers convey ownership of the policyholder list to the agent (i.e., the company cannot approach policyholders directly), whereas exclusive agents usually do not have this ownership right.

Because product quality in insurance is essentially unobserved, researchers have been unable to reach consensus on whether the market imperfections hypothesis or the product quality hypothesis is more consistent with the observed cost data. This lack of consensus leaves open the interesting economic question of whether the market works well in solving the problem of minimizing product distribution costs, and leaves unresolved the policy issue of whether marketing costs in property-liability insurance are excessive and perhaps should receive regulatory attention. The latter question is important because regulators in several states, including

California, Florida, and Massachusetts, have argued that the high costs of automobile insurance are partly attributable to insurer inefficiency in marketing, administration, and claims settlement. The significance of this policy issue is underscored by the magnitude of distribution costs in property-liability insurance: such costs represent about 60 percent of the total non-loss expenses of the industry.

This paper proposes a new methodology for distinguishing between market imperfections and product quality as explanations for the coexistence of alternative technologies in markets where quality is not directly observed. Using frontier efficiency methods, we estimate both profit efficiency and cost efficiency for a sample of independent and exclusive agency insurers. Measuring profit efficiency helps to identify unobserved product quality differences because customers should be willing to pay extra for higher quality. Thus, our approach allows for the possibility that one group may provide higher quality service on average and be rewarded with higher average revenues that are reflected in profit efficiency. That is, the profit efficiency approach allows for the possibility that some firms may incur additional costs providing superior service and be compensated for these costs through higher revenues. Moreover, profit efficiency also implicitly incorporates the qualities of loss control and risk management services, since insurers that more effectively control losses and manage risks should have higher average risk-adjusted profits but not necessarily lower costs than less effective insurers.

A key statistic in our analysis will be the proportion of the average difference in measured cost efficiency between the firms employing the two distribution systems that remains when we estimate profit efficiency. If most of the measured cost efficiency differential translates into a profit efficiency differential, then the market imperfections hypothesis would be supported. In this event, the profit inefficiency, which includes both cost inefficiency and revenue inefficiency, would reinforce the efficiency difference between the two groups. In contrast, if most of the measured cost efficiency differential is eliminated when the more encompassing profit efficiency is measured, then the product quality hypothesis would be supported. This event would be consistent with the difference in service quality being reflected in higher revenues. We apply this methodology to a panel of 472 property-liability insurers, representing almost 90 percent of industry assets, over the period

1981-1990.

By way of preview, we find the data to be fairly consistent with the product quality hypothesis. Consistent with the literature, we measure independent agency insurers as less cost efficient on average than direct writers, but most of this measured cost efficiency differential does **not** translate into a profit efficiency differential. Indeed, after controlling for firm characteristics such as size and business mix, the profit efficiency differential between the two groups of firms is not statistically significant even though a significant cost efficiency differential is still present.

The paper is organized as follows. Section II summarizes some of the problems encountered in the extant empirical literature and discusses in an intuitive manner how our methodology addresses these difficulties. Section III gives the details of our methodology and model specification. Section IV discusses the measurement of inputs, outputs, and prices in property-liability insurance. Section V describes the data set, Section VI presents the efficiency estimates, and Section VII provides a regression analysis that checks the robustness of the estimates. Section VIII concludes.

## **II. Methodological Difficulties in the Extant Literature**

Three major methodological problems have been encountered in the literature on insurance distribution costs. First, product quality is essentially unobserved. If some firms incur additional costs in providing a higher quality product to consumers, such as extra assistance with claims settlement or greater product variety, this may be incorrectly identified as a cost inefficiency unless proper controls for product quality are used. Ex ante, we might expect greater customer service from independent agencies because they can offer customers choices among the products of many insurance companies, perhaps better tailoring the insurance product to the needs of the individual customer as well as dealing with more complex loss exposures for both consumer and business customers. In addition, independent agencies may be more likely to act as advocates for customers in claims settlement disagreements than exclusive agents, since independent agents are not tied to the individual insurer and can threaten to steer business elsewhere if settlements are unsatisfactory (see Kim.

Mayers, and Smith, 1994). Unfortunately, control variables for insurance product quality are generally lacking in the data sets available to researchers.

Prior attempts to deal with the problem of disentangling product quality from cost inefficiency have been unconvincing. Braeutigam and Pauly (1986), for example, tried to control explicitly for service quality using the loss ratio (the ratio of losses to premiums). This variable appears unlikely to be strongly correlated with the service quality it is intended to measure. Moreover, it may be spuriously correlated with their dependent variable, measured expenses, which constitute the non-loss part of the premium.

In this paper, we do not attempt to measure cost efficiency net of the influence of product quality because adequate controls for product quality are simply not available. Instead, we estimate profit efficiency, which incorporates both cost efficiency and revenue efficiency, and should net out most of the differences in product quality. That is, in an efficiently functioning output market, customers who prefer higher quality insurance services will pay more for these services, compensating the supplying firm with additional revenues that cover the extra costs of providing the higher quality services.

The second major difficulty encountered in empirical studies of the product quality-inefficiency issue lies in the specifications of the null and alternative hypotheses. Most previous studies took as the null hypothesis that all property-liability insurers had the same managerial competence or X-efficiency, i.e., that all would have the same predicted costs for providing a given scale and mix of insurance products, given the same set of input prices. As the alternative hypothesis, these studies allowed the predicted costs to differ only by a multiplicative constant for the firms in the direct writer and independent agency groups (e.g., Joskow, 1973, Cummins and VanDerhei, 1979, Pauly, Kleindorfer, and Kunreuther, 1986). That is, the maintained hypothesis for these tests was that there were no X-efficiency differences within either group, with the alternative hypothesis only allowing for a crude shift in efficiency between the two groups.

Advances in the measurement of efficiency have rendered such comparisons obsolete. Frontier studies of efficiency in the insurance industry by Weiss (1990), Cummins and Weiss (1993), Fecher, Kessler, Perelman, and Pestieau (1993), Gardner and Grace (1993), Yuengert (1993), and Zi (1994) found very signifi-

cant dispersion in efficiency both within groups of firms and between groups of firms, particularly by size of firm, clearly rejecting the maintained hypothesis of only one or two efficiency levels for all insurers.

In contrast to the prior studies comparing distribution systems in property-liability insurance, we use frontier efficiency models to allow for efficiency differences within each group of insurers. That is, each firm is allowed to have its own level of inefficiency. Our null and alternative hypotheses are that the **average** efficiencies of the direct writer and independent agency groups are the same and different, respectively.

The third major difficulty in this prior literature measuring cost differences between direct writers and independent agency insurers is that the cost functions specified were often ad hoc. Generally, output was measured by a single proxy variable -- total losses or premiums -- despite the multi-product nature of the property-liability insurance business (e.g., Joskow, 1973, Pauly, Kleindorfer, and Kunreuther, 1986, Braeutigam and Pauly, 1986). Subsequent literature on frontier efficiency in financial services has allowed for multiple products and typically used the standard translog cost function specification (e.g., Weiss, 1990, Cummins and Weiss, 1993). The issue of the coexistence of the two distribution systems for property-liability insurance has not been investigated using these multiproduct, frontier efficiency techniques.

The latest efficiency studies of financial institutions have taken two further steps, which we combine in our empirical analysis. Some studies have replaced the standard translog specification with more globally flexible specifications, such as the Fourier-flexible functional form (see Mitchell and Onvural, 1992, McAllister and McManus, 1993, and Berger, et al., 1994). Global approximations are particularly important when studying an industry like insurance, where firms produce within very wide ranges of scale and product mix. Local approximations such as the translog often perform poorly at points well away from the mean and thus are potentially quite inaccurate for describing much of the data. Other recent efficiency analyses have switched from the simple analysis of cost efficiency to profit efficiency, which incorporates both cost and revenue efficiency, and can help ameliorate problems of unobserved input and output quality differences (see Berger, Hancock, and Humphrey, 1993). We address these issues of specification by estimating multiproduct, Fourier-flexible cost and profit frontiers.

The profit function assumes that the firm can freely change its organizational form (stock versus mutual), its scale of operations, and its product mix. The cost function takes scale and product mix as exogenous but assumes the firm has free choice of organizational form. If insurers cannot quickly and costlessly switch their organizational form, scale, or output mix, then efficiency may be mismeasured.

To control for this potential problem, we conduct an ex post regression analysis on the inefficiencies. We regress our measured cost and profit inefficiencies on variables representing firm organizational form, size, and business mix as regressors, as well as dummy variables and interaction terms for independent agency versus direct writer distribution system. Thus, in addition to comparing averages of the efficiency ratios, we compare the cost and profit inefficiencies of the two distribution systems in the ex post regression analysis allowing for differential effects by organizational form, size, and output mix. As discussed further below, the ex post regression analysis also allows us to control for and/or test a number of other hypotheses about insurer distribution systems and organizational form. As an additional method of controlling for insurer size and business mix, we also estimate inefficiency from a 'nonstandard' profit function that replaces the output prices in the standard profit function with output quantities, effectively treating output scale and mix as fixed. The use of ex post regression analysis and the two different profit function specifications helps to ensure that our conclusions are not affected by differences in firm characteristics or equation specification.

### **III. Methodology and Econometric Model Specifications**

Our objective is to measure differences in efficiency across the property-liability insurance industry. Cost efficiency is defined as the minimum costs that could have been expended to produce a given output **bundle divided by the actual costs expended** ( $\hat{c}^{\text{Min}}/\hat{c}^{\text{Act}}$ ), **both adjusted to be predicted values to remove random error that temporarily makes costs high or low.** The cost efficiency ratio may be thought of as an estimate of the proportion of total costs or resources that are used efficiently. The ratio varies over the range (0, 1], with higher numbers indicating greater efficiency or closeness of predicted actual costs to predicted minimum costs. A firm on the cost frontier will have efficiency of 1, since actual costs equal minimum possible costs (plus

random error) for such a firm. Similarly, profit efficiency is the ratio of predicted actual profits to the predicted maximum potential profits that could be earned, predicted values again being used to remove random error ( $\hat{\pi}^{Act} / \hat{\pi}^{Max}$ ). **Thus, the profit efficiency ratio gives an estimate of the proportion of potential profits that are realized.** Profit efficiency is also maximized at 1, where predicted actual profits equal potential profits. **The range of profit efficiency is  $(-\infty, 1]$**  – there is no minimum since profits can be negative of any magnitude. The calculation of both cost and profit efficiency takes as given some external conditions, such as the input prices faced, so that the minimum costs and maximum potential profits both differ across firms.

We calculate frontier efficiency or X-efficiency for each firm using both cost and profit functions. X-inefficiency includes technical inefficiency, or errors that result in general overuse of inputs (or underproduction of outputs in the profit function). X-inefficiency also includes allocative inefficiency, or errors in choosing an input mix (or output mix in the profit function) that is not consistent with relative prices. X-inefficiency is calculated by estimating a frontier cost or profit function which characterizes X-efficient firms, and then measuring the inefficiencies of all other firms as distances from this frontier. For the profit function, X-inefficiency incorporates errors in the choice of output scale and mix, since the output choices are free to vary in the profit function. For the cost function, however, outputs are taken to be fixed.

Our efficiency analysis utilizes the “distribution free” methodology introduced by Schmidt and Sickles (1984) and modified by Berger (1993). This approach avoids imposing arbitrary distributional assumptions on the composed error terms of econometric cost and profit functions to separate inefficiencies from random error. Instead, we simply assume that inefficiencies are persistent or stable over time, whereas random error tends to average out over time. Other efficiency methods typically require quite restrictive distributional assumptions concerning the random errors and inefficiencies that affect costs, profits, or production.<sup>1</sup>The

---

<sup>1</sup>The three main alternative approaches are mathematical programming techniques such as data envelopment analysis (DEA) and free disposal hull (FDH), the econometric frontier approach (EFA), and the thick frontier approach (TFA). Mathematical programming practitioners usually assume that there is no random error. EFA users generally assume that the inefficiencies in the composed error term of a cost or profit function follows a half-normal or other asymmetric distribution, while the random error follows a symmetric normal distribution. Those who apply TFA typically assume that deviations from predicted costs

assumption that efficiencies are relatively stable over time has been supported by earlier research (see Berger and Humphrey 1991, 1992b, Bauer, et al., 1993, Berger 1993).

For cost efficiency, the assumptions of the distribution-free method mean that good management keeps costs relatively low over long periods of time, although costs may fluctuate from trend because of luck or measurement error. If efficiency does change somewhat over time, then the distribution free method captures the *average* deviation of each firm from the *average* best-practice frontier. Cost functions are estimated over a period of time and the residuals for each firm are averaged over the period to reduce the random error, with the remaining part of the residual providing an estimate of X-efficiency for each firm. Similarly, for profit efficiency, good management keeps profits high over the long-run, creating high average residuals. In either case, some additional truncation is used to account for random error that does not fully average out over time. In this study we estimate pooled cross section-time series cost and profit functions with 10 annual observations available for each of the 472 insurers in the sample. Firms without continuously available data for the period 1981 through 1990 were deleted. Inefficiency is estimated for each firm by averaging its residuals over the ten-year period, truncating the distribution of average residuals across firms, and then computing efficiency relative to the firms with the best average residuals (lowest for costs, highest for profits).

Formally, we refer to outputs and inputs as netputs and distinguish between variable and fixed netputs **in our cost and profit models. The netput vector  $y = (y_I, y_O, y_F)$  denotes the netput vector containing  $n$  variable inputs  $y_I$ ,  $m$  variable outputs  $y_O$ , and  $q$  fixed netputs  $y_F$ , with the variable inputs  $y_I$  measured negatively so that for both inputs and output, the  $y$  values give the net supply by the firm. The fixed netputs are outputs or inputs that are taken as given by the firm, either because they are difficult to change except over the long run or because other impediments such as regulation or imperfect competition prevent them from changing. The vector  $p = (p_I, p_O, p_F)$  denotes the price vector corresponding to the arguments in  $y$ . The prices of fixed netputs**

---

or profits within the lowest and highest average-cost or profit quantiles of firms represent random error while deviations between the lowest and highest quantiles represent inefficiencies. All of these assumptions have been shown to be fairly well violated by financial institutions data (see Berger, Hunter, and Timme 1993).

$p_i$  are noted for convenience, but are not used in the firm's optimization exercise or in our efficiency estimation.

The cost function for insurer  $i$ , which takes as exogenous the input prices  $p_i$ , variable outputs  $y_o$ , and fixed netputs  $y_f$  (which may be inputs or outputs), is specified as:

$$VC = C(p_I, y_O, y_F) \cdot u_c \cdot e_c$$

or

(1)

$$\ln VC = \ln C(p_I, y_O, y_F) + \ln u_c + \ln e_c$$

where VC is variable costs  $p_i \cdot y_i$  ( $Z$  indicates inner product);  $C(p, y_o, y_f)$  is a cost function with input prices, variable outputs, and all fixed netputs as arguments,  $u_c$  is a multiplicative X-efficiency factor, and  $e_c$  is a random error term. The X-efficiency factor  $u_c$  and random error  $e_c$  enter the overall cost specification multiplicatively and are separable from the other cost function arguments by assumption. As described below, this composed error will be separated out below using the assumption that the efficiency factor  $u_c$  is stable over time, while the random error  $e_c$  tends to average out over time.

The profit function is specified very similarly to the cost function:

$$\pi = \pi(p_O, p_I, y_F) \cdot u_\pi \cdot e_\pi$$

or

(2)

$$\ln \pi = \ln \pi(p_O, p_I, y_F) + \ln u_\pi + \ln e_\pi$$

where  $\pi$  denotes profits plus a constant term,  $u_\pi$  is an X-efficiency factor, and  $e_\pi$  is a random error term. There are three notable differences from the cost function. First, variable output prices  $p_o$  in the profit function replace variable output quantities  $y_o$  in the cost function. Under profit maximization, the firm is free to choose the variable outputs to maximize profits and failure to do so results in measured profit inefficiency. Thus, profit inefficiency includes cost inefficiency from non-optimizing levels of inputs plus revenue inefficiency from non-optimizing levels of outputs.

Second, we use total profits in constructing the dependent variable, rather than variable profits, which would be analogous to variable costs. If output prices and quantities were measured perfectly, the dependent variable  $\pi$  would be appropriately measured using variable profits. However, it is important for studying the question at hand to allow for the possibility that output prices and quantities may not be measured well, i.e., that there may be important product quality differences that are not incorporated in these measures. For this reason, we measure  $\pi$  using the **actual** profits reported by the insurance firms (put into real terms), which allows for the possibility that we measure firms using one of the distribution systems as being more efficient on average if they provide higher (unmeasured) product quality on average and receive higher revenues reflecting this.

Third, since profits are sometimes nonpositive and logs can only be taken of positive numbers, we add to the dependent variable one plus the absolute value of the largest negative profits in the sample. This is, the dependent variable for firm  $k$  at time  $t$  is  $\ln\pi_{kt} = \ln(\text{profit} + 1 + |\text{profit}_{\min}|)$ , where *profit* is measured profits and *min* indicates the sample minimum, which is negative. This modification is made for **all** observations.

We use the Fourier-flexible functional form because it is a global approximation that has been shown to dominate the commonly specified translog form in fitting financial institution data (see, for example, Mitchell and Onvural, 1992, McAllister and McManus, 1993, Berger, et al., 1994). The specification includes both pure Fourier trigonometric terms (cosines and sines) and a standard translog, following Gallant's (1981) suggestion to combine Fourier and Taylor series approximations to reduce the number of terms needed for a close approximation. In forming the trigonometric terms, we adjust each of the price and output terms to span the interval  $[\cdot 1 \cdot 2\pi, \cdot 9 \cdot 2\pi]$  before taking cosines and sines. Technically, we need only reduce the variables to the  $[0, 2\pi]$  interval, but we cut 10 percent off of each end of this interval to reduce approximation problems near the endpoints (see Gallant, 1981). Thus, for each argument of the cost or profit function  $\ln x$ , we form the adjusted variable  $z = \cdot 2\pi - \mu \cdot a + \mu \cdot \ln x$ , where  $[a, b]$  is the range of  $\ln x$  and  $\mu = (\cdot 9 \cdot 2\pi - \cdot 1 \cdot 2\pi) / (b - a)$ . For notational convenience, we define  $z^c$  to be the transformed values of the arguments of the cost function  $(p_t, y_o, y_f)$  and  $z^p$  to be the transformed values of the profit function arguments  $(p_t, p_o, y_f)$ . The Fourier-flexible form, including a full translog and

all first-order, second-order, and third-order trigonometric terms, as well as the X-efficiency and random error terms may be written as follows:

$$\begin{aligned}
\ln C(p_I, y_O, y_F) = & \alpha + \sum_{i=1}^n \phi_i \ln p_i + 1/2 \sum_{i=1}^n \sum_{j=1}^n \phi_{ij} \ln p_i \ln p_j \\
& + \sum_{r=1}^{m+q} \beta_r \ln y_{n,r} + 1/2 \sum_{r=1}^{m+q} \sum_{s=1}^{m+q} \beta_{rs} \ln y_{n,r} \ln y_{n,s} \\
& + \sum_{i=1}^n \sum_{r=1}^{m+q} \gamma_{ir} \ln p_i \ln y_{n,r} + \sum_{i=1}^{n+m+q} \left[ \delta_i \cos z_i^c + \theta_i \sin z_i^c \right] \\
& + \sum_{i=1}^{n+m+q} \sum_{j=i}^{n+m+q} \left[ \delta_{ij} \cos (z_i^c + z_j^c) + \theta_{ij} \sin (z_i^c + z_j^c) \right] \\
& + \sum_{i=1}^{n+m+q} \sum_{j=i}^{n+m+q} \sum_{k=j}^{n+m+q} \left[ \delta_{ijk} \cos (z_i^c + z_j^c + z_k^c) + \theta_{ijk} \sin (z_i^c + z_j^c + z_k^c) \right] \\
& + \ln u_c + \ln e_c
\end{aligned} \tag{3}$$

Thus, each of the input prices, variable output quantities, and fixed netput quantities appears in the translog and Fourier functions, up to the second order in the translog and third order in the Fourier (time and firm subscripts are suppressed for notational convenience). The standard symmetry restrictions apply to the translog portion of the function ( $\phi_{ii} = \phi_{ii}$ ,  $\beta_{rr} = \beta_{rr}$ ), although homogeneity restrictions cannot be easily applied because of the trigonometric terms.

The Fourier-Flexible form is a global approximation because of the orthogonalities among the trigonometric terms, so that each cosine wave or sine wave added to the specification can make the approximating function fit the data more closely wherever it is most needed. For data that are perfectly evenly distributed over the  $[0, 2\pi]$  interval, the cosine terms of the  $n$ -th order ( $n = 1, 2, 3$ ) have zero correlation with cosine terms of other orders and with sine terms of all orders, while sine terms of the  $n$ -th order have zero correlation with sine terms of other orders and with all cosine terms. For our data, where the distribution over the interval is not perfectly even, the correlations are not zero but are very small. These near-orthogonalities among the trigonometric terms gives the function a great deal of flexibility in fitting the data.

The profit function takes the same form as the cost function except that it is a function of  $(p_i, p_o, y_i)$  instead of  $(p_i, y_o, y_F)$ :

$$\begin{aligned}
\ln \pi(p_i, p_o, y_F) = & \alpha + \sum_{i=1}^{n \cdot m} \phi_i \ln p_i + 1/2 \sum_{i=1}^{n \cdot m} \sum_{j=1}^{n \cdot m} \phi_{ij} \ln p_i \ln p_j \\
& + \sum_{r=1}^q \beta_r \ln y_{n \cdot m \cdot r} + 1/2 \sum_{r=1}^q \sum_{s=1}^q \beta_{rs} \ln y_{n \cdot m \cdot r} \ln y_{n \cdot m \cdot s} \\
& + \sum_{i=1}^{n \cdot m} \sum_{r=1}^q \gamma_{ir} \ln p_i \ln y_{n \cdot m \cdot r} + \sum_{i=1}^{n \cdot m \cdot q} \left[ \delta_i \cos z_i^\pi + \theta_i \sin z_i^\pi \right] \\
& + \sum_{i=1}^{n \cdot m \cdot q} \sum_{j=i}^{n \cdot m \cdot q} \left[ \delta_{ij} \cos (z_i^\pi + z_j^\pi) + \theta_{ij} \sin (z_i^\pi + z_j^\pi) \right] \\
& + \sum_{i=1}^{n \cdot m \cdot q} \sum_{j=i}^{n \cdot m \cdot q} \sum_{k=j}^{n \cdot m \cdot q} \left[ \delta_{ijk} \cos (z_i^\pi + z_j^\pi + z_k^\pi) + \theta_{ijk} \sin (z_i^\pi + z_j^\pi + z_k^\pi) \right] \\
& + \ln u_\pi + \ln e_\pi
\end{aligned} \tag{4}$$

Thus, the profit function model has the same functional form, same number of terms, and the same right-hand-side variables as the cost function except that output prices replace output quantities. This is important to our interpretation of the difference in efficiency results between the two models as primarily representing product quality differences, rather than differences in specification.

The models are estimated using data over the ten-year period 1981-1990. The residuals from the cost and profit function regressions are analyzed using the “distribution-free” approach to estimate X-efficiencies for the firms in the sample. For the cost function, the error term for insurer  $k$  at time  $t$  ( $\ln u_{ckt} + \ln e_{ckt}$ ) is treated as a composite error term, and the average of the ten residuals for each insurer  $k$  is calculated. This **average residual, denoted by  $\ln \hat{u}_{ck}$ , is an estimate of  $\ln u_{ck}$ , given that the random errors  $\ln e_{ckt}$  tend to cancel each other out in the averaging.** The estimated cost X-efficiency for firm  $k$ ,  $X\text{-EFF}_{ck}$ , is then calculated as follows:

$$X-EFF_{ck} = \exp(\ln \hat{u}_c^{\min} - \ln \hat{u}_{ck}) \quad (5)$$

where  $\ln \hat{u}_c^{\min}$  is the minimum  $\ln \hat{u}_{ck}$  and acts as an "anchor" so that the firm with the lowest average cost function residual is measured as being 100 percent efficient. Undoing the logs and exponents,  $X-EFF_{ck}$  is a measure of  $\hat{u}_c^{\min}/\hat{u}_{ck}$ . Since  $u_{ck}$  is multiplicative to costs,  $X-EFF_{ck}$  is an estimate of the ratio of predicted costs for the most efficient insurer to the predicted costs for insurer  $k$  for a given vector of variable input prices, variable output quantities, and fixed netput quantities. This corresponds to the conventional notion of efficiency as the ratio of the minimum costs needed to the actual costs expended, but with the estimated effects of the random error  $e_{ck}$  removed.

Because the averaging procedure for the residuals is imperfect, the  $X-EFF_{ck}$  measure contains some error from the  $\ln e_{ck}$  not fully canceling out over the ten-year period as well as standard estimation error. **This error is likely to be largest for insurers near the extremes of the  $\ln \hat{u}_{ck}$ 's, which may have had persistently "lucky" or "unlucky" random errors that did not fully average out.** This may create a problem for estimating **overall industry efficiency, because the insurer with the lowest  $\ln \hat{u}$  is the efficient insurer against which all others are measured.** For this reason, we compute truncated measures as in Berger (1993). In the results reported below, the top and bottom 5 percent of the  $\ln \hat{u}_{ck}$ 's are set to the 5th and 95th percentiles, respectively of their distributions. No observations are discarded in this truncation procedure -- rather, the extreme values are simply assigned slightly less extreme values. Our findings were checked for robustness by recomputing all the results with varying levels of truncation and the findings were materially unchanged.

Profit X-efficiency is computed similarly to cost efficiency. However, a complicating factor is that **actual profits are not multiplicative in the efficiency factor  $u_{\pi}$  because of the addition of extra constant (1 plus the absolute value of the largest negative profits) before logging the profits.** For this reason, although the efficiency factor  $u_{\pi}$  is assumed to be constant over time for firm  $k$ , its efficiency ratio will depend somewhat on the level of the regressors in the profit function (the logs of variable netput prices, logs of fixed netput

quantities, etc.). Our measured profit efficiency ratio,  $X\text{-EFF}_{\pi k}$  is an estimate of the ratio of predicted profits for insurer k to the predicted profits for the most efficient insurer, both evaluated at the mean levels for the profit function regressors for firm k. That is, the profit efficiency ratio is an estimate at the insurer's mean regressors of the ratio of actual to potential profits, or the proportion of maximum profits which are actually earned, with the estimated effects of the random error  $e_{\pi}$  removed. The same truncation procedure is performed on the average profit function residuals as is performed on the average cost function residuals to reduce the effects of outliers.<sup>2</sup>

#### **IV. Definition and Measurement of Outputs and Inputs**

This section briefly discusses several measurement issues in constructing the data set. We first describe the process for choosing which services to measure as outputs in property-liability insurance. We then show how we measure the output and input quantities and prices used in the cost and profit functions. More detailed information is available from the authors.

**Definition of Insurance Output.** Insurers are analogous to other firms in the financial sector of the economy in that their outputs consist primarily of services, many of which are intangible. Three principal approaches have been used to define outputs in the financial services sector: the asset or intermediation approach, the user-cost approach, and the value-added approach (see Berger and Humphrey 1992b). The asset approach treats financial service firms as pure financial intermediaries, borrowing funds from one set of decision makers, transforming the resulting liabilities into assets, and receiving and paying out interest and dividends to cover the time value of funds used in this capacity. The asset approach would be inappropriate

---

<sup>2</sup>Formally, for insurer k, we compute the average predicted value of the dependent variable  $\ln \pi_k^{\text{Pred}}$  as the inner product of the regression coefficients and the mean regressors for firm k, plus the average residual  $\ln \hat{u}_{\pi k}$  (truncated at the 5th and 95th percentiles as above). The value that the dependent variable would take for a fully efficient firm facing firm k's mean regressors is  $\ln \pi_k^{\text{Max}} = \ln \pi_k^{\text{Pred}} + \ln \hat{u}_{\pi}^{\text{Max}} - \ln \hat{u}_{\pi k}$ , where  $\ln \hat{u}_{\pi}^{\text{Max}}$  is the maximum value of the  $\ln \hat{u}_{\pi k}$  distribution (after truncation). Undoing the logs and subtracting the constant  $(1 + |\text{profit}_{\min}|)$  from both predicted and maximum profits gives  $\text{profit}_k^{\text{Pred}} = \exp(\ln \pi_k^{\text{Pred}}) - (1 + |\text{profit}_{\min}|)$  and similarly for  $\text{profit}_k^{\text{Max}}$ . The profit efficiency ratio is thus given by  $\text{profit}_k^{\text{Pred}} / \text{profit}_k^{\text{Max}}$ .

for property-liability insurers because they provide many services in addition to financial intermediation. In fact, the intermediation function is somewhat incidental to property-liability insurers, arising out of the contract enforcement costs that would be incurred if premiums were not paid in advance of covered loss events.

The user cost method determines whether a financial product is an input or output on the basis of its net contribution to the revenues of the financial institution. If the financial returns on an asset exceed the opportunity cost of funds or if the financial costs of a liability are less than the opportunity costs, then the product is considered to be a financial output. Otherwise, it is classified as a financial input. This method is theoretically sound but requires precise data on product revenues and opportunity costs, which are difficult to estimate.<sup>3</sup> It is particularly inaccurate in industries such as property-liability insurance, because insurance policies bundle together many services (risk pooling, claims settlement, intermediation, etc.), which are priced implicitly.

The value-added approach considers all asset and liability categories to have some output characteristics rather than distinguishing inputs from outputs in a mutually exclusive way. The categories having significant value added, as judged using operating cost allocations, are employed as important outputs. Others are treated as unimportant outputs, intermediate products, or inputs, depending on the characteristics of the specific activity under consideration. We adopt a modified version of the value-added approach to define property-liability insurer outputs.

Property-liability insurers provide three principal services:

**~Risk-pooling and risk-bearing.** Insurance provides a mechanism for consumers and businesses exposed to property-liability losses to engage in risk reduction through the diversification effect of pooling. Insurers collect premiums from their customers and redistribute most of the funds to those policyholders who sustain losses. The actuarial, underwriting, and related expenses incurred in operating the risk pool are a major component of value added in the industry. Policyholders may also have their risks reduced because some of these risks are borne by shareholders of the insurance company (for stock companies), by previous policyholders whose capital has been left in the company (for mutual organizations), or by other parties holding the debt of the insurance company (for both

---

<sup>3</sup>Efforts to apply the user cost method in banking found that the classifications of inputs and outputs were sometimes not robust to the choice of opportunity cost estimates nor were they robust over time (see Berger and Humphrey, 1992b).

groups). The costs of raising these other funds also contributes to the value added of the firm.

**Ž"Real" financial services relating to insured losses.** Insurers provide a variety of real services for policyholders. These include risk surveys to identify unusual loss exposures and the design of programs to cover these and other risks, and recommendations regarding deductibles and policy limits. Insurers also provide loss prevention services such as programs to reduce the incidence of employment-related injuries. Loss settlement services include valuation of property losses, negotiations with contractors, and legal representation for liability claims. By contracting with insurers to provide these services, policyholders can take advantage of insurers' extensive experience and specialized expertise to reduce costs associated with insurable risks.

**ŽIntermediation.** Insurers collect premiums in advance of loss payments and hold the funds in reserves until claims are paid, similar to corporate debt. In a competitive market, policyholders receive a discount in the premiums they pay to compensate for the opportunity cost of the funds held by the insurer, analogous to interest payments on corporate debt. The borrowed funds are invested primarily in marketable securities.

Obtaining precise information on value added in property-liability insurance is difficult because publicly available data do not break down costs according to the services provided. Nevertheless, some rough estimates are available to help us identify outputs. In 1992, about 30.9% of total industry operating expenses were for loss adjustment costs, the primary nonfinancial service provided by the industry. About 67.3% of operating costs were accounted for by marketing and administrative costs. Some of these costs are attributable to real services but the majority, such as actuarial, underwriting, and administrative costs, are attributable to the risk-pooling function, as stated above. The remaining 1.8% of total expenses were absorbed by the intermediation function. The small percentage of operating costs attributable to intermediation is not surprising in view of the fact that property-liability insurers invest almost exclusively in marketable securities, which typically require very little analysis.

A strict application of the value-added approach would identify risk pooling and real services as important outputs and intermediation as an unimportant output. However, in view of the amount of assets controlled by insurers (about \$700 billion in 1992) and the importance of investment income as a source of revenue for the industry, we elected to retain the intermediation function in defining industry output. This is particularly important in estimating the profit function in view of the fact that insurers rely on investment income to cover the premium discount for the use of policyholder funds. A small amount of inefficiency in

investing these funds could easily wipe out all profits. Moreover, estimation of a profit function virtually requires the inclusion of investment income, since otherwise profits would almost always be negative.

**Measurement of Output Quantities.** Ideally, we would have available transactions flow data to measure the outputs provided by insurers. This would include information on the number of applications processed, the number of policies issued and renewed, the number of claims settled, etc. Unfortunately, this type of information is not publicly available. However, a satisfactory proxy for the amount of risk-pooling and real insurance services provided is the present value of real losses incurred. Losses incurred are defined as the value of claims that are expected to be paid as the result of providing insurance coverage during a particular period of time. Because the objective of risk pooling is to collect funds from the policyholder pool and redistribute them to those who incur losses, proxying output by the amount of losses incurred seems quite appropriate. After discounting and putting into real terms, losses incurred also proxy for the amount of real services provided, since the amount of claims settlement and risk management services should be highly correlated with loss aggregates.

There are two drawbacks to the use of discounted real losses as the metric for insurance output, both of which are addressed by our use of the profit function. First, although services are likely to be highly correlated with real losses for both independent agency firms and direct writers, measured losses will not capture any systematic differences **between** direct writers and independent agency insurers in the levels of service intensity per dollar of loss. Such differences in intensity levels, such as additional help to customers in loss adjustment or policy choice, likely cannot be well measured by losses or by any other observable variables. As discussed above, use of the profit function helps ameliorate this problem, since the unmeasured extra service will create revenues that tend to offset the costs of providing the service. Use of actual profits in the profit function specification also helps in this regard, since multiplying industry price by measured quantity to obtain variable profits would understate the revenues attributable to product quality.

The second drawback of using losses incurred to measure insurance output is that its use ignores the important outputs of loss control and risk management. An insurer that is very successful in its underwriting

and loss-prevention practices will incur fewer losses for the same amount of premiums written, but will be measured as having less output. Similarly, a firm that is relatively successful at managing its risks will earn higher risk-adjusted average profits for its owners. Fortunately, our use of the profit function at least partially ameliorates these measurement problems as well. As with the unmeasured differences in product quality discussed above, insurers that have higher quality underwriting and loss prevention or superior risk management will have higher average profits and higher measured profit efficiency, all else equal. Such differences are not generally reflected in cost efficiency.

Because service intensity varies by line of business (e.g., commercial accounts generate proportionately more costs than personal policies), we disaggregate losses into four subcategories: short-tail personal lines, short-tail commercial lines, long-tail personal lines, and long-tail commercial lines. The designations “long-tail” and “short-tail” refer to the length of time between policy inception date and when bulk of the loss payment have been made. In short-tail lines such as auto collision, the lag is usually less than two years, while for long-tail lines such as commercial liability some losses may remain unpaid for 10 or 15 years after the policy coverage period began. Long-tail lines generally require more services than short-tail lines, including higher attorney fees and multiple transactions resulting from individual claims. Because insurers report their losses incurred at undiscounted values, we discount the losses to present value using estimated industry-wide payout patterns.<sup>4</sup> The discount rates are based on the U.S. Treasury yield curves reported by Coleman, Fisher, and Ibbotson (1989), updated through 1990 using data from other sources. Losses are deflated by the Consumer Price Index (CPI).

Our modeling of the intermediation function views insurers as raising funds by borrowing from policyholders and then investing the funds in marketable securities. The output of the intermediation function is measured by the mean of total real invested assets for the year, with the CPI used as the deflator.

---

<sup>4</sup>Payout patterns are estimated from data reported in *Best's Aggregates and Averages* (A.M. Best Company, Oldwick, NJ, various years). We estimate the payout proportions using the method prescribed by the Internal Revenue Service for obtaining the present value of losses for tax purposes.

**Measurement of Output Prices.** As discussed above, we specify the prices of variable outputs in place of their quantities in the profit function. All five of our outputs -- the four insurance outputs (long- and short-tail for both commercial and personal) and the intermediation output -- are considered to be variable in the analysis.

The conventional measure of the price of insurance in research efforts is the mark-up of premiums over losses, i.e., the ratio of premiums to losses minus 1 (e.g., Pauly, Kleindorfer, and Kunreuther, 1986). However, the premium represents the **present value** of expected losses, expenses, and profits, whereas losses are reported as **undiscounted values**. Thus, the conventional mark-up ratio measures the ‘true’ price of insurance (i.e., the value-added by the insurer) minus the time cost of funds borrowed from policyholders.

To accurately measure insurance output prices, it is necessary to separate the price of insurance from the cost of funds borrowed from policyholders by comparing premiums with the present value of losses (see, for example, Winter, 1994). Thus, the prices of the four insurance outputs are measured as follows:

$$p_i = \frac{PREM_i - PV(L_i)}{PV(L_i)} \quad (6)$$

where  $PREM_i$  is the real premium for output category  $i$ ,  $L_i$  measures the real losses for output category  $i$ , and  $PV$  is the present value operator. Thus, the price is the net real cost to the policyholders of having the present value of a dollar of real losses redistributed through the insurance company, i.e., the unit price per dollar of insurance output.

To illustrate the difference between our price measure and the conventional mark-up ratio, consider a simple example where premiums are paid at time 0 and a single loss payment of  $L$  is made at time 1. Assume that the price of insurance is a proportion  $v$  of losses. The competitive market premium will be  $PREM = L(1 + v)/(1 + r)$ , where  $r$  is the appropriate discount rate (representing the time cost of funds borrowed from policyholders). The conventional mark-up ratio for this case is  $(PREM - L)/L = (v - r)/(1 + r)$ , i.e., the present value of the price of insurance ( $v$ ) less the cost of debt capital ( $r$ ). According to equation (6),

our measure of the price of insurance for this example is  $p = (\text{PREM}-\text{PV}(\text{L}))/\text{PV}(\text{L}) = v$ , where  $\text{PV}(\text{L}) = \text{L}/(1+r)$ .

The price of the remaining output, the intermediation output, is the expected rate of return on assets, defined as expected investment income divided by average assets. Expected investment income is the sum of the expected income on stocks and debt instruments. The expected rate of return on stocks for any given year is estimated as the average 90-day Treasury bill yield for the year plus the expected equity risk premium for common stock with a beta coefficient of 1.0, assuming that insurers hold stock portfolios of average risk. Following standard procedures, the expected equity risk premium is estimated as the average risk premium from 1926 to the end of the preceding year from Ibbotson Associates (1993). Using this approach smooths out fluctuations due to capital gains and reflects the fact that investment decisions are based on ex ante rather than ex post returns. Expected income on stocks is equal to the value of the insurer's stock portfolio at the beginning of the year multiplied by the expected return on stocks. By using market-based returns, rather than actual returns in constructing the price, we allow for the possibility of some firms being more efficient in investing. A firm that consistently beats the stock market will be appropriately measured as more profit efficient than another firm, all else equal. For debt instruments, actual income was used as a proxy for expected income because the information available on the composition of insurer bond portfolios is quite limited.

**Defining and Measuring Input Quantities and Prices.** Insurance inputs can be classified into four groups: labor, business services, debt capital (including policyholder funds), and equity capital. Insurance is a labor intensive industry, with personnel costs (excluding agents' commissions) accounting for about 40% of total operating expenses. Labor costs include salaries, employee benefits, payroll taxes, and miscellaneous employment-related costs. We treat labor as a variable input, and so specify only its price, not its quantity, as an exogenous variable in the cost and profit functions (although the endogenously determined quantity of labor obviously affects measured costs and profits). The price of labor is measured by a salary deflator, which indexes total labor costs per employee for the industry, giving each firm the same price for the same year.

The business services category is dominated by outside business services such as agents' commissions and loss adjustment expenses from lawyers and loss adjustment firms. Less important components of the business services category are travel, communications, and printing. The costs of physical capital (mainly rental expenses and computers) are small relative to the other inputs, and therefore are simply incorporated into the business services category. The price deflator for this variable input is the business services deflator compiled by the U.S. Department of Commerce, Bureau of Economic Analysis. As above for labor, it is assumed that all firms face the same business services price for the same year.

The final two inputs, which reflect the funding sources of the P-L insurance industry, are treated as fixed netputs for the purposes of our analysis. The debt capital of insurers consists primarily of funds borrowed from policyholders. These funds are measured in real terms as the sum of loss reserves and unearned premium reserves, deflated by the CPI.<sup>5</sup> Loss reserves represent the company's obligations for unpaid losses, and unearned premium reserves represent premiums held for coverage not yet provided. Insurers reimburse the policyholders for the use of these funds implicitly through charging lower insurance premiums on the policies.

Equity capital for property-liability insurers averages about 25% of assets, much higher than comparable ratios for banks or life insurers due to the highly stochastic nature of property-liability losses. Equity capital is an input for the risk-pooling and risk-bearing function because it provides assurance that the company will pay claims even if they are larger than expected. Thus, we measure the real value of equity capital as a fixed input.

It might be argued that our two fixed netputs, debt capital and equity capital, are fixed only in the short

---

<sup>5</sup>The unearned premium reserve is reduced by an estimate of prepaid expenses. Under statutory accounting rules, insurers are required to maintain reserves equal to 100 percent of unearned premiums, even though they have already paid a substantial proportion of the commissions and administrative costs covered by the expense component of the premium. We use a standard GAAP accounting adjustment for prepaid expenses, adding back to equity the following amount:  $UPR_t * (1 - .5 * (loss\ ratio_t + loss\ ratio_{t-1}))$ , where  $UPR_t$  is the unearned premium reserve at the end of year t, and  $loss\ ratio_t$  is the ratio of loss and loss adjustment expenses incurred to premiums earned for year t.

run and may vary somewhat over our 10-year sample period in reaction to relative price changes. However, we prefer to hold these measures statistically fixed because the current distribution of insurer size evolved over a period of many decades. That is, the smallest firms or even the average firms could not accumulate nearly as much policyholder debt capital or equity capital as the largest firms in a single decade. When we tried treating the capital variables instead as variable inputs, the profit efficiency rankings were completely dominated by the largest firms, which had the highest profits for a given set of prices by virtue of their cumulative size. Thus, for the remainder of the analysis, we treat the capital inputs as fixed. Note that this problem did not occur for cost efficiency because the cost function specifies all the output quantities, effectively treating all of the variable outputs as fixed. As a result, costs for large insurers are not particularly large, given the exogenous variables in the cost function.

To summarize, we specify five variable outputs -- the real discounted losses incurred on four types of insurance output (short- and long-tailed for both commercial and personal lines) and real invested assets. We also specify two variable inputs, labor and business services, and two fixed inputs, policyholder-supplied debt capital, and financial equity capital. These nine netputs -- which are included in either quantity or price form in the cost and profit efficiency equations (3) and (4) -- should reasonably represent the conditions facing insurers as they attempt to minimize costs and maximize profits.

## **V. The Data**

The primary source of data for this study is the A.M. Best Company data tapes. The regulatory annual statements filed with state insurance commissioners are the original source of the Best's data. The distribution-free approach requires a panel of firms with data continuously available over a sample period sufficiently long to average out most of the random error. We chose the ten-year period 1981-1990, the longest period for which all of the data we needed were available to us. The decision making units in the insurance industry consist of groups of affiliated insurers under common ownership as well as some individual, unaffiliated insurers. Our sample initially consisted of all groups and unaffiliated single insurers for which data

were available over the sample period, a total of 538 insurers. We encountered data problems with some of these insurers, including missing values, negative revenues, negative outputs, and, in a few cases, negative net worth. Further investigation revealed that most of these problems were attributable to insurers that were approaching insolvency, exiting major lines of business, or winding down their operations. Eliminating these companies reduced the final sample to 472 insurers. These firms accounted for 88.9% of industry assets in 1985, the midpoint of the sample period, so that our results may be considered reasonably representative of the entire industry.

One drawback of our sample selection method is that it creates survivorship bias, since exiting firms or firms that are acquired by others are excluded from the sample. However, the hypotheses about insurance distribution systems as well as the theory underlying the cost and profit functions relate to on-going firms in equilibrium, rather than to firms winding down their businesses or failed firms. Fortunately, our coverage of almost 90% of the P-L industry virtually guarantees that any survivorship bias would have little effect on the results.

Finally, there were a few firms with incomplete information or mixed information on their distribution systems. A total of 26 insurers switched from the direct writing to independent agency system or vice versa over the sample period. In addition, we could not determine with certainty the distribution system used by 53 firms. Thus, of the 472 insurers used in the efficiency estimations, 393 have clear distribution system affiliations, with 114 direct writers and 279 independent agency firms. Thus, while we include the entire 472 firms in the efficiency estimation, we compare only the average efficiencies of 393 of them in order to make the clearest distinction for answering the question of why both distribution techniques persist in the market. Summary statistics on the variables used in estimating the models are presented in Table 1.

## **VI. Efficiency Estimates**

We estimated the cost and profit models using ordinary least squares over the ten-year period 1981-1990. Due to the sample size, the number of terms, and the lack of cross-sectional variation in prices, we

were not able to estimate the equations year by year. Thus, the estimated coefficients are constrained to equality across firms and across years. We do not include the often-specified input or output share equations that incorporate Shephard's Lemma or Hotelling's Lemma restrictions on optimal netput choices in order to allow for the possibility that insurers are allocatively inefficient and choose netput shares that do not minimize costs or maximize profits. Prior research suggests that inclusion or exclusion of share equations does not materially affect efficiency estimates (see Berger, 1993).

The 10 annual observations on each of the 472 insurance firms included in the analysis provided 4,720 total observations to be used in the efficiency estimations. The recommended number of parameters to include in Fourier-flexible specifications is about  $T^{2/3}$ , where T is the number of observations. This 4,720 observations yields an "ideal" number of parameters of about 281. The full model in equations (3) and (4) with a translog plus all first-, second-, and third-order Fourier terms had 492 parameters. To reduce this number while maintaining symmetric treatment of all the outputs, we dropped all the third-order trigonometric terms in which the same z terms appeared more than once (i.e., the terms in the sum in which  $i=j$ ,  $i=k$ , or  $j=k$ ). For reasons of collinearity, we also dropped the second-order Fourier terms in which both terms represented the variable input prices. Recall that these prices do not vary in the cross section, and so take on a total of only 10 different values. The remaining specification had 324 parameters, reasonably close to the "ideal" number. We note that F-tests of the null hypothesis that all the Fourier coefficients were zero terms always rejected the null, confirming that the Fourier-flexible functional form fits the data better than the more commonly specified translog form. The cost and profit function estimates are shown in Appendix table A1.

The cost and profit X-efficiency estimates for the firms in the sample are summarized in Table 2. This table presents efficiency ratios for the insurers in the sample categorized by distribution system. The results are also presented by insurer size quartile (smallest quartile = size 1), with insurers ranked by total insurance output, the sum of the four insurance outputs (i.e., the total present value of real losses). Recall that measured cost efficiency (minimum costs/actual costs) is an estimate of the ratio of predicted costs for the most efficient insurer to the predicted costs for insurer k for insurer k's input prices, output quantities, and fixed

netput quantities. Similarly, measured profit efficiency (actual profits/maximum potential profits) is an estimate of the ratio of predicted profits for insurer  $k$  to the predicted profits for the most efficient insurer for insurer  $k$ 's mean input and output prices and fixed netput quantities.

The results presented in Table 2 are weighted averages, with weights equal to predicted costs for cost efficiency and potential profits for profit efficiency. The weighting allows us to view the averages as estimates of the proportions of total sample costs that are used efficiently (cost efficiency) and total sample potential profits that are realized (profit efficiency).

Table 2 shows that direct writers have substantially better cost efficiency on average than independent agency firms when measured against the same frontier. The average efficiency for direct writers is 63.9%, while the average for independent agency insurers is 54.8%, a difference of 9.1% of predicted costs. This is consistent with the prior insurance cost literature that did not use frontier efficiency techniques, but rather compared costs assuming that both groups had no efficiency deviations within them (Joskow 1973, Cummins and VanDerhei 1979, Kim, Mayers, and Smith 1994).

Based on the simple group cost efficiency averages shown in Table 2, the marked difference in measured cost efficiency between direct writers and independent agency insurers does not appear to be the result of differences in firm size. Direct writers dominate independent agency firms in every size class except the smallest (Size 1), where there is a limited sample size of only 17 direct writers. This result as well as the size skewness in the direct writer sample (the number of direct writers increases monotonically by size class) is consistent with the Sass and Gisser (1989) hypothesis that direct writers need to be large to provide a sufficient volume of business to attract agents into exclusive dealing relationships.

A final observation from inspection of the cost efficiencies in Table 2 is that the cost efficiency ratios for all the groups are low relative to the cost efficiency estimates presented in prior studies of property-liability insurers (Weiss, 1990, Cummins and Weiss, 1993) and most prior studies of non-insurance financial institutions (see Berger, Hunter, and Timme 1993) but higher than prior cost efficiency estimates for life insurers (Yuengert, 1993, Gardner and Grace, 1993, Zi, 1994). The measured efficiency ratios of 0.639 and

0.548 for direct writing and independent agency firms, respectively, suggest that about 36% and 45% of their costs are lost to inefficiency. As demonstrated below, these high degrees of measured inefficiency likely include some variation in product quality even within a group of firms with the same distribution system.

The profit efficiencies based on equation (4) are shown in the 'Standard Profit Function' columns of Table 2. These results reveal that direct writers are also more profit efficient on average than independent agency firms when these firms are measured against the same profit frontier. The average profit efficiency for direct writers is 69.9%, while the average for independent agency insurers is 60.3%, a difference of 9.6% of predicted potential profits, the denominator of the profit efficiency ratio. This percentage difference in measured profit efficiency between the two distribution systems is not directly comparable with the measured cost efficiency percentage difference because the denominators are different (predicted potential profits versus predicted costs). We will adjust these efficiencies to be comparable shortly.

The data in Table 2 suggest that the average profit efficiency difference between the two product distribution groups may well depend upon the relationships between these groups and firm size. As can be seen in the 'Standard Profit Function' section of the table, measured profit efficiency is strongly increasing in insurer size, with weighted average efficiency rising from about 10% for Size 1 to over 80% for Size 4. There are three likely reasons for these measured profit scale economies. First, there may simply be strong scale economies in terms of insurer revenues. Since there appear to be no substantial cost scale economies or diseconomies within the range of observed insurer sizes, it may simply be the case that selling more insurance at a given set of input and output prices raises revenues more than costs.<sup>6</sup> Second, there may be a measurement problem in comparing the outputs of large and small firms, with larger firms engaging in product sub-lines that are more service-intensive and generate greater revenues. This is consistent with considerable anecdotal evidence in the insurance trade press that larger firms tend to dominate the market for large, complex national and international risks that require specialized loss prevention services as well as a high level

---

<sup>6</sup>As discussed by Berger, Hancock, and Humphrey (1993), profit efficiency could be overstated in this circumstance if the firm could not sell its full-efficiency level of output without lowering prices.

of underwriting and risk management expertise. By contrast, many smaller firms operate regionally and focus either on small niche markets or on predictable, standardized coverages such as personal automobile insurance.

Third, there may be a scale economy bias in the measured profit efficiencies because of the treatment of outputs as completely variable. As we argued above for treating debt and equity capital as fixed netputs, it may take many decades for firms to build up to the size of the largest insurers in terms of insurance output, measured here as the real present value of losses. If firms in Size 1 cannot reasonably produce the output levels of Size 4 within the sample period, then their predicted potential profits (the denominator of the profit efficiency ratio) are overstated, biasing their measured profit efficiency downward. That is, smaller firms may be compared to a frontier that is unattainable, making these firms appear exceptionally inefficient when they are not. This problem does not occur for cost inefficiency, because the cost equation (3) treats all of the output quantities as exogenous.

To determine whether the differing treatment of output between the cost and profit function is responsible for the profit efficiency scale effect, we also estimated an alternative ‘nonstandard’ profit function that specifies all outputs as fixed. That is, we replace the output prices in the standard profit function with output quantities, yielding an identical specification to the cost function except for the dependent variable. Thus, this alternative form -- which is similar to the nonstandard revenue function employed by Pulley, Berger, and Humphrey (1993) -- removes the one difference in specification between the cost equation (3) and the profit equation (4), to be sure that our results are not related to specification. As well, it serves as a robustness check on our main results. The nonstandard profit efficiency estimates, shown in the ‘Nonstandard Profit Function’ columns (the last two columns) of Table 2, are quite comparable to the standard efficiency estimates. The weighted average nonstandard profit efficiency estimate for direct writers is 65.5 percent, compared to 55.3 percent for independent agency insurers, a difference of 10.2 percent. Thus, our overall profit efficiency results are robust to the specification of the profit function. Moreover, the finding of very strong scale economies is also robust and thus does not appear to be related to the profit function specification.

The profit size effect is analyzed further in the regression analysis below. The size controls in our

regressions permit us to disentangle the effects of distribution systems on profit efficiency from the size effect. This is particularly important in view of the Sass and Gisser (1989) hypothesis that firms using the direct writing distribution system tend to be larger than those using the independent agency system. Thus, direct writers could tend to look more efficient simply because they are larger, but may be no more efficient for a given size.

Despite the potential difficulties in measuring profit efficiencies, a comparison of these efficiencies with some commonly used indicators of profitability suggest that our profit efficiency measures are reasonably well behaved. The Spearman (rank-order) correlation of profit efficiency with return on equity (ROE) is .22, and with return on assets (ROA) is .08, both statistically significant at the 1% level. Finally, the average profit efficiencies in Table 2 of about 60% to 70% suggests that insurers tend to lose about 30% to 40% of their potential profits to inefficiency. While these inefficiencies may seem high, they are actually somewhat less than the profit inefficiencies found for other financial institutions (Berger, Hancock, and Humphrey 1993).

As discussed above, it is important to compare the magnitudes of the cost and profit efficiencies. If most of the measured cost efficiency difference between direct writers and independent agency insurers remains as a profit efficiency differential, then the market imperfections hypothesis would be supported. In contrast, if most of the measured cost efficiency difference is eliminated when the profit efficiency is measured, then the product quality hypothesis would be supported. This is because extra costs that go into product quality improvements would tend to be compensated for on the revenue side.

The cost and profit efficiency ratios shown in Table 2 are not directly comparable because cost efficiency is measured in terms of the proportion of costs that are spent efficiently, whereas profit efficiency is measured in terms of the proportion of potential profits that are earned. In order to compare the cost and profit findings, they must be put into comparable terms. To do so, we state both cost and profit performance in terms of the proportion of potential profits that are lost to inefficiency. Thus, for both costs and profits, we compute the ratio of the dollar value of inefficiencies (actual costs minus minimum costs, potential profits minus actual profits) to potential profits (all corrected for random error). In this manner, the profit

inefficiency ratios should include all of the “true” inefficiency included in the cost inefficiency ratio plus any revenue inefficiencies, and should net out any mismeasured cost inefficiencies that arise from extra expenditures on product quality that are recompensed on the revenue side.

The comparison of cost and profit inefficiencies is presented in Table 3. The weighted average cost inefficiency for direct writers is an astounding 138.9% of potential profits. Thus, if the cost efficiencies are to be believed, these firms are losing money on average. The profit inefficiencies, in contrast, are a weighted average of only 30.1% of potential profits. A similar situation in which measured cost inefficiencies exceed potential profits and far outstrip profit inefficiency occurs for insurers using the independent agency distribution system. For this group, measured cost inefficiencies consume 168.5% of potential profits, whereas profit inefficiencies consume only 39.7%. By definition, “true” cost inefficiencies can be no greater than profit inefficiencies, since profit inefficiencies include both cost and revenue inefficiencies. These findings are consistent with the *product quality hypothesis*, i.e., the notion that measured cost inefficiencies primarily reflect unobserved differences in product quality, rather than true inefficiency, even among firms using the same insurance distribution system. The results imply that firms differ in the intensity or quality of service they provide, creating variation in costs, but they are recompensed for most of these cost differences on the revenue side.

To address the main question of this paper -- how the two product distribution systems coexist with different costs -- we compare the difference in measured cost inefficiency between direct writers and independent agency insurers with the profit inefficiency difference between the two groups. The results in Table 3 show that independent agency firms are both more cost inefficient and profit inefficient than direct writing insurers, but that the measured cost inefficiency difference is much larger. The cost inefficiency differential is 29.6% of potential profits (168.5% - 138.9%), whereas the profit inefficiency differential between the groups based on the standard profit function (equation (4)) is only 9.6% of potential profits (39.7% - 30.1%), about one-third as large. Thus, most of the cost inefficiency differential between the groups does not carry through as profit inefficiency. As mentioned above, the robustness of this result is confirmed

by the nonstandard profit function estimates, which show a comparable profit efficiency differential of 10.2% between direct writers and independent agency firms. These results provide strong support for the *product quality hypothesis*, that much of the measured cost inefficiency is not true inefficiency, but rather the costs of providing better service for which the independent agency insurers are compensated with higher revenues.

## **VII. Ex Post Regression Analysis**

As discussed above, the efficiency comparisons shown in Tables 2 and 3 could be affected by some of the assumptions made about what conditions the firm can control. The use of the profit function in (4) assumes that the firm can freely choose its organizational form (stock versus mutual), its scale of operations, and its product mix to maximize profits. The use of the cost function (3) also allows organizational form to vary, but takes scale and product mix as exogenous. If insurers are not able to quickly and costlessly switch their organizational form, scale, or output mix because of difficulties in changing charters, regulatory impediments to moving quickly across state lines, or barriers created by customer allegiances to other companies, then efficiency may be mismeasured. The minimum predicted costs or maximum predicted potential profits implied by the cost or profit function estimation may not be achievable except over a period of decades, biasing the measured efficiency downward. In this circumstance, if the distribution system is statistically related to the organizational form, scale, or product mix, then the average difference in measured efficiency between direct writing and independent agency insurers could be overstated or understated. That is, if direct writers are more often represented among stock or mutual forms, are larger or smaller than independent agency firms, or have a different average product mix from independent agency insurers, this may explain part of the measured difference in efficiency between the two groups.

For this reason, we test whether our results are robust by controlling for these factors in an ex post regression analysis. We regress the cost and profit inefficiency ratios from Table 3 on a dummy variable for whether the firm is a direct writer (independent agency is the omitted category), and also include controls and interaction effects for organizational form, scale, and product mix to see if the effect of being a direct writer

on efficiency is altered by these other variables. The regression analysis also provides evidence on several hypotheses that have been advanced in the literature concerning the relationship between insurer efficiency and organizational form, size, and product mix.

An extensive literature has developed on organizational form in insurance, primarily based on agency theory. Several organizational forms are present in the insurance industry, the most prominent being the stock and mutual forms of ownership. The ‘expense preference hypothesis’ of organizational form predicts that mutuals will have higher costs than stocks because the mutual form of ownership affords owners less effective mechanisms for controlling and disciplining managers (e.g., Verbrugge and Jahera, 1981, Mester, 1989).<sup>7</sup> Thus, the managers of mutuals may engage in excessive consumption of perquisites (expense preference behavior), and mutual managers may be less likely than stock managers to pursue the owners’ objective of maximizing profits.

Fama and Jensen (1983a, 1983b) hypothesize that stocks and mutuals will be sorted into market segments where they have comparative advantages in dealing with various types of principal-agent problems. The ‘managerial discretion hypothesis’ predicts that stock insurers should be more successful in lines of insurance requiring relatively high levels of managerial discretion because stock ownership provides a superior mechanism for controlling principal-agent conflicts between managers and owners (Mayers and Smith, 1988). Agency theory also predicts that mutuals should be relatively successful in lines of insurance where policyholder-owner conflicts are important, because the mutual form merges the policyholder and ownership functions.

The expense preference hypothesis predicts that mutuals will be less efficient than stocks. However, if firms are sorted into market segments on the basis of their ability to control different types of principal-agent problems, firms may be equally efficient in the market segments where they have comparative advantages.

---

<sup>7</sup>The stock form of ownership provides several mechanisms for controlling managers that are not available to mutuals, including the alienability of residual claims, proxy fights, and the market for takeovers (Fama and Jensen, 1983a, 1983b).

Thus, if our controls for size and business mix effectively proxy for market segmentation, there may be no significant efficiency differential between stocks and mutuals, especially if product market competition mitigates expense preference behavior.<sup>8</sup>

Kim, Mayers, and Smith (1994) analyze the relationship between organizational form and distribution system and hypothesize that stock firms using independent agents will be more successful than direct writing stock firms because independent agents are more effective than exclusive agents in controlling policyholder-owner conflicts. Again, this is due to the credible threat to switch business to other insurers if owners take actions that are detrimental to policyholder interests. We test two empirical predictions of the Kim-Mayers-Smith hypothesis: (1) stock firms are more likely than mutuals to use independent agents, and (2) stock firms that use independent agents are more efficient than stocks that use exclusive agents.

An important hypothesis regarding the relationship between firm size and distribution systems is provided by Sass and Gisser (1989), who predict that larger firms are more likely to use exclusive agents because they are more able than small firms to generate a sufficient volume of business to support exclusive agents. Thus, it may be more efficient in terms of costs or profits for direct writers to be relatively large, suggesting that any relationship between size and efficiency is likely to be stronger for direct writing firms than for independent agency firms. We provide evidence on this hypothesis by including interactions between size

---

<sup>8</sup>There are several other reasons to control for business mix. One reason is that business mix differs systematically by distribution system. Exclusive agency insurers generate about three-fourths of their revenues from personal lines, whereas independent agency insurers generate more than half of their business from the commercial lines (A.M. Best Company, 1994). Thus, if service intensity differs among lines of insurance, failure to control for line of business mix could bias the estimates of cost and profit efficiency for the two distribution systems. Service intensity is generally believed to be higher in the relatively complex commercial lines than in the more standardized personal lines, and commercial lines also may generate higher profits because they expose the insurer to greater risk (Lamm-Tennant and Starks, 1993). Other reasons for controlling for line of business mix are suggested by Marvel (1982) and Grossman and Hart (1986). Marvel hypothesizes that independent agency firms may be less successful in lines of business where advertising is relatively important because independent agents can expropriate the benefits of advertising by placing customers with other insurers who may pay higher commissions but incur less advertising expense. Grossman and Hart argue that independent agents are more likely to be present in lines where agents incur relatively high costs in acquiring and servicing business because independent agency contracts give agents ownership of the customer list, thus forestalling insurer expropriation of the agent's sales and service investment.

and distribution system in some of our regression specifications.

The cost inefficiency regressions are presented in Table 4, Models 1 through 10. The dependent variable in the regressions is the ratio of the measured cost inefficiency to potential profits for each firm. Several versions of the regression model are presented, with different combinations of control variables and interactions to account for the effects of organizational form, scale, and product mix. The 378 observations included in these regression equations exclude 15 of the 393 firms (114 direct writers, 279 independent agency insurers) reported in the earlier tables because of switching between organizational forms or missing data on whether they were stock or mutual firms.<sup>9</sup>

Model 1 includes dummy variables for distribution system, organizational form, and size class. In each case, there is an omitted category where the dummy variables equal zero, and the effects are measured relative to this base case. *DIRECT* gives the effect of being a direct writer as opposed to the base case of being an independent agency firm, *STOCK* gives the effect of being a stock firm as opposed to the base case of being a mutual organization, and *SIZE2*, *SIZE3*, and *SIZE4* give the effects of being in the largest three size classes as opposed to the base case of being in the smallest size class. As shown, the coefficient of *DIRECT* is -0.324, which is statistically significantly different from zero at standard confidence levels. This estimate is very close to the cost efficiency differential of 29.6% of potential profits (168.5% - 138.9%), given in Table 3. This supports the robustness of our earlier result -- direct writers maintain a cost inefficiency to potential profits ratio advantage over independent agency insurers of about 30%, even after controlling for organizational form and size class. The other coefficients in Model 1 suggest that organizational form is not important for determining the proportion of potential profits lost to cost inefficiency, but that larger firms are less efficient in this regard.

---

<sup>9</sup>There were fourteen firms in the sample that are organized as reciprocals, an organizational form where the policyholders are owners of the firm but where the legal and organizational characteristics of the firm differ somewhat from mutuals (see Mayers and Smith, 1988). In the regression analysis, the reciprocals were included in the mutual category because of the policyholder ownership feature. In preliminary analysis, the exclusion of reciprocals from the regressions had no noticeable effect on the results.

Model 2 adds control variables for product mix, defined as the ratios of insurance output by category to total insurance output. Three output proportions are included: long-tail personal lines and long- and short-tail commercial lines. The long-tail commercial lines proportion is the omitted category. Inclusion of these variables (along with all the controls for organizational form and scale variables), accounts for the possibility that some firms may be stuck with suboptimal product mix for historical or regulatory reasons, at least over the sample period. The regression results show that the coefficient of DIRECT becomes slightly larger in absolute value, -0.399, and is again statistically significant, further supporting the robustness of our result that direct writers maintain a measured cost advantage over independent agency insurers of about 30% (or perhaps more) of potential profits. The three insurance output proportions are also statistically significant, suggesting that cost inefficiency is increasing in the proportion of long-tail commercial coverage written by insurers.<sup>10</sup>

In Models 3, 4, and 5, we begin testing the cost efficiency effect of distribution systems using interaction terms. We interact DIRECT and STOCK with a measure of insurer size, LN(INS OUT), the natural log of total insurance output (discounted real losses for the four lines of insurance). The purpose of switching to the continuous measure of scale instead of the three dummies used in Models 1 and 2 is to conserve on the number of interaction terms. These interaction terms allow the effects of distribution system and organizational form to differ by insurer size. In order to determine the effect of distribution system from these equations, i.e., the effect on the dependent variable of DIRECT, we take the derivative with respect to **DIRECT at the mean value of LN(INS OUT). That is, we evaluate  $\partial CI / \partial DIRECT = \beta + \gamma \text{LN(INS OUT)}$  at the mean of the data, where CI is the cost inefficiency ratio and  $\beta$  and  $\gamma$  are the coefficients of DIRECT and LN(INS OUT)  $\times$  DIRECT, respectively.** The values of these derivatives are shown in the bottom row of the Table, including the derivatives from Models 1 and 2, which are trivially equal to the coefficients on

---

<sup>10</sup>The product mix result is not surprising, given that our sample period was a time of turmoil for the long-tail commercial lines market, which primarily consists of commercial liability and workers' compensation. Losses and prices fluctuated dramatically during the mid-1980s, leading to a severe crisis in liability markets (see, for example, Winter 1992). Under such conditions it would not be surprising to observe insurers making inefficient decisions such as incorrect allocations of resources to services such as legal fees and claims adjustment.

DIRECT, since no interaction terms were included in those regressions. Note that whenever we include LN(INS OUT) in the interaction terms, we also include its level to be an extra control variable and also to be sure that the interactions are not picking up the independent effect of size.

In Model 3, we include DIRECT, STOCK, the scale variable LN(INS OUT) and the interactions of the scale variable with the other two variables. In Model 4, we add the controls for product mix. In Model 5, we also add back in the dummy variables for size class to allow for an extra non-continuous effect of size. The derivatives with respect to DIRECT shown in the bottom row of the table continue to confirm our original estimates, indicating that direct writers have a measured cost advantage of 30% or more over independent agency insurers in terms of potential profits.

Models 6 through 10 on the second page of Table 4 replicate the Models 1 through 5, except that we allow for interaction effects between the distribution system and organizational form of the insurer. We replace the two dummy variables DIRECT and STOCK with three dummies, DIRECT $\checkmark$ STOCK, DIRECT $\checkmark$ MUTUAL, and AGENCY $\checkmark$ STOCK (AGENCY $\checkmark$ MUTUAL is the base case). Thus, each combination of distribution system and organizational form is allowed to have a completely different effect on the cost inefficiency ratio. For Models 8 through 10, we interact the three new dummy variables with the LN(INS OUT) variable in place of the interactions with the separate DIRECT and STOCK dummies.

In Model 6, we determine the effect of distribution systems on cost inefficiency separately for stock and mutual insurers. The effect of DIRECT for stock firms is the coefficient of DIRECT $\checkmark$ STOCK (-0.283) minus the coefficient of AGENCY $\checkmark$ STOCK (0.002), yielding a 28.5% effect, close to the consensus effect in Table 3 and all the prior equations in Table 4. The effect of DIRECT for mutuals is simply the coefficient of DIRECT $\checkmark$ MUTUAL, since AGENCY $\checkmark$ MUTUAL is the omitted base case. The effect is a 34.6% advantage of direct writers over independent agency firms in terms of cost inefficiency/potential profits, again confirming our main result.

The derivatives with respect to DIRECT for both stock and mutual firms are shown at the bottom of the second page of Table 4. Although Models 6 and 7 imply that both direct writing stocks and direct writing

mutuals have a significant cost efficiency advantage over their independent agency counterparts, the differentials for mutuals are larger than for stocks and the mutual derivatives are significant at higher confidence levels. In the most fully specified models (Models 8-10), there is no significant difference in inefficiency between direct writing and independent agency stock insurers, whereas the efficiency advantage of direct writing mutuals over agency mutuals is statistically significant and ranges from 32.8 to 44.7%. A possible explanation for this finding is the Kim, Mayers, and Smith (1994) hypothesis that the independent agency system helps to control owner-policyholder conflicts in the stock form of ownership, leading to lower agency costs which may offset the cost efficiency advantage of the direct writing distribution system.

Table 5 shows exactly the same 10 regression equations as Table 4, the only difference being that the dependent variable is the ratio of **profit** inefficiency to potential profits, rather than using cost inefficiency in the numerator. Recall that in Table 3, we found the average difference in the profit inefficiency ratio between direct writers and independent agency firms to be about 10% of potential profits, with direct writers being more efficient. The derivatives with respect to DIRECT, DIRECTŽSTOCK, and DIRECTŽMUTUAL in Table 5 suggest a profit efficiency differential smaller (in absolute value) than the 10 percent differential shown in Table 3. The maximum derivative (in absolute value) in Models 1 through 5 is -5.0%, implying that direct writers are about 5% more profit efficient than independent agency firms.

In Models 6 through 10, the maximum differential between direct writing and independent agency stock insurers is -8.6%, and the maximum for mutuals is -3.5%. The most fully specified models (8-10) in Table 5 suggest that stock direct writers are 6.6 to 8.2% **more** profit efficient than stock independent agency firms and that mutual direct writers are from 3.1% **more** profit efficient to 1.4 percent **less** profit efficient than mutual independent agency insurers. Moreover, none of the derivatives in Models 8-10 is statistically significant, implying that there is no statistically measurable difference in profit efficiency between direct writers and independent agency firms after controlling for size, organizational form, and business mix.

The results provide strong support for the *product quality hypothesis*. That is, the differences in measured cost inefficiency shown in Table 4 actually reflect unmeasured differences in product quality (service

intensity), which are recompensed by additional revenues, so that there are no statistically significant differences in profit inefficiency between direct writers and independent agency firms.

Finally, we can draw some inferences regarding the other hypotheses about distribution systems and firm characteristics discussed above. Our findings do not support the expense preference hypothesis, i.e., there is no evidence that cost inefficiencies are significantly higher for mutuals than for stocks based on the derivatives with respect to STOCK in Table 4. The profit efficiency results in Table 5 provide some support for the hypothesis that stocks are more successful in maximizing profits than mutuals, but the profit inefficiency differentials between stocks and mutuals are not statistically significant in the more fully specified models.

The managerial discretion hypothesis rests on the assumption that insurance markets are segmented into submarkets requiring differing degrees of managerial discretion. Our findings provide evidence of market segmentation in insurance and of the existence of service intensity differentials across the principal segments. The large firms in our sample are less cost efficient but more profit efficient than small firms, suggesting that large firms are engaged in more complex and perhaps more risky activities (such as national and international coverage of commercial risks) that generate higher costs but also higher profits, and are likely to require higher levels of managerial discretion. With regard to business mix, the measured cost efficiencies are lowest for long-tail commercial lines insurance in comparison to short-tail commercial and personal lines coverages. However, the profit efficiencies are highest for the long-tail commercial lines, confirming that service intensity (e.g., settlement of complex products liability lawsuits) is highest for this type of insurance. Managerial discretion is generally believed to be more important in the commercial lines because of the need for individualized underwriting and pricing. Consistent with the hypothesis, stock insurers generate 60% of their revenues from the commercial lines, whereas mutuals obtain only 35% of their revenues from the commercial lines (A.M. Best Company, 1994).

The results are also consistent with the principal-agent theory of organizational form -- there is no significant cost efficiency difference between stocks and mutuals (Table 4) and the profit inefficiency

differentials between the two groups of firms are not significant after controlling for size, business mix, and organizational form (Table 5). This would be the likely outcome in a competitive market where firms are sorted into market segments where they have comparative advantages, leading to comparable profit efficiencies in the various market segments. This finding is reinforced by the significant difference in business mix across the stock and mutual segments of the industry. These results parallel our findings for the direct writing and independent agency distribution systems.

We also provide some support for the Kim, Mayers, and Smith hypothesis. Based on Table 1, it is clear that stock insurers are more likely to use independent agents than mutuals, consistent with the hypothesis (50% of stocks use independent agents, compared to only 28% of mutuals). Based on Table 4, direct writing mutuals are significantly more cost efficient than independent agency mutuals, whereas direct writing stocks are not significantly more cost efficient than independent agency stocks in the more fully specified models. However, these tendencies do not carry over to profit efficiency -- neither direct writing stocks nor direct writing mutuals are significantly more profit efficient than independent agency firms.

The cost efficiency results support the Sass-Gisser hypothesis that it is advantageous for direct writers to be large. The significant negative coefficients on the  $\text{LN}(\text{INS OUT}) \times \text{DIRECT}$  variable in equations 3 through 5 of Table 4 imply that large direct writers are more cost efficient than smaller direct writers. Equations 8 through 10 of Table 4 also support this inference, although the results are weaker for direct writing stock insurers than for direct writing mutuals. The profit efficiency results generally do not support the Sass-Gisser hypothesis -- the interaction terms for distribution system and firm size have the expected negative signs but are almost always insignificant. Thus, we find mixed support for the Sass-Gisser hypothesis.

## **VIII. Conclusion**

The long-term coexistence of alternative distribution systems for the same or similar financial products poses an economic puzzle. This paper examines a particularly interesting case of alternative distribution systems, the independent agent and direct writing systems found in the property-liability insurance industry. Prior research indicates that the independent agency system has higher costs, and two hypotheses have been advanced to explain the survival of independent agents. According to the *market imperfections hypothesis*, impediments to competition allow insurers using independent agents to be less efficient. Thus, firms with higher costs that result from inefficiency can coexist with other firms using more efficient product distribution systems and simply earn lower profits than the more efficient firms. In contrast, the *product quality hypothesis* explains the coexistence of firms using independent and exclusive agents in terms of product quality niches; independent agency insurers provide more or better services than exclusive agency insurers and are compensated for the higher costs with higher revenues.

This paper introduces a new methodology to resolve the controversy. We estimate both cost and profit functions for a sample of independent and direct writing insurers, using the Fourier-flexible functional form for both costs and profits. If measured cost inefficiencies are attributable to service intensity which is valued by the market, then the additional services should generate revenues to offset the higher costs so that the profit inefficiency differences should be less than measured cost inefficiency differences. On the other hand, if the measured cost inefficiency differential between the two groups of firms represents true inefficiency, then most of the cost differentials will be reflected in profit efficiency differentials.

Our empirical results confirm that independent agency firms have higher costs on average than direct writers. The principal finding of the study is that most of the average differential between the two groups of firms disappears in the profit function analysis. This is a robust result that holds both in our tables of averages and in the regression analysis and applies to both the standard and non-standard profit functions. Based on averages, the profit efficiency differential is at most one-third as large as the profit efficiency differential. Based on the regression analysis, the profit inefficiency differential is at most one-fourth as large as the cost

inefficiency differential, and the profit inefficiency differential is not statistically significant in the more fully specified models that control for size, organizational form, and business mix. The results thus provide strong support for the *product quality hypothesis* and do not support the *market imperfections hypothesis*. The higher costs of independent agents appear to be due almost entirely to the provision of higher quality services, which are compensated for by additional revenues.

These findings have potentially important implications for efficiency studies in other industries. They suggest that relying on cost efficiency alone is likely to produce misleading results, unless appropriate controls are available for product quality. Such controls often are not available, especially in the services sector where outputs are often intangible and implicitly priced. The estimation of profit as well as cost functions is likely to be necessary to measure the true levels of efficiency.

A significant public policy implication is that regulatory decisions perhaps should not be based on costs alone. Our findings imply that marketing cost differentials among insurers are mostly attributable to service differentials rather than to inefficiency and therefore do not represent social costs. Thus, using regulatory rate suppression as a policy mechanism to reduce marketing costs may deprive some market segments of desired services and adversely affect economic welfare. The profit inefficiency results show that there is room for improvement in both the independent and direct writing segments of the industry. However, facilitating competition is likely to be a more effective approach to increasing efficiency than restrictive price regulation.

## References

- A.M. Best Company, 1994, *Best's Aggregates and Averages* (Oldwick, NJ).
- Bauer, Paul W., Allen N. Berger, and David B. Humphrey, 1993, "Efficiency and Productivity Growth in U.S. Banking," in H.O. Fried, C.A.K. Lovell, and S.S. Schmidt, eds., *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford: Oxford University Press, 386-413.
- Berger, Allen N., 1993, "'Distribution-Free' Estimates of Efficiency in the U.S. Banking Industry and Tests of the Standard Distributional Assumptions," *Journal of Productivity Analysis*, 4 (September): 261-92.
- Berger, Allen N., Diana Hancock, and David B. Humphrey, 1993, "Bank Efficiency Derived from the Profit Function," *Journal of Banking and Finance*, 17 (April): 317-47.
- Berger, Allen N., and David B. Humphrey, 1991, "The Dominance of Inefficiencies over Scale and Product Mix Economies in Banking," *Journal of Monetary Economics* 28 (August): 117-48.
- Berger, Allen N., and David B. Humphrey, 1992a, "Megamergers in Banking and the Use of Cost Efficiency as an Antitrust Defense," *Antitrust Bulletin* 37 (Fall): 541-600.
- Berger, Allen N., and David B. Humphrey, 1992b, "Measurement and Efficiency Issues in Commercial Banking," in Z. Griliches, ed., *Output Measurement in the Service Sectors*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 56, University of Chicago Press (Chicago, IL): 245-79.
- Berger, Allen N., William C. Hunter, and Stephen G. Timme, 1993, "The Efficiency of Financial Institutions: A Review and Preview of Research Past, Present, and Future," *Journal of Banking and Finance*, 17 (April): 221-49.
- Berger, Allen N., John H. Leusner, and John J. Mingo, 1994, "The Efficiency of Bank Branches," working paper, Board of Governors of the Federal Reserve System, Washington, D.C.
- Berger, Lawrence A., Paul R. Kleindorfer, and Howard Kunreuther, 1989, "A Dynamic Model of the Transmission of Price Information in Auto Insurance Markets," *Journal of Risk and Insurance* 56: 17-33.
- Braeutigam, Ronald R. and Mark V. Pauly, 1986, "Cost Function Estimation and Quality Bias: the Regulated Automobile Insurance Industry," *Rand Journal of Economics* 17: 606-617.
- Bughin, J., 1993, "X-Inefficiency in the Insurance Industry: An Analysis of the Cost Effectiveness of the Investment Function of U.S. Companies," working paper, Université Libre de Bruxelles, Brussels, Belgium.
- Coleman, T., L. Fisher, and R. Ibbotson, *U. S. Treasury Yield Curves: 1926-1988* (New York: Moody's Investors Service).
- Cummins, J. David and Sharon Tennyson, 1992, "Controlling Automobile Insurance Costs," *Journal of Economic Perspectives* 6:95-115.
- Cummins, J. David and Mary A. Weiss, 1993, "Measuring Cost Efficiency In the Property-Liability Insurance Industry," *Journal of Banking and Finance* 17: 463-482.

- Cummins, J. David and Jack L. VanDerhei, 1979, "The Relative Efficiency of Property-Liability Distribution Systems," *Bell Journal of Economics* 10: 709-719.
- Dahlby, Bev and Douglas S. West, 1986, "Price Dispersion in an Automobile Insurance Market," *Journal of Political Economy* 94: 418-438
- Fama, Eugene and Michael Jensen, 1983a, "Separation of Ownership and Control," *Journal of Law and Economics* 26: 301-325.
- Fama, Eugene, and Michael C. Jensen, 1983b, "Agency Problems and Residual Claims," *Journal of Law and Economics* 26: 327-349.
- Fecher, F., D. Kessler, S. Perelman, and P. Pestieau, 1993, "Productive Performance in the French Insurance Industry," *Journal of Productivity Analysis* 4: 77-93.
- Ferrier, G.D. and C.A.K. Lovell, 1990, "Measuring Cost Efficiency In Banking: Econometric and Linear Programming Evidence," *Journal of Econometrics* 46: 229-245.
- Ferrier, G.D., S. Grosskopf, K. Hayes, and S. Yaisawarng, 1993, "Economies of Diversification in the Banking Industry: A Frontier Approach," *Journal of Monetary Economics* 31: 229-249.
- Gallant, A. R., 1981, "On the Bias in Flexible Functional Forms and an Essentially Unbiased Form: The Fourier Flexible Form," *Journal of Econometrics* 15: 221-245.
- Gardner, Lisa A. and Martin F. Grace, 1993, "X-Efficiency in the US Life Insurance Industry," *Journal of Banking and Finance* 17: 497-510.
- Greene, W.H., 1990, "A Gamma Distributed Stochastic Frontier Model," *Journal of Econometrics* 13: 141-163.
- Grossman, S. and O.D. Hart, 1986, "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration," *Journal of Political Economy* 94: 691-719.
- Ibbotson Associates, 1993, *Stocks, Bonds, Bills and Inflation: 1993 Yearbook* (Chicago).
- Joskow, Paul, 1973, "Cartels, Competition, and Regulation in the Property-Liability Insurance Industry," *Bell Journal of Economics and Management Science* 4: 395-427.
- Kim, Joong K., David Mayers, and Clifford W. Smith, Jr., 1994, "On the Choice of Insurance Distribution Systems," working paper, William E. Simon Graduate School of Business, University of Rochester, Rochester, NY.
- Lamm-Tennant, Joan and Laura T. Starks, 1993, "Stock versus Mutual Ownership Structures: The Risk Implications," *Journal of Business* 66: 29-46.
- Marvel, H. P., 1982, "Exclusive Dealing," *Journal of Law and Economics* 25: 1-25.
- Mayers, David, and Clifford W. Smith, Jr., 1981, "Contractual Provisions, Organizational Structure, and Conflict Control in Insurance Markets," *Journal of Business* 54: 407-434.

- Mayers, David and Clifford W. Smith, Jr., 1988, "Ownership Structure Across Lines of Property-Casualty Insurance," *Journal of Law and Economics* 31: 351-378.
- McAllister, Patrick and Douglas McManus, 1993, "Resolving the Scale Efficiency Puzzle In Banking," *Journal of Banking and Finance* 17: 389-405.
- Mester, Loretta, 1989, "Testing for Expense Preference Behavior: Mutual Versus Stock Savings and Loans," *Rand Journal of Economics* 20: 483-498.
- Mitchell, Karlyn and Nur M. Onvural, 1993, "Economies of Scale and Scope at Large Commercial Banks: Evidence from the Fourier Flexible Functional Form," working paper, College of Management, North Carolina State University, Raleigh, NC.
- Pauly, Mark V., Howard Kunreuther, and Paul Kleindorfer, 1986, "Regulation and Quality Competition in the U.S. Insurance Industry," in Jorg Finsinger and Mark Pauly, eds., *The Economics of Insurance Regulation* (New York: St. Martin's Press).
- Pulley, Lawrence B., Allen N. Berger, and David B. Humphrey, 1993, "Do Consumers Pay for One-Stop Banking? Evidence from a Non-Standard Revenue Function," FEDS Working Paper #93-30, Board of Governors of the Federal Reserve System (August).
- Regan, Laureen and Sharon Tennyson, 1994, "Agent Discretion and the Choice of Insurance Marketing System," working paper, University of Pennsylvania, Philadelphia, PA.
- Sass, Tim and Micha Gisser, 1989, "Agency Costs, Firm Size, and Exclusive Dealing," *Journal of Law and Economics* 32: 381-400.
- Schmidt, P. and R.C. Sickles, 1984, "Production Frontiers and Panel Data," *Journal of Business and Economic Statistics* 2: 367-374.
- Verbrugge, J. E., and J.S. Jahera, 1981, "Expense Preference Behaviour in the Savings and Loan Industry," *Journal of Money, Credit, and Banking* 13: 465-476.
- Weiss, Mary A., 1990, "Productivity Growth and Regulation of P/L Insurance: 1980-1984," *Journal of Productivity Analysis* 2: 15-38.
- Winter, Ralph, 1991, "The Liability Insurance Market," *Journal of Economic Perspectives* 5: 115-136.
- Winter, Ralph, 1994, "The Dynamics of Competitive Insurance Markets," *Journal of Financial Intermediation* 3: 379-415.
- Yuengert, Andrew M., 1993, "The Measurement of Efficiency In Life Insurance: Estimates of a Mixed Normal-Gamma Error Model," *Journal of Banking and Finance* 17: 483-496.
- Zi, Hongmin, 1994, "Measurement of Cost Efficiency In the U.S. Life Insurance Industry: A Comparison of Alternative Methodologies," working paper, University of Pennsylvania, Philadelphia, PA.

**Table 1**  
**VARIABLES USED IN THE COST AND PROFIT FUNCTIONS**

		Sample Means, By Insurer Type				
Symbol	Definition	Direct Writers	Ind. Agents	Dis. System Mixed	Missing	Total
N	Number of firms	114	279	26	53	472
S	Percent Stock	28.1%	50.2%	84.6%	41.5%	45.8%
VC	Variable Costs	172.18	111.59	37.71	30.81	113.08
Π	Profits	32.64	14.60	11.57	4.83	17.70
P1	Price of labor input	0.986	0.986	0.986	0.986	0.986
P2	Price of materials input	1.216	1.216	1.216	1.216	1.216
P3	Price of short tail personal lines output	0.576	0.668	0.564	0.573	0.629
P4	Price of short tail commercial output	0.663	0.938	0.685	0.740	0.836
P5	Price of long tail personal lines output	0.504	0.704	0.491	0.501	0.621
P6	Price of long tail commercial output	1.041	1.110	0.921	0.937	1.064
P7	Price for real investment output	0.100	0.104	0.103	0.107	0.103
Y3	Short tail personal lines output: present value of real loss	64.91	15.22	10.08	3.61	25.64
Y4	Short tail commercial output: present value of real losses	32.59	22.15	23.48	14.00	23.83
Y5	Long tail personal lines output: present value of real losses	138.91	40.39	7.85	7.05	58.65
Y6	Long tail commercial output: present value of real losses	37.52	49.91	15.21	16.12	41.21
Y7	Output volume for real invested assets	734.10	415.18	212.67	138.55	449.99
Y8	Policy holders' real debt capital input	542.47	362.42	168.12	108.68	366.71
Y9	Volume of real equity capital input	280.90	144.78	79.69	62.94	164.88

NOTE: Quantities are in millions of real 1982 dollars.

Table 2  
Average Cost Efficiency and Profit Efficiency

	Standard Cost Function: Minimum Costs/Actual Costs		Standard Profit Function: Actual Profits/Potential Profits		Nonstandard Profit Function: Actual Profits/Potential Profits	
	Direct Writers	Ind. Agency	Direct Writers	Ind. Agency	Direct Writers	Ind. Agency
Size1	0.554 17	0.574 80	0.097 17	0.081 80	0.104 17	0.068 80
Size2	0.648 24	0.539 73	0.162 24	0.126 73	0.118 24	0.082 73
Size3	0.653 30	0.521 64	0.459 30	0.363 64	0.377 30	0.306 64
Size4	0.665 43	0.555 62	0.841 43	0.850 62	0.821 43	0.828 62
Total	0.639 114	0.548 279	0.699 114	0.603 279	0.655 114	0.553 279

Note: Firms are ranked by total insurance output (total present value of losses incurred). Size1 = smallest size group. The upper entry in each cell = efficiency ratio, lower entry = number of observations. Efficiencies are weighted averages for firms in each cell. Weights = actual predicted costs and potential profits. Firms that switched marketing system or for which the marketing system is unknown are omitted from the sample.

**Table 3**  
**Cost and Profit Inefficiencies**  
**As Proportions of Potential Profits**

	Direct Writers	Independent Agency
Cost Inefficiency/Potential Profits	1.389	1.685
Profit Inefficiency/Potential Profits: Standard Profit Function	0.301	0.397
Non-standard Profit Function	0.345	0.447
Number of Observations	114	279

NOTE: The inefficiency ratios are total dollar-valued cost and profit inefficiencies for the firms in the sample divided by total potential profits. The inefficiencies and potential profits are measured at the 5 percent truncation level. Firms that switched marketing system or organizational form or for which the marketing system or organizational form are unknown are omitted from the applicable category.

TABLE 4: REGRESSIONS OF COST INEFFICIENCY ON FIRM CHARACTERISTICS

VARIABLE	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
	Coeff	t-Ratio								
INTERCEPT	0.179	1.683	0.628	3.533	-6.593	-9.235	-6.391	-8.352	-3.970	-3.265
DIRECT	-0.324	-2.865	-0.399	-3.324	1.915	2.058	1.493	1.507	1.693	1.721
STOCK	0.018	0.177	0.002	0.017	0.572	0.690	0.775	0.893	0.894	1.009
LONG-TAIL PERSONAL			-0.464	-2.004			-0.220	-0.904	-0.307	-1.290
SHORT-TAIL COMMERCIAL			-0.627	-2.944			-0.278	-1.272	-0.462	-2.153
SHORT-TAIL PERSONAL			-0.599	-2.112			-0.461	-1.556	-0.486	-1.691
SIZE 2	0.215	1.561	0.189	1.354					-0.200	-1.920
SIZE 3	0.821	5.864	0.780	5.460					0.045	0.196
SIZE 4	2.185	15.586	2.182	15.050					0.881	2.469
LN(INS OUT)					0.463	10.380	0.464	10.118	0.311	3.836
LN(INS OUT) • DIRECT					-0.134	-2.418	-0.111	-1.912	-0.125	-2.156
LN(INS OUT) • STOCK					-0.039	-0.765	-0.051	-0.972	-0.057	-1.069
ADJUSTED R-SQUARE	0.443		0.456		0.441		0.442		0.477	
NUMBER OF OBSERVATIONS	378		378		378		378		378	
		<u>t-Ratio</u>								
DERIVATIVE: DIRECT	-0.324	-2.865	-0.399	-3.325	-0.299	-2.536	-0.346	-2.861	-0.366	-2.971
DERIVATIVE: STOCK	0.018	0.177	0.002	0.017	-0.066	-0.641	-0.062	-0.554	-0.046	-0.425

NOTE: Dependent variable = dollar value of cost inefficiency/potential profits. The mean of LN(INS OUT) = the mean of the natural log of insurance output = 16.503 (to calculate the derivative of the inefficiency ratio with respect to the direct writer dummy variable in models 3, 4, and 5). The derivative with respect to DIRECT is (the coefficient of DIRECT) + (for models 3, 4, and 5), (the coefficient of LN(INS OUT)•Direct) \* (the mean of LN(INS OUT)).

TABLE 4 (Continued): REGRESSIONS OF COST INEFFICIENCY ON FIRM CHARACTERISTICS

VARIABLE	MODEL 6		MODEL 7		MODEL 8		MODEL 9		MODEL 10	
	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio
INTERCEPT	0.185	1.698	0.667	3.586	-6.986	-8.524	-6.818	-7.733	-4.729	-3.513
DIRECT ● STOCK	-0.283	-1.503	-0.346	-1.732	2.122	1.377	1.976	1.246	2.421	1.521
DIRECT ● MUTUAL	-0.346	-2.434	-0.469	-3.029	2.667	2.150	2.249	1.692	2.711	2.019
AGENCY ● STOCK	0.002	0.018	-0.048	-0.371	1.113	1.113	1.345	1.277	1.727	1.582
LONG-TAIL PERSONAL			-0.502	-2.112			-0.210	-0.837	-0.308	-1.254
SHORT-TAIL COMMERCIAL			-0.649	-3.014			-0.273	-1.230	-0.470	-2.159
SHORT-TAIL PERSONAL			-0.579	-2.030			-0.480	-1.608	-4.995	-1.730
SIZE 2	0.217	1.568	0.191	1.369					-0.236	-1.390
SIZE 3	0.822	5.863	0.780	5.455					-0.023	-0.096
SIZE 4	2.190	15.449	2.196	15.002					0.817	2.265
LN(INS OUT)					0.489	9.443	0.492	9.200	0.363	4.061
LN(INS OUT) ● DIRECT ● STOCK					-0.151	-1.633	-0.144	-1.527	-0.170	-1.792
LN(INS OUT) ● DIRECT ● MUTUAL					-0.182	-2.433	-0.160	-2.303	-0.191	-2.405
LN(INS OUT) ● AGENCY ● MUTUAL					-0.074	-1.188	-0.088	-1.367	-0.112	-1.681
ADJUSTED R-SQUARE	0.441		0.455		0.439		0.440		0.478	
NUMBER OF OBSERVATIONS	378		378		378		378		378	
DERIVATIVES:		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>
DIRECT (FOR STOCK FIRMS)	-0.285	-1.694	-0.298	-1.613	-0.272	-0.230	-0.298	-0.241	-0.261	-0.197
DIRECT (FOR MUTUALS)	-0.346	-2.434	-0.469	-3.029	-0.328	-2.175	-0.386	-2.435	-0.447	-2.903
STOCK (DIRECT FIRMS)	0.064	0.316	0.123	0.611	-0.044	-0.047	-0.015	-0.015	0.066	0.059
STOCK (AGENCY FIRMS)	0.002	0.018	-0.048	-0.371	-0.100	-0.826	-0.103	-0.777	-0.121	-0.944

NOTE: Dependent variable = dollar value of cost inefficiency/potential profits. The mean of LN(INS OUT) = the natural log of insurance output = 16.503 (to calculate the derivative of the inefficiency ratio with respect to the direct writer dummy variable in models 8, 9, and 10). The derivative with respect to the Direct Writer dummy variable (DIRECT) for stock firms is (the coefficient of DIRECT●STOCK) - (the coefficient of AGENCY●STOCK) + (for models 8, 9, and 10), [ (the coefficient of LN(INS OUT)●DIRECT●STOCK) - (the coefficient of LN(INS OUT)●AGENCY●STOCK)] \*(the mean of LN(INS OUT)). The derivative with respect to DIRECT for mutual firms is (the coefficient of DIRECT●MUTUAL) + (for models 8, 9, and 10) (the coefficient of LN(INS OUT)●DIRECT●MUTUAL)\*(the mean of LN(INS OUT)).

TABLE 5: REGRESSIONS OF PROFIT INEFFICIENCY ON FIRM CHARACTERISTICS

VARIABLE	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
	Coeff	t-Ratio								
INTERCEPT	0.962	40.17	0.883	21.91	2.638	17.09	2.577	15.68	2.169	8.369
DIRECT	-0.052	-1.975	-0.030	-1.118	0.135	0.670	0.301	1.413	0.219	1.047
STOCK	-0.056	-2.478	-0.044	-1.752	0.146	0.790	0.195	1.046	0.120	0.637
LONG-TAIL PERSONAL			0.111	2.116			0.121	2.305	0.130	2.560
SHORT-TAIL COMMERCIAL			0.073	1.520			-0.013	-0.283	0.029	0.637
SHORT-TAIL PERSONAL			0.093	1.449			0.045	0.701	0.049	0.795
SIZE 2	-0.038	-1.235	-0.041	-1.298					0.094	2.623
SIZE 3	-0.265	-8.407	-0.265	-8.171					0.010	0.199
SIZE 4	-0.648	-20.53	-0.658	-20.03					-0.136	-1.788
LN(INS OUT)					-0.116	-12.05	-0.116	-11.80	-0.092	-5.306
LN(INS OUT) • DIRECT					-0.011	-0.933	-0.020	-1.577	-0.015	-1.189
LN(INS OUT) • STOCK					-0.011	-1.024	-0.013	-1.172	-0.009	-0.795
ADJUSTED R-SQUARE	0.614		0.618		0.643		0.648		0.676	
NUMBER OF OBSERVATIONS	378		378		378		378		378	
		<u>t-Ratio</u>								
DERIVATIVE: DIRECT	-0.050	-1.975	-0.030	-1.118	-0.050	-2.272	-0.025	-0.834	-0.023	-0.963
DERIVATIVE: STOCK	-0.056	-2.479	-0.044	-1.752	-0.043	-1.850	-0.022	-1.095	-0.029	-1.114

NOTE: Dependent variable = dollar value of profit inefficiency/potential profits. The mean of LN(INS OUT) = the mean of the natural log of insurance output = 16.503 (to calculate the derivative of the inefficiency ratio with respect to the direct writer dummy variable in models 3, 4, and 5). The derivative with respect to DIRECT is (the coefficient of DIRECT) + (for models 3, 4, and 5), (the coefficient of LN(INS OUT)•Direct) \* (the mean of LN(INS OUT)).

TABLE 5 (Continued): REGRESSIONS OF PROFIT INEFFICIENCY ON FIRM CHARACTERISTICS

VARIABLE	MODEL 6		MODEL 7		MODEL 8		MODEL 9		MODEL 10	
	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio	Coeff	t-Ratio
INTERCEPT	0.957	38.99	0.865	20.55	2.612	14.75	2.521	13.34	2.132	7.440
DIRECT ● STOCK	-0.127	-3.012	-0.098	-2.167	0.138	0.416	0.354	1.042	0.208	0.612
DIRECT ● MUTUAL	-0.029	-0.919	0.003	0.079	0.255	0.950	0.481	1.687	0.352	1.230
AGENCY ● STOCK	-0.042	-1.587	-0.020	-0.679	0.198	0.916	0.282	1.247	0.164	0.706
LONG-TAIL PERSONAL			0.129	2.400			0.140	2.593	0.152	2.898
SHORT-TAIL COMMERCIAL			0.084	1.718			-0.001	-0.027	0.043	0.931
SHORT-TAIL PERSONAL			0.084	1.298			0.035	0.545	0.040	0.644
SIZE 2	-0.040	-1.278	-0.042	-1.334					0.093	2.566
SIZE 3	-0.266	-8.443	-0.265	-8.182					0.009	0.189
SIZE 4	-0.653	-20.49	-0.665	-20.09					-0.142	-1.847
LN(INS OUT)					-0.115	-10.28	-0.114	-9.929	-0.091	-4.766
LN(INS OUT) ● DIRECT ● STOCK					-0.015	-0.767	-0.026	-1.272	-0.017	-0.859
LN(INS OUT) ● DIRECT ● MUTUAL					-0.017	-1.076	-0.029	-1.714	-0.020	-1.206
LN(INS OUT) ● AGENCY ● MUTUAL					-0.014	-1.044	-0.017	-1.260	-0.010	-0.722
ADJUSTED R-SQUARE	0.614		0.619		0.642		0.648		0.677	
NUMBER OF OBSERVATIONS	378		378		378		378		378	
DERIVATIVES:										
		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>		<u>t-Ratio</u>
DIRECT (FOR STOCK FIRMS)	-0.086	-2.264	-0.078	-1.867	-0.082	-0.322	-0.066	-0.247	-0.073	-0.261
DIRECT (FOR MUTUALS)	-0.029	-0.919	0.003	0.079	-0.031	-0.956	0.004	0.114	0.014	0.434
STOCK (DIRECT FIRMS)	-0.098	-2.174	-0.101	-2.214	-0.083	-0.412	-0.074	-0.352	-0.093	-0.394
STOCK (AGENCY FIRMS)	-0.042	-1.587	-0.020	-0.679	-0.032	-1.165	-0.005	-0.167	-0.005	-0.168

NOTE: Dependent variable = dollar value of profit inefficiency/potential profits. The mean of LN(INS OUT) = the natural log of insurance output = 16.503 (to calculate the derivative of the inefficiency ratio with respect to the direct writer dummy variable in models 8, 9, and 10). The derivative with respect to the Direct Writer dummy variable (DIRECT) for stock firms is (the coefficient of DIRECT●STOCK) - (the coefficient of AGENCY●STOCK) + (for models 8, 9, and 10), [ (the coefficient of LN(INS OUT)●DIRECT●STOCK) - (the coefficient of LN(INS OUT)●AGENCY●STOCK)] \*(the mean of LN(INS OUT)). The derivative with respect to DIRECT for mutual firms is (the coefficient of DIRECT●MUTUAL) + (for models 8, 9, and 10) (the coefficient of LN(INS OUT)●DIRECT●MUTUAL)\*(the mean of LN(INS OUT)).

Appendix Table A1

## REGRESSION COEFFICIENTS FOR THE FOURIER COST AND lnPROFIT FUNCTIONS

Standard Cost Function			Standard Profit Function			Nonstandard Profit Function		
Dependent Variable = ln VC			Dependent Variable = ln $\pi$			Dependent Variable = ln $\pi$		
Variable	Parameter	t-stat	Variable	Parameter	t-stat	Variable	Parameter	t-stat
INTERCEP	25.290502	0.267	INTERCEP	20.756155	4.737	INTERCEP	-0.134825	-0.027
lnP1	133.086154	1.373	lnP1	-66.848177	-12.842	lnP1	-9.696171	-1.928
lnP2	130.8178	0.934	lnP2	4.845976	0.678	lnP2	35.209698	4.845
lnP1lnP1 / 2	-181.77672	-1.049	lnP3	0.029788	0.115	lnP1lnP1 / 2	-14.437618	-1.607
lnP1lnP2 / 2	-11.037119	-0.072	lnP4	0.160356	0.815	lnP1lnP2 / 2	49.827289	6.233
lnP2lnP2 / 2	-167.84862	-0.755	lnP5	0.107905	0.476	lnP2lnP2 / 2	-60.285431	-5.226
lnY3	0.945109	1.946	lnP6	0.430318	1.726	lnY3	0.016025	0.636
lnY4	-0.549601	-2.085	lnP7	-2.211767	-1.039	lnY4	0.078798	5.764
lnY5	0.535747	0.821	lnP1lnP1 / 2	36.346348	3.976	lnY5	0.147974	4.372
lnY6	0.209417	0.555	lnP1lnP2 / 2	104.50768	15.322	lnY6	0.064369	3.29
lnY7	-6.90246	-1.419	lnP1lnP3 / 2	0.146538	0.956	lnY7	-2.029895	-8.045
lnY8	-1.105066	-1	lnP1lnP4 / 2	-0.035445	-0.387	lnY8	0.110012	1.919
lnY9	-6.919637	-1.453	lnP1lnP5 / 2	0.048935	0.427	lnY9	-0.363117	-1.47
lnY3lnY3 / 2	-0.084104	-1.715	lnP1lnP6 / 2	-0.030476	-0.379	lnY3lnY3 / 2	-0.001179	-0.464
lnY3lnY4 / 2	-0.007596	-2.824	lnP1lnP7 / 2	0.024984	0.03	lnY3lnY4 / 2	8.9903E-05	0.644
lnY3lnY5 / 2	-0.002847	-1.157	lnP2lnP2 / 2	-48.693672	-4.414	lnY3lnY5 / 2	-4.998E-05	-0.392
lnY3lnY6 / 2	-0.005544	-2.075	lnP2lnP3 / 2	0.103902	0.824	lnY3lnY6 / 2	0.000208	1.504
lnY3lnY7 / 2	-0.049154	-1.954	lnP2lnP4 / 2	0.080061	0.912	lnY3lnY7 / 2	-0.003838	-2.941
lnY3lnY8 / 2	0.030132	1.339	lnP2lnP5 / 2	0.052246	0.254	lnY3lnY8 / 2	0.000183	0.157
lnY3lnY9 / 2	0.041578	2.016	lnP2lnP6 / 2	0.220018	1.603	lnY3lnY9 / 2	0.002688	2.513
lnY4lnY4 / 2	0.03656	1.338	lnP2lnP7 / 2	0.299648	0.251	lnY4lnY4 / 2	-0.008035	-5.67
lnY4lnY5 / 2	-0.003999	-1.557	lnP3lnP3 / 2	-0.252664	-0.62	lnY4lnY5 / 2	-5.154E-05	-0.387
lnY4lnY6 / 2	0.00018	0.106	lnP3lnP4 / 2	0.018889	0.928	lnY4lnY6 / 2	0.000105	1.191
lnY4lnY7 / 2	0.012125	0.779	lnP3lnP5 / 2	0.08227	2.771	lnY4lnY7 / 2	-0.001397	-1.73
lnY4lnY8 / 2	-0.079534	-5.299	lnP3lnP6 / 2	-0.018474	-0.79	lnY4lnY8 / 2	-0.000665	-0.854
lnY4lnY9 / 2	0.099779	5.878	lnP3lnP7 / 2	0.132877	0.489	lnY4lnY9 / 2	0.001201	1.364
lnY5lnY5 / 2	0.044225	0.73	lnP4lnP4 / 2	-0.264946	-1	lnY5lnY5 / 2	-0.014363	-4.574
lnY5lnY6 / 2	0.000724	0.263	lnP4lnP5 / 2	0.020636	1.018	lnY5lnY6 / 2	-4.118E-05	-0.288
lnY5lnY7 / 2	-0.043491	-2.43	lnP4lnP6 / 2	-0.020676	-1.3	lnY5lnY7 / 2	0.000162	0.174
lnY5lnY8 / 2	-0.031558	-1.461	lnP4lnP7 / 2	0.013704	0.078	lnY5lnY8 / 2	-0.002113	-1.886
lnY5lnY9 / 2	0.010135	0.501	lnP5lnP5 / 2	-0.258968	-0.697	lnY5lnY9 / 2	0.001482	1.412
lnY6lnY6 / 2	0.000672	0.019	lnP5lnP6 / 2	-0.0353	-1.577	lnY6lnY6 / 2	-0.005274	-2.859
lnY6lnY7 / 2	-0.026908	-1.84	lnP5lnP7 / 2	-0.05218	-0.19	lnY6lnY7 / 2	-0.001231	-1.623
lnY6lnY8 / 2	-0.002444	-0.161	lnP6lnP6 / 2	-0.647026	-2.264	lnY6lnY8 / 2	-0.002773	-3.514
lnY6lnY9 / 2	0.020386	1.386	lnP6lnP7 / 2	0.182943	0.878	lnY6lnY9 / 2	0.00173	2.267
lnY7lnY7 / 2	0.13831	0.384	lnP7lnP7 / 2	17.98387	0.922	lnY7lnY7 / 2	0.148276	7.939
lnY7lnY8 / 2	0.328834	5.989	lnY8	0.0728	0.482	lnY7lnY8 / 2	0.009476	3.328
lnY7lnY9 / 2	0.216007	1.816	lnY9	1.14658	5.154	lnY7lnY9 / 2	0.008827	1.431
lnY8lnY8 / 2	0.061141	0.611	lnY8lnY8 / 2	0.06763	0.653	lnY8lnY8 / 2	-0.01285	-2.476
lnY8lnY9 / 2	-0.279769	-5.107	lnY8lnY9 / 2	-0.238208	-3.808	lnY8lnY9 / 2	-0.004399	-1.548
lnY9lnY9 / 2	0.349613	1.285	lnY9lnY9 / 2	1.140372	7.55	lnY9lnY9 / 2	0.032943	2.335
lnP1lnY3	0.048394	0.96	lnP1lnY8	-0.180655	-2.455	lnP1lnY3	0.000601	0.23
lnP1lnY4	0.052956	1.122	lnP1lnY9	-0.036915	-0.308	lnP1lnY4	-0.002933	-1.198
lnP1lnY5	-0.033088	-0.613	lnP2lnY8	0.0018	0.025	lnP1lnY5	0.000167	0.06
lnP1lnY6	-0.023876	-0.514	lnP2lnY9	-2.186656	-16.946	lnP1lnY6	-0.001976	-0.82
lnP1lnY7	0.272274	0.675	lnP3lnY8	-0.081123	-2.807	lnP1lnY7	0.061393	2.933
lnP1lnY8	-0.28012	-1.428	lnP3lnY9	0.121613	2.052	lnP1lnY8	-0.013703	-1.347
lnP1lnY9	-0.206004	-0.522	lnP4lnY8	0.108168	3.756	lnP1lnY9	-0.061073	-2.982
lnP2lnY3	-0.135215	-2.154	lnP4lnY9	-0.176432	-3.321	lnP2lnY3	0.002954	0.907
lnP2lnY4	-0.017399	-0.308	lnP5lnY8	0.292674	5.94	lnP2lnY4	0.003272	1.116
lnP2lnY5	-0.041752	-0.603	lnP5lnY9	-0.510672	-6.183	lnP2lnY5	-0.003458	-0.962
lnP2lnY6	-0.037856	-0.686	lnP6lnY8	0.044775	1.268	lnP2lnY6	0.003984	1.393
lnP2lnY7	0.114498	0.299	lnP6lnY9	0.193211	3.857	lnP2lnY7	0.049606	2.494
lnP2lnY8	0.275095	1.245	lnP7lnY8	-0.70826	-1.759	lnP2lnY8	-0.00792	-0.691
lnP2lnY9	0.095372	0.229	lnP7lnY9	-1.130424	-1.389	lnP2lnY9	-0.283183	-13.125
CZ1	0.795699	1.043	CZ1	-0.212997	-5.318	CZ1	0.103329	2.612
SZ1	-0.067389	-0.437	SZ1	0.020612	2.811	SZ1	-0.037826	-4.727
CZ2	1.66187	1.252	CZ2	-0.085705	-1.246	CZ2	0.279966	4.068
SZ2	0.362886	0.907	SZ2	0.058628	2.955	SZ2	0.095176	4.585
CZ3	3.585878	2.21	CZ3	0.015095	1	CZ3	0.019387	0.23
SZ3	0.490189	0.695	SZ3	-0.00186	-0.287	SZ3	0.058781	1.608
CZ4	-1.125435	-1.219	CZ4	0.030908	2.275	CZ4	0.202576	4.231
SZ4	1.204497	2.487	SZ4	0.042059	7.639	SZ4	-0.031164	-1.241

Appendix Table A1 (continued)

Variable	Parameter	t-stat	Variable	Parameter	t-stat	Variable	Parameter	t-stat
CZ5	0.877046	0.409	CZ5	-0.007459	-0.512	CZ5	0.402931	3.621
SZ5	3.626477	4.615	SZ5	0.0102	1.69	SZ5	-0.145368	-3.567
CZ6	0.892983	0.739	CZ6	0.060541	4.439	CZ6	0.092347	1.474
SZ6	0.309838	0.631	SZ6	0.020587	3.78	SZ6	-0.001129	-0.044
CZ7	-5.48314	-0.372	CZ7	-0.050509	-2.937	CZ7	-5.874462	-7.682
SZ7	-15.787555	-3.141	SZ7	0.033661	4.387	SZ7	-0.919822	-3.529
CZ8	0.735408	0.185	CZ8	0.074884	1.416	CZ8	0.603154	2.933
SZ8	-7.69536	-4.05	SZ8	0.021566	0.639	SZ8	-0.266425	-2.703
CZ9	-6.035152	-2.53	CZ9	-0.411493	-5.938	CZ9	-0.181709	-1.469
SZ9	-1.761394	-1.91	SZ9	0.398139	10.562	SZ9	0.123282	2.577
CZ13	0.005583	0.055	CZ13	-0.011532	-2.579	CZ13	0.007967	1.527
SZ13	-0.016131	-0.13	SZ13	-0.024457	-5.921	SZ13	0.002573	0.4
CZ14	0.212721	2.366	CZ14	0.020044	5.15	CZ14	0.010332	2.216
SZ14	0.081715	0.83	SZ14	0.005286	1.518	SZ14	0.004971	0.973
CZ15	-0.215169	-1.98	CZ15	-0.00227	-0.479	CZ15	-0.010765	-1.91
SZ15	0.054256	0.413	SZ15	0.029535	6.309	SZ15	-0.005649	-0.828
CZ16	-0.096229	-1.003	CZ16	0.014216	3.182	CZ16	-0.003231	-0.65
SZ16	0.025644	0.232	SZ16	-0.014869	-3.89	SZ16	-0.001254	-0.219
CZ17	-0.009337	-0.024	CZ17	-0.005732	-1.055	CZ17	0.080252	4.057
SZ17	-0.068729	-0.192	SZ17	0.022124	4.275	SZ17	-0.031812	-1.715
CZ18	-0.202104	-0.756	CZ18	0.010598	1.147	CZ18	0.028398	2.047
SZ18	0.021194	0.077	SZ18	0.016034	1.436	SZ18	0.029216	2.037
CZ19	0.053372	0.274	CZ19	-0.003769	-0.297	CZ19	-0.061285	-6.069
SZ19	-0.193066	-0.968	SZ19	0.191148	12.358	SZ19	0.087145	8.422
CZ23	-0.219339	-1.747	CZ23	-0.014666	-3.157	CZ23	0.006217	0.955
SZ23	0.007	0.055	SZ23	-0.021305	-4.707	SZ23	-0.000121	-0.018
CZ24	0.117953	1.003	CZ24	0.013055	3.152	CZ24	0.005251	0.861
SZ24	0.244913	2.527	SZ24	0.013219	3.768	SZ24	0.006911	1.375
CZ25	-0.092463	-0.673	CZ25	0.000726	0.135	CZ25	-0.006956	-0.976
SZ25	-0.03046	-0.225	SZ25	0.001731	0.344	SZ25	-0.003926	-0.56
CZ26	-0.124854	-1.072	CZ26	0.023314	4.665	CZ26	-0.001383	-0.229
SZ26	-0.103798	-0.899	SZ26	0.003332	0.823	SZ26	-0.009233	-1.542
CZ27	-0.35862	-0.753	CZ27	-0.029123	-4.584	CZ27	0.05994	2.427
SZ27	0.566867	1.371	SZ27	0.017697	3.638	SZ27	-0.01558	-0.727
CZ28	-0.065251	-0.184	CZ28	4.1936E-05	0.004	CZ28	-0.00318	-0.173
SZ28	0.040265	0.159	SZ28	0.035349	3.063	SZ28	0.074516	5.656
CZ29	0.031093	0.131	CZ29	-0.11901	-8.974	CZ29	-0.15909	-12.877
SZ29	-0.315499	-1.55	SZ29	0.265858	14.856	SZ29	0.072775	6.895
CZ33	0.409196	2.231	CZ33	0.002182	0.988	CZ33	0.005468	0.575
SZ33	-0.168803	-1.615	SZ33	0.000284	0.292	SZ33	-0.00639	-1.179
CZ34	-0.201465	-1.924	CZ34	-0.009345	-3.504	CZ34	0.002304	0.424
SZ34	0.083349	0.588	SZ34	-0.009409	-3.639	SZ34	0.003762	0.512
CZ35	0.317609	3.391	CZ35	0.009261	3.202	CZ35	0.002843	0.585
SZ35	0.583795	4.428	SZ35	2.2379E-05	0.007	SZ35	0.009245	1.352
CZ36	-0.03021	-0.258	CZ36	0.002005	0.651	CZ36	-0.011168	-1.837
SZ36	0.432652	2.861	SZ36	-0.006673	-2.394	SZ36	-0.0145	-1.848
CZ37	-0.472518	-0.693	CZ37	0.00614	1.508	CZ37	-0.126397	-3.576
SZ37	-0.387513	-0.759	SZ37	0.015422	4.334	SZ37	0.055834	2.109
CZ38	-0.451667	-0.721	CZ38	0.007887	1.203	CZ38	-0.026375	-0.812
SZ38	0.027979	0.064	SZ38	-0.034382	-4.613	SZ38	-0.004882	-0.217
CZ39	0.788075	2.786	CZ39	-0.003867	-0.475	CZ39	-0.020363	-1.388
SZ39	-0.160554	-0.488	SZ39	0.03028	2.949	SZ39	-0.043803	-2.568
CZ44	-0.253047	-2.318	CZ44	0.000724	0.378	CZ44	0.026211	4.63
SZ44	0.012635	0.164	SZ44	0.000212	0.23	SZ44	-0.016203	-4.059
CZ45	0.199666	2.022	CZ45	0.002611	0.904	CZ45	0.000887	0.173
SZ45	0.297782	2.064	SZ45	0.013412	4.441	SZ45	0.001843	0.246
CZ46	-0.180029	-1.957	CZ46	0.00087	0.361	CZ46	-0.001555	-0.326
SZ46	0.094156	0.876	SZ46	-0.0054	-2.162	SZ46	-0.00317	-0.568
CZ47	-1.750005	-3.045	CZ47	0.032849	7.941	CZ47	-0.077799	-2.61
SZ47	-1.181596	-2.854	SZ47	-0.000118	-0.035	SZ47	0.034355	1.6
CZ48	-0.571738	-1.134	CZ48	-0.010793	-1.578	CZ48	-0.025973	-0.993
SZ48	0.775403	1.98	SZ48	0.02475	3.014	SZ48	-0.001043	-0.051
CZ49	0.424779	1.619	CZ49	0.024309	2.737	CZ49	-0.019548	-1.436
SZ49	-1.427773	-4.859	SZ49	-0.071767	-7.226	SZ49	-0.02388	-1.567
CZ55	0.047838	0.187	CZ55	0.0015	0.763	CZ55	0.04541	3.429
SZ55	0.262664	2.064	SZ55	0.0015	1.498	SZ55	-0.024364	-3.692
CZ56	0.128698	1.05	CZ56	0.002966	1.008	CZ56	0.010137	1.595
SZ56	0.286753	1.845	SZ56	0.005374	1.846	SZ56	0.006658	0.826
CZ57	-0.759476	-1.197	CZ57	0.005632	1.352	CZ57	0.001196	0.036
SZ57	2.073614	3.566	SZ57	-0.012313	-3.058	SZ57	-0.034857	-1.156
CZ58	-0.739372	-1.145	CZ58	-0.026204	-3.238	CZ58	-0.065344	-1.951

Appendix Table A1 (continued)

Variable	Parameter	t-stat	Variable	Parameter	t-stat	Variable	Parameter	t-stat
SZ58	0.379185	0.804	SZ58	-0.00484	-0.51	SZ58	-0.06315	-2.582
CZ59	-1.065291	-3.562	CZ59	0.037073	3.595	CZ59	0.026027	1.678
SZ59	-0.557017	-1.509	SZ59	0.010444	0.994	SZ59	-0.034559	-1.805
CZ66	0.120825	0.823	CZ66	0.003267	1.63	CZ66	0.016899	2.219
SZ66	-0.174379	-2.469	SZ66	0.001034	1.103	SZ66	-0.013025	-3.556
CZ67	0.45292	0.992	CZ67	0.005085	1.345	CZ67	-0.054324	-2.295
SZ67	0.678055	1.656	SZ67	0.00967	2.573	SZ67	0.002326	0.11
CZ68	-0.664506	-1.452	CZ68	-0.006775	-0.977	CZ68	-0.094223	-3.969
SZ68	-0.309075	-0.912	SZ68	0.031895	3.846	SZ68	-0.024027	-1.367
CZ69	-0.074829	-0.311	CZ69	-0.019499	-2.119	CZ69	-0.004735	-0.38
SZ69	-0.590594	-2.25	SZ69	-0.066359	-7.19	SZ69	-0.028688	-2.107
CZ77	-0.706735	-2.403	CZ77	-0.002518	-1.16	CZ77	-0.647691	-7.113
SZ77	-1.541891	-1.205	SZ77	-0.000463	-0.419	SZ77	-0.341115	-5.138
CZ78	8.014388	6.262	CZ78	-0.003795	-0.458	CZ78	0.174765	2.633
SZ78	-0.86749	-1.142	SZ78	-0.017025	-1.484	SZ78	0.041725	1.059
CZ79	1.353228	1.826	CZ79	0.067364	5.976	CZ79	0.030599	0.796
SZ79	-0.511289	-0.592	SZ79	0.006574	0.513	SZ79	-0.037805	-0.844
CZ88	-1.748214	-3.516	CZ88	-0.00631	-1.186	CZ88	0.049059	1.902
SZ88	0.127402	0.454	SZ88	0.001777	0.225	SZ88	-0.007874	-0.541
CZ89	-0.052021	-0.109	CZ89	0.03271	2.554	CZ89	0.003301	0.133
SZ89	-1.31704	-2.17	SZ89	-0.041517	-2.867	SZ89	0.087721	2.786
CZ99	-0.935526	-4.1	CZ99	-0.013353	-0.876	CZ99	-0.002209	-0.187
SZ99	0.898841	4.687	SZ99	0.110507	9.061	SZ99	0.01125	1.131
CZ123	-0.02511	-0.922	CZ123	0.000918	1.231	CZ123	0.000814	0.577
SZ123	0.018019	0.851	SZ123	0.000545	0.747	SZ123	-0.000425	-0.387
CZ124	-0.022469	-0.836	CZ124	0.000652	1.016	CZ124	0.000214	0.154
SZ124	0.02537	1.165	SZ124	0.000788	1.19	SZ124	-0.000949	-0.84
CZ125	-0.014742	-0.448	CZ125	-0.000964	-1.114	CZ125	-0.000744	-0.436
SZ125	-0.010769	-0.452	SZ125	1.127E-06	0.002	SZ125	0.001199	0.97
CZ126	0.017851	0.732	CZ126	0.000175	0.239	CZ126	0.00088	0.696
SZ126	-0.006105	-0.293	SZ126	-0.00096	-1.649	SZ126	-0.001209	-1.118
CZ127	-0.075172	-0.656	CZ127	-2.811E-05	-0.036	CZ127	-0.014752	-2.481
SZ127	-0.155638	-1.128	SZ127	0.000409	0.51	SZ127	-0.0309	-4.317
CZ128	-0.021712	-0.285	CZ128	0.025942	7.101	CZ128	0.007383	1.868
SZ128	0.144996	1.83	SZ128	0.011272	2.801	SZ128	-0.000378	-0.092
CZ129	0.044552	0.846	CZ129	-0.035972	-6.808	CZ129	-0.00679	-2.487
SZ129	-0.065234	-1.223	SZ129	0.079382	12.996	SZ129	0.004718	1.705
CZ134	-0.055226	-1.586	CZ134	0.00000904	0.013	CZ134	0.00017	0.094
SZ134	0.05662	1.555	SZ134	0.000289	0.4	SZ134	-0.000279	-0.148
CZ135	-0.000838	-0.033	CZ135	-0.000996	-1.144	CZ135	0.000305	0.231
SZ135	0.005281	0.224	SZ135	0.000404	0.54	SZ135	-0.000367	-0.3
CZ136	-0.020742	-0.707	CZ136	0.000996	1.18	CZ136	-0.000991	-0.652
SZ136	0.01233	0.456	SZ136	0.001113	1.559	SZ136	-0.00027	-0.192
CZ137	0.32081	1.532	CZ137	0.000262	0.315	CZ137	0.00561	0.516
SZ137	0.019623	0.105	SZ137	-0.001472	-1.709	SZ137	0.010438	1.074
CZ138	-0.025404	-0.193	CZ138	0.008644	1.85	CZ138	-0.002388	-0.349
SZ138	-0.101857	-0.747	SZ138	-0.023689	-5.327	SZ138	0.00385	0.544
CZ139	0.090328	1.025	CZ139	-0.012824	-1.857	CZ139	-0.004975	-1.088
SZ139	0.185759	1.995	SZ139	0.051212	7.869	SZ139	0.003604	0.746
CZ145	0.02999	0.891	CZ145	0.000158	0.201	CZ145	0.000619	0.354
SZ145	-0.069188	-1.932	SZ145	-0.000512	-0.768	SZ145	-0.000636	-0.342
CZ146	-0.0385	-1.288	CZ146	0.000819	1.117	CZ146	-0.000702	-0.453
SZ146	0.017074	0.582	SZ146	0.000324	0.494	SZ146	-0.000345	-0.226
CZ147	0.215193	1.191	CZ147	0.000949	1.261	CZ147	0.001816	0.194
SZ147	0.215765	1.273	SZ147	-0.000105	-0.132	SZ147	0.021907	2.492
CZ148	-0.121742	-0.937	CZ148	-0.001034	-0.223	CZ148	0.003922	0.582
SZ148	-0.070858	-0.551	SZ148	0.020127	4.641	SZ148	-0.001781	-0.267
CZ149	0.01699	0.211	CZ149	-0.010928	-1.672	CZ149	-0.005925	-1.418
SZ149	0.012107	0.154	SZ149	-0.036482	-5.899	SZ149	0.008319	2.037
CZ156	0.054174	1.818	CZ156	-7.975E-05	-0.099	CZ156	0.001355	0.877
SZ156	-0.01559	-0.586	SZ156	0.000943	1.215	SZ156	0.000613	0.444
CZ157	-0.382633	-1.802	CZ157	-8.143E-05	-0.095	CZ157	0.001217	0.111
SZ157	-0.32508	-1.806	SZ157	2.8333E-05	0.033	SZ157	-0.021376	-2.29
CZ158	0.026623	0.196	CZ158	-0.018586	-3.388	CZ158	-0.001807	-0.257
SZ158	0.19576	1.415	SZ158	0.005402	1	SZ158	-0.001853	-0.258
CZ159	-0.007938	-0.089	CZ159	0.036982	4.903	CZ159	0.009608	2.079
SZ159	-0.220608	-2.244	SZ159	-0.027394	-3.355	SZ159	-0.002794	-0.548
CZ167	0.052513	0.299	CZ167	0.000442	0.527	CZ167	-0.007887	-0.866
SZ167	-0.066545	-0.399	SZ167	-0.000365	-0.443	SZ167	-0.010963	-1.266
CZ168	-0.051569	-0.454	CZ168	0.023027	4.859	CZ168	0.00212	0.36
SZ168	-0.052894	-0.472	SZ168	0.013106	2.724	SZ168	0.004644	0.799

Appendix Table A1 (continued)

Variable	Parameter	t-stat	Variable	Parameter	t-stat	Variable	Parameter	t-stat
CZ169	0.097355	1.204	CZ169	-0.043349	-6.275	CZ169	0.003207	0.765
SZ169	0.05364	0.65	SZ169	-0.007844	-1.099	SZ169	-0.004593	-1.073
CZ178	-0.126771	-0.565	CZ178	-0.0201	-3.271	CZ178	-0.001333	-0.114
SZ178	0.050025	0.215	SZ178	-0.008905	-1.501	SZ178	0.065689	5.437
CZ179	0.341801	1.551	CZ179	0.038219	4.17	CZ179	-0.027485	-2.404
SZ179	-0.053353	-0.235	SZ179	-0.005244	-0.629	SZ179	-0.029937	-2.541
CZ189	-0.393098	-1.699	CZ189	0.010177	3.091	CZ189	-0.028771	-2.398
SZ189	-0.039206	-0.173	SZ189	0.019175	6.198	SZ189	0.013076	1.11
CZ234	-0.116155	-3.377	CZ234	0.000479	0.66	CZ234	0.000468	0.263
SZ234	0.056202	1.436	SZ234	-0.000231	-0.32	SZ234	0.000355	0.175
CZ235	-0.019275	-0.784	CZ235	-0.000577	-0.659	CZ235	0.000538	0.422
SZ235	-0.033168	-1.24	SZ235	-5.771E-05	-0.083	SZ235	0.000751	0.542
CZ236	0.014209	0.528	CZ236	-0.000541	-0.619	CZ236	-0.000943	-0.675
SZ236	-0.041796	-1.35	SZ236	0.0003	0.451	SZ236	-0.000277	-0.173
CZ237	0.231931	0.984	CZ237	0.000941	1.038	CZ237	0.003599	0.295
SZ237	0.011971	0.065	SZ237	-0.00126	-1.522	SZ237	0.007288	0.763
CZ238	0.012392	0.083	CZ238	0.005075	1.036	CZ238	-0.003397	-0.439
SZ238	-0.15263	-1.168	SZ238	-0.036063	-7.279	SZ238	-0.000915	-0.135
CZ239	0.079522	0.892	CZ239	-0.004702	-0.61	CZ239	-0.003054	-0.66
SZ239	0.181303	1.875	SZ239	0.064179	9.422	SZ239	3.5944E-05	0.007
CZ245	0.079507	2.423	CZ245	0.00006089	0.076	CZ245	0.000762	0.447
SZ245	-0.097572	-2.454	SZ245	-0.000414	-0.63	SZ245	-0.000187	-0.091
CZ246	-0.048593	-1.733	CZ246	0.000248	0.321	CZ246	-0.000144	-0.099
SZ246	-0.031713	-1.005	SZ246	0.000575	0.946	SZ246	-0.000911	-0.557
CZ247	-0.048378	-0.237	CZ247	0.000353	0.435	CZ247	-0.007914	-0.747
SZ247	0.130195	0.697	SZ247	0.000491	0.637	SZ247	0.005125	0.529
CZ248	-0.03415	-0.242	CZ248	0.010078	2.037	CZ248	0.00173	0.237
SZ248	0.097033	0.702	SZ248	0.007774	1.731	SZ248	0.005534	0.772
CZ249	0.028659	0.35	CZ249	-0.011673	-1.674	CZ249	-0.003617	-0.851
SZ249	-0.002865	-0.033	SZ249	-0.025019	-3.948	SZ249	0.001078	0.239
CZ256	0.053116	1.953	CZ256	0.00049	0.592	CZ256	0.000857	0.608
SZ256	0.004789	0.155	SZ256	0.001001	1.286	SZ256	0.000615	0.383
CZ257	-0.25968	-1.065	CZ257	0.000481	0.453	CZ257	0.010707	0.847
SZ257	-0.231571	-1.326	SZ257	-0.000459	-0.549	SZ257	-0.005756	-0.635
CZ258	-0.046926	-0.305	CZ258	-0.000908	-0.164	CZ258	-0.004681	-0.586
SZ258	0.140621	1.05	SZ258	0.024383	4.121	SZ258	-0.005114	-0.736
CZ259	-0.005154	-0.057	CZ259	0.000648	0.081	CZ259	0.004637	0.981
SZ259	-0.192989	-1.892	SZ259	-0.025858	-3.053	SZ259	0.002609	0.493
CZ267	0.238265	1.163	CZ267	-5.947E-05	-0.061	CZ267	0.003434	0.323
SZ267	-0.059364	-0.359	SZ267	-0.000572	-0.762	SZ267	-0.019895	-2.322
CZ268	-0.061435	-0.464	CZ268	0.01126	2.443	CZ268	0.000104	0.015
SZ268	-0.037845	-0.346	SZ268	0.015774	2.804	SZ268	0.003906	0.689
CZ269	0.035318	0.447	CZ269	-0.026099	-3.779	CZ269	0.009899	2.414
SZ269	0.183007	2.034	SZ269	-0.029906	-3.561	SZ269	-0.001883	-0.404
CZ278	-0.458847	-1.739	CZ278	-0.020274	-3.353	CZ278	-0.073126	-5.345
SZ278	-0.101422	-0.43	SZ278	-0.027508	-4.07	SZ278	0.04703	3.841
CZ279	0.538516	2.25	CZ279	0.055801	5.885	CZ279	-0.052525	-4.232
SZ279	0.206583	0.834	SZ279	0.031736	3.43	SZ279	-0.052191	-4.06
CZ289	-0.384157	-1.602	CZ289	0.016627	4.812	CZ289	-0.016919	-1.361
SZ289	-0.474324	-1.894	SZ289	0.033747	9.541	SZ289	-0.025737	-1.981
CZ345	0.054967	1.849	CZ345	-0.000379	-0.816	CZ345	0.0004	0.26
SZ345	0.115767	4.542	SZ345	0.000363	0.789	SZ345	-0.000681	-0.515
CZ346	-0.045592	-1.323	CZ346	-7.857E-05	-0.172	CZ346	0.00133	0.744
SZ346	0.038377	1.163	SZ346	3.5304E-05	0.079	SZ346	9.7768E-05	0.057
CZ347	-0.048186	-0.242	CZ347	-0.000658	-1.201	CZ347	-0.011859	-1.149
SZ347	-0.575933	-2.572	SZ347	-0.000264	-0.49	SZ347	0.019729	1.698
CZ348	-0.039865	-0.302	CZ348	0.004734	1.556	CZ348	0.004012	0.585
SZ348	-0.266868	-1.669	SZ348	-0.004079	-1.296	SZ348	-0.006905	-0.833
CZ349	0.522266	4.489	CZ349	-0.002861	-0.665	CZ349	-0.008673	-1.437
SZ349	-0.309397	-3.029	SZ349	0.016676	3.551	SZ349	-0.000841	-0.159
CZ356	-0.076061	-2.572	CZ356	-0.000365	-0.782	CZ356	-0.000319	-0.208
SZ356	-0.033328	-1.774	SZ356	0.00019	0.404	SZ356	-0.000147	-0.151
CZ357	-0.696231	-4.248	CZ357	-0.00025	-0.447	CZ357	-0.010219	-1.202
SZ357	0.609357	2.701	SZ357	-0.000255	-0.459	SZ357	0.007665	0.655
CZ358	0.081202	0.778	CZ358	0.019489	5.129	CZ358	0.003295	0.609
SZ358	-0.228441	-1.519	SZ358	-0.011864	-3.319	SZ358	0.002723	0.349
CZ359	-0.061183	-0.776	CZ359	-0.024801	-4.255	CZ359	-0.003527	-0.863
SZ359	-0.346939	-4.893	SZ359	0.007157	1.419	SZ359	-0.001525	-0.415
CZ367	-0.365857	-1.813	CZ367	-0.000532	-0.932	CZ367	-0.000834	-0.08
SZ367	0.169578	0.756	SZ367	-0.000411	-0.726	SZ367	-0.022951	-1.972
CZ368	-0.02506	-0.223	CZ368	-0.006406	-1.964	CZ368	-8.204E-05	-0.014

Appendix Table A1 (continued)

Variable	Parameter	t-stat	Variable	Parameter	t-stat	Variable	Parameter	t-stat
SZ368	0.103054	0.714	SZ368	0.016488	4.595	SZ368	0.00227	0.303
CZ369	-0.107666	-1.088	CZ369	0.000322	0.066	CZ369	0.006021	1.174
SZ369	-0.199238	-2.107	SZ369	-0.013084	-2.529	SZ369	-0.004241	-0.865
CZ378	0.425957	1.009	CZ378	-0.026888	-6.022	CZ378	-0.049604	-2.266
SZ378	-0.128649	-0.293	SZ378	-0.009908	-2.25	SZ378	-0.039585	-1.739
CZ379	-0.768378	-2.851	CZ379	0.033452	5.322	CZ379	0.013686	0.979
SZ379	-0.36989	-1.318	SZ379	-0.00619	-0.998	SZ379	0.008845	0.608
CZ389	0.675522	2.247	CZ389	-0.008843	-3.07	CZ389	0.001846	0.118
SZ389	1.335203	4.434	SZ389	-0.001386	-0.548	SZ389	-0.032688	-2.093
CZ456	0.139624	3.95	CZ456	-0.00092	-2.108	CZ456	0.000597	0.326
SZ456	-0.052043	-1.709	SZ456	0.000286	0.679	SZ456	-0.000355	-0.225
CZ457	0.272069	1.493	CZ457	-0.000841	-1.587	CZ457	0.004016	0.425
SZ457	0.995353	4.673	SZ457	5.0096E-05	0.096	SZ457	0.00416	0.377
CZ458	-0.40178	-3.091	CZ458	-0.002776	-0.726	CZ458	-0.001872	-0.278
SZ458	-0.158503	-1.05	SZ458	0.009739	2.536	SZ458	-0.002852	-0.364
CZ459	-0.5013	-4.476	CZ459	0.009752	1.794	CZ459	0.000372	0.064
SZ459	0.293393	2.895	SZ459	-0.022237	-3.968	SZ459	0.003482	0.662
CZ467	-0.134086	-0.83	CZ467	-0.000242	-0.453	CZ467	-0.004003	-0.478
SZ467	0.057367	0.294	SZ467	0.000404	0.778	SZ467	0.00877	0.866
CZ468	-0.25278	-2.454	CZ468	0.010882	3.23	CZ468	-0.000709	-0.133
SZ468	-0.240874	-1.84	SZ468	0.000485	0.153	SZ468	-0.006902	-1.017
CZ469	0.056282	0.645	CZ469	-0.016293	-3.409	CZ469	-0.004716	-1.043
SZ469	-0.155008	-1.938	SZ469	0.002898	0.677	SZ469	-0.001676	-0.404
CZ478	-0.136558	-0.41	CZ478	0.027567	5.853	CZ478	-0.037916	-2.196
SZ478	-0.873724	-2.339	SZ478	0.022887	5.119	SZ478	-0.029863	-1.542
CZ479	-0.693766	-2.292	CZ479	-0.053533	-8.09	CZ479	0.010785	0.687
SZ479	0.991957	3.14	SZ479	-0.042706	-6.623	SZ479	0.010149	0.619
CZ489	1.312338	4.502	CZ489	-0.0038	-1.438	CZ489	-0.002592	-0.171
SZ489	-1.046406	-3.388	SZ489	0.000722	0.291	SZ489	-0.031542	-1.969
CZ567	0.112812	0.633	CZ567	0.00039	0.725	CZ567	0.010664	1.153
SZ567	0.45308	1.93	SZ567	0.000149	0.28	SZ567	0.016729	1.374
CZ568	-0.282071	-2.675	CZ568	-0.008761	-2.41	CZ568	-0.006033	-1.103
SZ568	-0.141149	-0.939	SZ568	0.006234	1.698	SZ568	0.003228	0.414
CZ569	-0.129507	-1.283	CZ569	0.009201	1.772	CZ569	-0.006689	-1.277
SZ569	0.183474	1.994	SZ569	-0.012932	-2.514	SZ569	0.005464	1.145
CZ578	-0.702603	-1.701	CZ578	0.006343	1.293	CZ578	0.031295	1.461
SZ578	-0.108091	-0.213	SZ578	0.018527	3.632	SZ578	-0.054098	-2.056
CZ579	0.555927	1.771	CZ579	-0.018359	-2.629	CZ579	0.033451	2.055
SZ579	-0.542296	-1.668	SZ579	-0.012465	-1.763	SZ579	-0.000521	-0.031
CZ589	-0.238621	-0.679	CZ589	0.004951	1.446	CZ589	0.001902	0.104
SZ589	-0.355271	-1.086	SZ589	0.003996	1.2	SZ589	0.005799	0.342
CZ678	0.214467	0.666	CZ678	0.02257	4.38	CZ678	-0.022274	-1.333
SZ678	0.260233	0.769	SZ678	-0.018017	-4.35	SZ678	-0.050259	-2.864
CZ679	0.721667	3.212	CZ679	-0.019247	-2.652	CZ679	0.017884	1.535
SZ679	-0.50112	-1.951	SZ679	0.006924	1.179	SZ679	0.006088	0.457
CZ689	-0.44839	-1.947	CZ689	0.009831	3.56	CZ689	-0.003165	-0.265
SZ689	0.269191	1.052	SZ689	0.009028	3.444	SZ689	-0.016881	-1.272
CZ789	1.203192	3.204	CZ789	-0.01363	-2.966	CZ789	-0.020387	-1.047
SZ789	-0.662697	-2.28	SZ789	-0.003397	-0.897	SZ789	0.043848	2.909
R squared	0.958			0.868			0.779	
Num. Obs.	4720			4720			4720	

where variables are defined in Table 1 and page 11, and

$$cz_i = \cos(z_i)$$

$$sz_i = \sin(z_i)$$

$$cz_{ij} = \cos(z_i + z_j)$$

$$sz_{ij} = \sin(z_i + z_j)$$

$$cz_{ijk} = \cos(z_i + z_j + z_k)$$

$$sz_{ijk} = \sin(z_i + z_j + z_k)$$