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On the Cost Structure of the Japanese Property-Casualty Insurance Industry

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Abstract

This article tests economies of scale and economies of scope for the property-casualty insurance companies in Japan. We fit a composite cost function to a set of Japanese firms over the period from 1980 to 1995 and employ an error components model. Our main findings are as follows. First, statistically significant economies of scale are observed in both Japanese firms and foreign firms operating in Japan. Second, economies of scope are also statistically significant for Japanese firms and most of the foreign insurers between the "third sector" products and the rest of the property-casualty insurance lines.

Introduction

The Japanese property-casualty (hereafter P/C) insurance industry is currently undergoing major changes due to deregulation. Until the mid 1990s, entry into the insurance industry was tightly regulated, and insurance firms in Japan, including foreign companies operating in Japan, were legally required to use premium rates set by the insurance rating organization to sell fire, earthquake, personal accident, automobile, and compulsory automobile liability insurance. The industry was highly concentrated. In 1995, 26 Japanese P/C insurance firms and 29 foreign firms were in Japan.[1] The market share of the four largest firms in the industry (all Japanese) received roughly 47 percent of the premium income.

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[1] Two of the 26 Japanese insurers specialize in reinsurance, and another four were licensed to operate after 1980, the first year of our data set. These six firms are not included in our data set of the Japanese insurers.

Then the "Financial Big Bang" (a series of financial deregulations taking place in the 1990s in Japan) and the U.S.–Japan Insurance Talks concluded in 1996 brought about major changes in the industry. The premium rates were gradually liberalized, with full liberalization taking effect in 1998. Foreign P/C insurance firms operating in Japan started offering low-priced insurance. The Insurance Business Law revised in 1995 removed the restriction on mutual entry between the life and P/C insurance sectors. Afterwards, several life insurance companies started offering fire and automobile insurance via newly established subsidiaries, and P/C insurance firms started selling life insurance via their new subsidiaries. Profitability of the P/C insurance companies declined gradually over the 1990s; the average ROE of the 20 Japanese P/C insurers included in our data set exceeded 14 percent every year until 1990 but decreased to 12.6 percent in 1991, 7.5 percent in 1993, 5.5 percent in 1995 (the last year of our study), 4.5 percent in 1997, and to 2.4 percent in 2000.[2]

This article empirically investigates the cost structure of the P/C insurance firms in Japan for 1980–1995. We estimate economies of scale in the Japanese and the foreign-owned P/C insurers operating in Japan using a panel data set. From an industrial organization perspective, discovery of significant scale economies is important, since small- and medium-size firms may find it difficult to withstand increased competition from deregulation; in the long run only a few firms will survive. In fact, there was a wave of mergers between prominent Japanese P/C insurance firms in 1999 and 2000. As of Spring 2002, the set of insurers that have agreed to merge with each other are Mitsui MFI and Sumitomo MFI (MFI stands for Marine & Fire Insurance), the third and fourth largest firms in the P/C insurance industry in terms of total assets; Nippon FMI and Koa FMI (FMI stands for Fire & Marine Insurance), the fifth and eighth largest firms; Dai-Tokyo FMI and Chiyoda FMI, the seventh and ninth largest companies; and Yasuda FMI (the second largest P/C insurer) and midsize Nissan FMI and Taisei FMI. The P/C insurance industry giant Tokio MFI announced a comprehensive partnership with Nichido FMI (the sixth largest) and Asahi Mutual Life Insurance, a life insurer. This is the first time in the history of the Japanese P/C insurance industry in which consolidations occurred on such a major scale. Also, in 2000, Dai-Ichi Mutual FMI became the first Japanese P/C insurance firm to become insolvent and go out of business.

Second, this article examines whether there are economies of scope between the "third sector" products (personal accident, medical expenses and nursing care expense insurance) currently offered by P/C insurers and the rest of the P/C insurance lines. The third sector covers the products that are at the borderline between the "first sector" (life insurance) and the "second sector" (P/C insurance). The classification of representative insurance products into the first, second, and third sectors are summarized in Table 1. We focus on the third sector because we believe these "borderline" insurance may be different from the second sector non-life insurance. Examining cost complementarity between the second and third sector products that the P/C insurers currently write could provide useful information about the cost structure of P/C insurers.

[2] Dai-Ichi Mutual is not included in the average ROE in 2000, as the company went out of business that year; ROE figures for foreign-owned P/C insurers are not available.

Table 1
Representative Insurance Products

Personal Insurance			
	Third Sector[a] (Personal Accidents Other Than Life and Death)		
First Sector (Human Life and Death; Provided by Life Insurers)	(Provided by Life Insurers)	(Provided by P/C Insurers)	Second Sector (Provided by P/C Insurers)
Endowment insurance	Medical[b]	Personal accident[c]	Fire
Whole life	Specified policy on accident hospitalization	Savings-type personal accident[d]	Marine
Term	Specified policy on sickness hospitalization	Disability	Automobile
Savings	Nursing care	Nursing care expenses	Compulsory automobile liability
Endowment with term	Specified policy on personal accident	Medical expenses	Fidelity & credit
Term with survival benefit			Guarantee
Individual annuities			Workers' compensation
Group annuities			Miscellaneous pecuniary loss
Whole life with term			

Source: Excerpt from Tables 3–6, p. 59, Yasuda Research Institute (1993), *Songai Hoken Nyumon* (Introduction to P/C Insurance, in Japanese), Tokyo, Toyo Keizai.

Notes: The list of insurance products is not exhaustive.

[a]The division of provision of the third sector products by life and P/C insurers was removed in 1995 when the Insurance Business Law was revised.

[b]Nursing care and medical insurance offered by life insurers pay out a fixed amount of benefits; nursing care expenses and medical expenses insurance offered by P/C insurers indemnify an insurant for the actual amount of expenses borne by him.

[c]Personal insurance for accidents indemnifies an insurant for his own injury; compulsory automobile liability pays out when the insurant is liable in an automobile accident.

[d]Savings-type insurance is an insurance with maturity refund.

The article is organized as follows. "Related Literature" discusses the existing literature and how our article relates to the literature. Our model is presented in "Model." "Data, Output, and Input Specification" discusses the data and variables used for estimation. "Estimation Results" analyzes the regression results. The final section concludes and puts forth additional research topics.

RELATED LITERATURE

Empirical Literature on Economies of Scale and Economies of Scope in the Insurance Industry

Empirical research on the P/C insurance industry in Japan includes studies on product diversity and efficiency. Takao (1987) found that product diversity increases the profitability of large Japanese firms, but small firms are better off specializing in one area of expertise. Iguchi (1993) also found that economies of scale exist for Japanese firms and foreign insurers operating in Japan, although scale economies are the most pronounced for large-scale Japanese firms. On the other hand, Fukuyama (1994), who examined productive efficiency in P/C insurance companies using a nonparametric frontier approach (also called Data Envelopment Analysis) on cross-section data, found decreasing returns to scale for some firms.[3]

Most authors of cost studies of the Japanese life insurance industry confirm the existence of scale economies (see Tsutsui, Sekiguchi, and Chano, 1992; Chuma, Tachibanaki, and Takata, 1993; Kitasaka, 1996; Iwamoto and Koie, 1998), though Kitasaka (1996) finds scale economies were smaller for the largest firms. While Kitasaka found cost complementarity between underwriting and investment activities, Tsutsui et al. (1992) and Iwamoto and Koie (1998) did not. In short, most studies conclude that economies of scale exist in the life insurance and P/C insurance industries in Japan, although some research indicates that the scale effect disappears for the largest firms. Results on economies of scope are mixed.

Turning to markets in North America, Doherty (1981) found significant economies of scale in the Canadian property-liability insurance industry. In Cummins and Weiss (1993), small- and medium-size property-liability insurers in the United States were characterized by economies of scale. Hotta (1996) did not find significant scale economies for the largest U.S. property-liability insurance companies, but confirmed substantial cost reduction for the firms that offer a mix of insurance, indicating economies of scope. Berger et al. (2000) found that profit economies of scope between life and nonlife insurance exist for some insurance providers in the United States, but other firms do better by specializing.

Relationship Between This Article and the Literature

This article examines economies of scale and scope of 33 P/C insurance companies (20 Japanese and 13 foreign-owned firms) operating in Japan. Our article differs from the rest of the literature on the following accounts.

First, we estimate the cost structure using a composite function developed by Pulley and Braunstein (1992, henceforth PB). Many of the previous cost studies on the P/C

[3] For a discussion of other DEA studies that examined economies of scale, see Kim (2000).

insurance firms have used the translog function. The composite cost function has been applied to study economies of scope in banking (Pulley and Humphrey, 1993; McKillop, Glass, and Morikawa, 1996) and in the U.S. insurance companies (Berger et al., 2000). As discussed in "Cost Function," the composite cost function is better suited for examining economies of scope in multiproduct firms.[4]

Second, we use panel data, whereas previous research on the Japanese P/C insurance industry (Takao, 1987; Iguchi, 1993; Fukuyama, 1994) has been based on cross-section analyses. Panel data provide information that cannot be collected from cross-section data. While they use a composite functional form, PB and Pulley and Humphrey (1993) analyzed cross-section data, and McKillop et al. (1996) and Berger et al. (2000) examined panel data as the pooled sample data. Although our approach closely follows that of the above-mentioned studies in terms of the composite functional form estimated, this article departs from the previous studies in the treatment of the disturbance term. We employ the error component model in order to facilitate use of panel data. In contrast, previous cost studies using the composite function did not make explicit assumptions regarding the error term, and used the least squares estimator. We found that efficiency in estimation is significantly improved by correcting for autocorrelation and heteroscedasticity in the disturbance term.

This article also differs from the previous research on the Japanese P/C insurance firms in that it estimates economies of scope for both the Japanese and foreign firms operating in Japan. Hotta (1996) and Takao (1987) found that the product mix helps reduce the costs of the U.S. and the large Japanese insurance companies, respectively. This article conducts a similar test of scope economies by including foreign companies operating in Japan in the sample.

MODEL

Cost Function

Let q_j, for $j = 1, \ldots, m$, be output of good j, and r_h be the price of input h for $h = 1, \ldots, n$. Subscripts j and k stand for outputs, and h and l stand for inputs. The cost function C of a firm producing m goods using n inputs is expressed as

$$C = C(q_1, \ldots, q_m; r_1 \ldots, r_n).$$

The translog function has been used extensively to estimate the cost structures of multiproduct firms. However, the translog model cannot examine cost behavior when any output is zero; the output of the third sector lines was zero for several foreign insurers for the first few years of the sample period (see footnote 7). As a result, the translog cost function cannot be used to directly measure the costs of specialized production, as required by the estimation of economies of scope. One common approach is to infer economies of scope from the calculation of pair-wise cost complementarities. Nevertheless, the cost complementarities evaluated at a point in the sample, such as sample means, do not necessarily provide a good approximation of scope economies across the entire cost surface (Pulley and Humphrey, 1993). Further, applying the translog

[4] We thank an anonymous referee for referring us to the work of PB.

function to widely dispersed data could lead to serious misspecification problems (McAllister and McManus, 1993; Mitchell and Onvural, 1996).

For these reasons, we use the composite cost function developed by PB (1992). The composite cost function is appealing because it combines a quadratic output structure, allowing zero outputs in the estimation of multiproduct firms, with an input-price structure easily restricted to be linearly homogeneous, without imposing separability between output and input prices. We use superscripts in parentheses to represent the Box–Cox transformation as follows:

$$y^{(\phi)} = (y^{\phi} - 1)/\phi \quad \text{for } \phi \neq 0$$

and thus $y^{(\phi)} = y - 1$ for $\phi = 1$ and $y^{(\phi)} \to \ln y$ for $\phi \to 0$.

The composite cost function with an additive error term u is denoted

$$\begin{aligned} C^{(\phi)} = {} & \Big[\alpha_0 + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk} q_j q_k + \sum\sum \delta_{jh} q_j \ln r_h\Big] \\ & \times \exp\Big[\beta_0 + \sum \beta_h \ln r_h + (1/2)\sum\sum \beta_{hl} \ln r_h \ln r_l + \sum\sum \mu_{jh} q_j \ln r_h\Big]^{(\phi)} + u. \end{aligned} \tag{1}$$

For $\phi = 1$, Equation (1) becomes

$$\begin{aligned} C = {} & \Big[\alpha_0 + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk} q_j q_k + \sum\sum \delta_{jh} q_j \ln r_h\Big] \\ & \times \exp\Big[\beta_0 + \sum \beta_h \ln r_h + (1/2)\sum\sum \beta_{hl} \ln r_h \ln r_l + \sum\sum \mu_{jh} q_j \ln r_h\Big] + u, \end{aligned} \tag{2}$$

and for $\phi \to 0$, Equation (1) becomes

$$\begin{aligned} \ln C = {} & \ln\Big[\alpha_0 + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk} q_j q_k + \sum\sum \delta_{jh} q_j \ln r_h\Big] \\ & + \Big[\beta_0 + \sum \beta_h \ln r_h + (1/2)\sum\sum \beta_{hl} \ln r_h \ln r_l + \sum\sum \mu_{jh} q_j \ln r_h\Big] + u. \end{aligned} \tag{3}$$

Equations (1)–(3) are the composite model proposed by PB. We make the following modifications to the above composite functional form. First, estimating both constant terms α_0 and β_0 was problematical; following PB, we retained α_0 based on fit. The cross product term $\sum\sum \mu_{jh} q_j \ln r_h$ was deleted from the regression for the same reason. Second, PB and subsequent researchers using the composite function estimated ϕ employing the nonlinear-least-squares routine. Instead of estimating the value of ϕ in the model, we choose the logarithmic form of the composite cost function *a priori*, that is, we let ϕ approach zero. We believe that the logarithmic form is the appropriate form for our data set because the sample values of the dependent variable differ widely between the largest and the smallest firms, and the difference is reduced by taking the logarithm. Third, since we use panel data, we would like to examine firm-specific effects and aggregate shocks that shift the cost function over time. The effects of time will be incorporated in the error term,[5] while firm-specific effects are modeled as dummy variables. Taking these modifications into consideration, we use the following composite functional form

$$\ln C_{it} = \ln\left[\sum_{i}^{N} \psi_i D_i + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk} q_j q_k + \sum\sum \delta_{jh} q_j \ln r_h\right]$$
$$+ \left[\sum \beta_h \ln r_h + (1/2)\sum\sum \beta_{hl} \ln r_h \ln r_l\right] + u_{it}, \quad i = 1, \ldots, N,\ t = 1, \ldots, T, \tag{4}$$

where subscripts i and t denote the firm and the year, respectively, N is the number of firms, T is the number of years in the sample, and D_i is a dummy variable for firm i ($D_i = 1$ for firm i; 0 otherwise, $i = 1, \ldots, N$). The dummy variables allow the intercept of the cost function (4) to vary across firms. Thus, the intercept term α_0 is modified as the set of the firm-specific intercepts, $\sum_i^N \psi_i D_i$, to capture systematic differences in costs across firms.

Regularity Conditions

A well-behaved cost function must be homogeneous of degree one in input prices, which implies

$$\sum_h \beta_h = 1, \quad \sum_h \beta_{hl} = \sum_l \beta_{hl} = 0, \quad \text{and} \quad \sum_h \delta_{jh} = 0.$$

We also impose the homogeneity and symmetry restrictions ($\alpha_{jk} = \alpha_{kj}$ and $\beta_{hl} = \beta_{lh}$).

In addition to the homogeneity and symmetry conditions, a well-behaved cost function satisfies the following regularity conditions.

R1: The marginal cost of jth product is positive (positive MC condition).

R2: Cost increases with input prices (monotonicity).

Following PB (1992) and other studies using the composite cost function, we will count the number of observations for which the regularity conditions R1 and R2 are satisfied, instead of imposing the regularity conditions in the estimation.

Tests of Economies of Scale and Scope

A well-known measure of scale economies is ray scale economies, RSE, which is the elasticity of cost with respect to output holding output composition constant. RSE is most useful if firms grow by changing their scales but not the compositions of their output bundles.

[5] Kasuya (1989) and McKillop, Glass, and Morikawa (1996) include time trend terms in the cost function, instead of modeling the time effect in the error term. One could then interpret the time trend terms as representing the effect of deterministic technological change.

In practice, insurance firms do change the compositions of their output bundles as they grow, as shown later in Table 4. An appropriate measure of scale economies that takes these changes into account is the expansion path scale economy measure, $\mathrm{EPSE_{AB}}$, proposed by Berger, Hanweck, and Humphrey (1987). $\mathrm{EPSE_{AB}}$ is the elasticity of incremental cost with respect to incremental output, defined as follows:

$$\mathrm{EPSE_{AB}} = \frac{\sum_j \left[(q_{\mathrm{B}_j} - q_{\mathrm{A}_j})/q_{\mathrm{B}_j}\right]\left[\partial \ln C(r, q_{\mathrm{B}})/\partial \ln q_j\right]}{[C(r, q_{\mathrm{B}}) - C(r, q_{\mathrm{A}})]/C(r, q_{\mathrm{B}})}, \tag{5}$$

where $q_{\mathrm{A}j}$ and $q_{\mathrm{B}j}$ are the quantities of the jth output at firms A and B, respectively, and $C(r,\, q_{\mathrm{A}})$ and $C(r,\, q_{\mathrm{B}})$ are operating costs at firms A and B, respectively, evaluated at sample median input prices. Firms A and B are chosen arbitrarily with firm A smaller than firm B. The numerator is the percentage change in cost when each output changes in the same proportion as it does between bundles A and B. The denominator is the percentage difference in costs between firms A and B computed from the cost function. There are scale economies (diseconomies) as $\mathrm{EPSE_{AB}}$ is less than (greater than) one. $\mathrm{EPSE_{AB}}$ for firms A and B using the composite cost function (4) is given by

$$\mathrm{EPSE_{AB}} = \frac{\sum_j \Delta q_{\mathrm{BA}j}\left(\alpha_j + \sum_k \alpha_{jk} q_{\mathrm{B}k} + \sum_h \delta_{jh} \ln r_h\right)}{(\psi_{\mathrm{B}} - \psi_{\mathrm{A}}) + \sum_j \Delta q_{\mathrm{BAj}}\left(\alpha_j + \sum_h \delta_{jh} \ln r_h\right) + (1/2)\sum_j \sum_k \alpha_{jk} \Delta q_{\mathrm{BA}_j} \Delta q_{\mathrm{BA}k}}, \tag{6}$$

where $\Delta q_{\mathrm{BA}j} \equiv q_{\mathrm{B}j} - q_{\mathrm{A}j}$. The derivation of (6) is presented in Appendix A. We will estimate economies of scale by evaluating (6) using the sample medians.

Economies of scope, on the other hand, refer to cost savings from producing several outputs in the same firm, rather than producing each output separately in a specialized firm. For the P/C insurers, economies of scope may be realized from combined customer databases and service centers, or from sharing inputs like managerial expertise and physical inputs in joint production. For the case of two outputs, the traditional measure of scope economies[6] is given by

$$\mathrm{SCOPE} = [C(q_1, 0; r) + C(0, q_2; r) - C(q_1, q_2; r)]/C(q_1, q_2; r). \tag{7}$$

In practice, the insurance companies in our sample do not specialize in the production of only one output.[7] In order to measure economies of scope for the firms in our sample

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[6] Berger et al. (2000) propose an alternative measure of scope economies by estimating cost functions separately for joint producers and specialized firms. This method is possible only when data are available on both types of insurers, which is not the case for our data.

[7] Outputs of some foreign firms are not positive for all years. Of the 208 (=13 firms times 16 years) observations on the foreign firms, 16 observed values of q_1 are zero; four foreign firms did not provide q_1 for the first several years of the sample period. None of q_2's are zero in any observation. The outputs of the Japanese firms are all positive.

at points that are representative of sample observations, we adopt a measure called "quasi-economies of scope" proposed by PB (1992) and Pulley and Humphrey (1993). The quasi-economies of scope formula extends the SCOPE formula by evaluating quasi-specialized production in which small amounts of the nonspecialized outputs are produced as well. Production of the specialized output is adjusted so that the total amount produced by the quasispecialized firms equals the quantity produced in joint production. Defining the parameter ϵ to be the proportion of the nonspecialized outputs produced, the quasi-economies of scope of a firm producing two types of output are defined as:

$$\mathrm{QSCOPE} = [C((1-\varepsilon)q_1, \varepsilon q_2; r) + C(\varepsilon q_1, (1-\varepsilon)q_2; r)C(q_1, q_2; r)]/C(q_1, q_2; r). \quad (8)$$

When $\varepsilon = 0$, QSCOPE becomes the traditional scope measure.[8] For $\varepsilon > 0$, QSCOPE is a subadditivity measure capturing both scope and scale effects. The maximum value for ε is 1/2, where the denominator 2 is the number of outputs in our model. Here quasi-specialized production amounts to producing a half of both outputs. At this point production is no longer specialized, and the QSCOPE reduces to a measure of scale economies along an output ray.

The QSCOPE measure for firm i for the composite cost function (4) is given by

$$\mathrm{QSCOPE}_i = \left[\psi_i - \sum_j \alpha_{jj}\varepsilon(1-\varepsilon)q_j^2 - (1/2)(\alpha_{12}+\alpha_{21})(1-2\varepsilon+2\varepsilon^2)q_1q_2\right] \Big/ \left[\psi_i + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk}q_jq_k + \sum\sum \delta_{jh}q_j \ln r_h\right]. \quad (9)$$

The derivation of (9) is given in Appendix A. Various values of $\varepsilon \in [0, 1/2]$ and the sample medians of q's and r's for each firm are substituted in (9) to estimate QSCOPE_i for firm i.

Econometric Considerations

Since we use the estimated cost function parameters to calculate scale and scope economies, a set of efficient estimates is needed to obtain a better inference about these economies. A typical and the simplest assumption often made for the panel data model with firm-specific dummies is that the disturbance term is white noise, that is,

$$u_{it} \sim \mathrm{IIN}(0, \sigma_\eta^2), \quad i = 1, \ldots, N, \ \ t = 1, \ldots, T. \quad (10)$$

This specification will be referred to as the "benchmark" model.

As will be discussed in "Estimation Results," the benchmark model does not yield good estimation results; the error term of Japanese firms appears to be autocorrelated, and the variance of the error term is not homoscedastic. Examination of our data

[8] This paragraph is an excerpt from Pulley and Humphrey (1993, p. 446).

reveal that the inputs and outputs of the Japanese firms have grown very smoothly over the sample period, but the same is not true for the foreign insurers. This fact led us to suspect that prior to deregulation in the mid 1990s, the Japanese P/C insurers, shielded from outside competition, rarely attempted to make changes in their business and thereby maintained their respective shares in the industry; this tendency could have caused autocorrelation among successive disturbances. On the other hand, most foreign insurers, being small and relatively new in the industry, experienced relatively large ups and downs in their business performance, which probably explains why their disturbance term seems to be more random.

To accommodate these group-wise differences as well as firm-specific heterogeneity, we use a special type of the error-components model proposed by Magnus and Woodland (1988).[9] Consider a nonlinear regression equation with a following disturbance term

$$u_{it} = e_t + \mu_{it}, \quad i = 1, \ldots, N, \;\; t = 1, \ldots, T, \tag{11}$$

where e_t is the unobservable aggregate effect, and μ_{it} is the noise term. In order to check our conjecture, we further assume that the aggregate shock component follows an AR(1) process and the noise component can be heteroscedastic across firms. Explicitly,

$$e_t = \rho e_{t-1} + \nu_t, \quad \nu_t \sim \text{IIN}\big(0, \sigma_\nu^2\big), \quad |\rho| < 1 \tag{12}$$

and

$$\mu_{it} = \lambda_i^{1/2} \eta_{it}, \quad \eta_{it} \sim \text{IIN}\big(0, \sigma_\eta^2\big), \qquad \lambda_i > 0 \quad (i = 1, \ldots, N) \tag{13}$$

with initial conditions

$$e_1 = (1 - \rho^2)^{-1/2} \nu_1 \quad \text{and} \quad \mu_{i1} = \lambda_i^{1/2} \eta_{i1}.$$

Our notation for the disturbance term is

$$u_i = (u_{i1}, u_{i2}, \ldots, u_{iT})' \quad \text{and} \quad u = (u_1', u_2', \ldots, \mathrm{u}_{\mathrm{N}}')'.$$

In other words, the disturbance term is first stacked by time index t, then by firm index i. The covariance matrix can then be written as

$$\Omega \equiv \mathrm{E}uu' = \sigma_\eta^2 (I_N \otimes I_T) + \sigma_\nu^2 (\iota_N \iota_N' \otimes M_\rho) \tag{14}$$

where I_N is an identity matrix of dimension N, ι_N is a vector of ones of dimension N, and M_ρ is a $T \times T$ symmetric matrix of the same structure as in Magnus and Woodland (1988).[10] By specifying the disturbance structure in this fashion, our most general

[9] Magnus and Woodland (1988) assumed a system of equation and a more complicated structure on the disturbances. See also Baltagi and Li (1991) for an alternative specification of the error components model.

[10] See their equation (2.3) on p. 711.

TABLE 2
Variable Definitions

Variable	Definitions
Dependent variable and output	
C_{it}[a]	(net operating expenses, in million yen)$_{it}$/CPI$_t$
Q_{1it}	(nominal incurred losses for the third sector, in million yen)$_{it}$[b]
Q_{2it}	(nominal incurred losses for the second sector, in million yen)$_{it}$
Inputs	
R_{Lt}	price of labor (wage index for employees in finance and insurance in year t)
R_{Ait}	price of agencies for Japanese firm i = (commissions paid to agencies in million yen)$_{it}$/(number of agencies)$_{it}$
R_{At}	price index of agencies (average of R_{Ait} over 20 Japanese firms in year t)
R_{Mit}	materials price for firm i in t, available for 14 Japanese firms with listed stocks = $\sum_h (R_{ht}\ \omega_{hit})$, where R_{ht} is price deflator of item h in the nonpersonnel (materials) expenses in year t; and ω_{hit} is the share of item h in the nonpersonnel (materials) expenses for firm i in year t
R_{Mt}	price of materials (average of R_{Mit} over 14 Japanese firms in year t)
X_{Lit}	(number of employees)$_{it}$
X_{Ait}	(number of agencies, weighted by the agency class)$_{it}$ (see footnote 17)
X_{Mit}	(volume of materials input)$_{it}$ = $\{C_{it} - (R_{Lt}\ X_{Lit} + R_{At}\ X_{Ait})\}/R_{Mt}$
Variables used in the regressions	
c_{it}	C_{it}/R_{Mt}
q_{1it}	Q_{1it}/CPI_t
q_{2it}	Q_{2it}/CPI_t
$\ln r_{Lt}$	$\ln(R_{Lt}/R_{Mt})$
$\ln r_{At}$	$\ln(R_{At}/R_{Mt})$

[a] i and t index firm and time, respectively.
[b] Nominal incurred losses are the sum of net claims paid and change in loss reserves.

model allows firm-wise heteroscedasticity and autocorrelated aggregate shocks. One can formally test the adequacy of specifications such as (10) by implementing a series of likelihood ratio (LR) tests.

Most of the previous research analyzing panel data does not have explicit assumptions regarding the error term and simply uses the least squares estimator corresponding to specification (10). With our specification, we can formally test the presence of autocorrelation and heteroscedasticity and, should they exist, explicitly correct them to obtain efficient estimates.

DATA, OUTPUT, AND INPUT SPECIFICATION

Output Specification

The variables used in our analysis are summarized in Table 2. Defining the production scale for the P/C insurance firms is not straightforward, as in the manufacturing industry. A common measure of output used in the literature is premiums earned. Using premiums earned as an explanatory variable, however, could cause simultaneous equations bias. Because the premiums earned are value measures of output, they would be a function of costs if the insurance rates depend on the costs.[11] The premiums earned are then an endogenous variable and not independent of the stochastic error term. In light of this, Doherty (1981) used claims paid as a measure of output. Following Weiss (1991) and Cummins and Weiss (1993, 2000), we use real incurred losses as a measure of output, where real incurred losses are defined as the sum of net claims paid and changes in loss reserves, deflated by CPI.[12] The reason for using real incurred losses is as follows. The basic function of insurance is to guarantee claims payment to insureds in the event of loss. The underwriting services are likely to vary directly with the expected loss payment. We use the actual value of incurred losses as a substitute for the unobservable expected losses. Although insurance companies provide services other than loss indemnification, incurred losses are a better measure of output than premiums earned because incurred losses are not a function of the dependent variable.

To measure economies of scope of a multiproduct insurer (whether or not the insurance company can reduce its cost by offering a mix of products), we divide the entire lines into the third sector and all other P/C insurance lines (the second sector). Following the Dictionary of Insurance Terms (1997), we include in the third sector personal accident, savings-type accident,[13] nursing care expenses (first introduced in 1989), and savings-type nursing care expenses insurance (first introduced in 1990), as noted in the third column of Table 1.[14] Again, the variables for each type of output are real incurred losses for the third sector, denoted as q_1, and for the rest of P/C insurance lines, denoted as q_2.

Cost and Input Variables

As a measure of costs (C), we use real net operating expenses, which are operating expenses net of reinsurance commissions, deflated by the CPI.[15] Operating expenses are the sum of loss adjustment expenses, general administrative expenses, and commissions and collection expenses.

Insurer inputs are classified as labor, agencies, and materials, denoted by subscripts L, A, and M, respectively.[16] As indicated in Table 2, the volume of labor input is measured by the number of employees (not including collection personnel). The volume of

[11] The premium rates set by the rating organization of Japan were based on the costs of the insurance firms (see Kamiyama, 1997).

[12] Loss reserves represent the estimated value of future insurance claims under policies already written.

[13] Savings-type insurance is an insurance product with maturity refund.

[14] Unfortunately, the data on nursing care expenses and savings-type nursing care expenses insurance are not available for *individual* foreign insurers. For foreign insurers as a whole, the share of nursing care expenses insurance (including savings-type) constitutes only about 0.03 percent of total P/C insurance products. Accordingly, we include only personal accident and savings-type personal accident insurance as the third sector for foreign firms. See Table 5 for more on this point.

[15] We use net operating expenses rather than operating expenses because data on operating expenses are not available for the foreign firms operating in Japan.

[16] Physical capital represents a small proportion of total costs in the insurance industry. We lump it together with materials, as explained below.

agencies input is measured by the number of agencies weighted by the class size of the agencies.[17] Because data on the number of workers employed in each agency are not available, we treat labor and agencies as separate inputs. Materials are treated as a residual input in this study; the volume of materials input equals the difference between net operating expenses and the sum of expenses on labor and agencies, divided by the price of materials, defined in the next paragraph.

The variables used for the input prices are as follows. The labor input price in year t ($R_{\mathrm{L}t}$) is the wage index of total cash earnings in finance and insurance.[18] The price of agencies for firm i in year t ($R_{\mathrm{A}it}$; $i = 1, \ldots, 20$) equals commissions paid by the insurance firm to its agencies divided by the number of agencies in year t. Because the data on agencies is available for only the 20 Japanese companies, we construct a price index of agencies ($R_{\mathrm{A}t}$) from the available sample of 20 Japanese firms over the 16-year period. The index $R_{\mathrm{A}t}$ is used as the price of agencies for all the firms in the sample. To compute the price of materials ($R_{\mathrm{M}t}$), we follow Kasuya (1989), who estimated the cost structure of the Japanese banking industry. The price of materials for firm i in year t ($R_{\mathrm{M}it}$) is given by

$$R_{\mathrm{M}it} = \sum_h (R_{ht}\omega_{hit}),$$

where R_{ht} is the price deflator of item h in the nonpersonnel (materials) expenses in year t, and ω_{hit} is the share of item h in the nonpersonnel expenses for firm i in year t. The items in the nonpersonnel expenses reported by individual firms are: rents on land, building, and machinery; repair expenses; travel expenses; communications expenses; expenses related to office work and office supplies; advertisement expenses; dues; and other expenses, including outsourcing. The data on ω_{hit} is available only for 14 Japanese stock companies with listed stocks. We construct the price index of materials ($R_{\mathrm{M}t}$) from the available sample of 14 Japanese firms, and use this index as the price of materials for all the firms in our data set. In this study, we use the aggregate price indexes $R_{\mathrm{L}t}$, $R_{\mathrm{A}t}$, and $R_{\mathrm{M}t}$ as the input prices for all the firms in the sample.

[17] In Japan, P/C insurance agencies are classified into special, upper, regular, and basic classes. To be certified as a special class agency, the agency is required to sell P/C insurance worth 50 million yen and over annually. Likewise, the required sales of insurance for an upper class and a regular class agencies are 10 and 1 million yen, respectively. In order to account for the fact that larger insurance companies tend to commission higher class agencies to sell insurance, we put weights 50, 10, 1, and 0.01 for each class of agencies. (Using the weights 0.1 or 0.5 instead of 0.01 for the basic class agency only changes the calculated figures slightly.) The number of agencies that work for insurance firm i, $X_{\mathrm{A}it}$, is counted as $X_{\mathrm{A}it} =$ (50 $\times$ the number of special-class agencies that work for firm i) + (10 $\times$ the number of upper-class agencies working for i) + (1 $\times$ the number of regular-class agencies working for i) + (0.01 $\times$ the number of basic-class agencies working for firm i).

[18] Berger et al. (2000) use the wage index for Standard Industrial Classification (SIC) class 6331 (fire, marine, and casualty insurers) as the price of labor for P/C insurers. We use the aggregate variables for the input prices because individual data on the input prices are not available for the foreign firms. While the available data show that larger firms tend to pay somewhat higher labor expenses per worker and higher commissions to agencies than smaller firms, inter-firm differences in input prices will be reflected in the firm dummies.

The initial values of R_{L1}, R_{A1}, and R_{M1} are set at 1. Since materials are the residual input in our study, the price of materials is numeraire. Our dependent variable and input prices are expressed in terms of the relative prices, that is, $c_{it} \equiv C_{it}/R_{Mt}$, $r_{Lt} \equiv R_{Lt}/R_{Mt}$, and $r_{At} \equiv R_{At}/R_{Mt}$.

Data

We estimate the cost structures of 20 Japanese and 13 foreign-owned P/C insurance companies operating in Japan for 1980 through 1995.[19] The names of the firms included in the data set are listed in Table B1 in Appendix B.

As mentioned in the "Introduction," there were 29 foreign insurance firms operating in Japan in 1995, but the sample includes only the firms that were in business for the entire duration of the sample. The data for the Japanese firms were taken from *Insurance: Songai Hoken Tokei-go* (The Statistics of Japanese Non-Life Insurance Business) published annually by Hoken Kenkyujo (Insurance Research Institute). The data for the foreign-owned firms were taken from *Hoken Nenkan* (The Insurance Yearbook) published by Okura Zaimu Kyokai.

As for the input prices, the wage index is taken from the *Annual Report on the Monthly Labour Survey* by the Japanese Ministry of Health, Labour and Welfare. CPI is taken from the *Annual Report on the National Accounts* by the Economic and Social Research Institute. The price deflators for materials expenses, r_{ht}, are from the *Input–Output Tables* by the Ministry of Economy, Trade and Industry, and the shares of item h for firm i in year t, ω_{hit}, are from the financial statements of the Japanese firms with listed stocks.

The industry's descriptive statistics are given in Table 3, and the composition of the third sector contracts written by the P/C insurers in our sample is given in Tables 4 and 5. As shown in Table 4, the third sector product share of all insurance contracts rose steadily from 6.0 percent in 1980 to 8.7 percent in 1995 for the 20 Japanese firms, and from 18.5 percent in 1980 to 27.6 percent in 1995 for the 13 foreign-owned firms.

Table 5 presents the detailed output composition of the 20 Japanese firms and the 13 foreign insurers in 1995. As mentioned in footnote 14, the data on nursing care expenses insurance is not available for individual foreign firms. For foreign insurers as a whole (including the firms not in our data set), the share of nursing care expenses insurance is only about 0.03 percent of total P/C insurance products (not shown in Table 5). Thus personal accident insurance constitutes the bulk of the third sector products for both the Japanese and the foreign insurers. Table 5 shows that the foreign P/C insurers as a group offer basically the same output bundle as the Japanese firms, though the compositions are different between the two groups.

Because the difference in sizes between large and small insurance companies is so great, we need to check whether it is appropriate to fit a single cost function to the entire sample of 33 firms. The sample is grouped into 20 Japanese firms and 13 foreign insurers operating in Japan. While we believe that the division of the sample into the Japanese and the non-Japanese companies is reasonable since most foreign insurers

[19] The sample ends in 1995 because the definition of operating expenses was changed in 1996. The availability of data on the foreign firms determined the initial year.

TABLE 3
Descriptive Statistics

Variable	Statistics	All Japanese (JPN20)	Foreign (F13)	Large Japanese (JPN15)	Small Japanese and Foreign (J5F13)	All Firms (ALL33)
$c = C/R_M$ (mil yen)	Mean	72302.7	1353.0	93359.0	3514.3	44352.8
	1st quartile	22479.9	129.6	56813.1	839.9	22479.9
	2nd quartile	65171.7	455.3	78105.4	1002.7	11242.7
	3rd quartile	95883.3	1482.4	108434.3	4478.5	75213.3
$q_1 = Q_1/\text{CPI}$ (mil yen)	Mean	8467.4	336.2	11056.0	437.7	5264.2
	1st quartile	2468.5	1.3	5023.6	5.2	80.4
	2nd quartile	5893.7	14.3	7970.5	134.6	1742.4
	3rd quartile	10277.9	193.9	12357.5	512.8	7123.5
$q_2 = Q_2/\text{CPI}$ (mil yen)	Mean	95283.5	1169.3	124253.0	3170.7	58208.1
	1st quartile	23051.4	54.7	70350.6	84.0	481.8
	2nd quartile	80532.0	265.1	99724.3	597.6	11353.7
	3rd quartile	129189.1	894.0	145740.2	4732.6	94856.1
Input prices						
Labor (R_L)	Mean	1.38	1.38	1.38	1.38	1.38
	Median	1.43	1.43	1.43	1.43	1.43
Agencies (R_A)	Mean	1.17	1.17	1.17	1.17	1.17
	Median	1.12	1.12	1.12	1.12	1.12
Materials (R_M)	Mean	1.29	1.29	1.29	1.29	1.29
	Median	1.27	1.27	1.27	1.27	1.27
No. of obs.		20	13	15	18	33

Note: The values of CPI, R_L, R_A, and R_M in the initial year (1980) are set at 1.00.

TABLE 4
Second and Third Sector Products Over Time

		20 Japanese (JPN20)		13 Foreign (F13)		All Firms (ALL33)	
Variable	Year	(mil yen)	Share (%)	(mil yen)	Share (%)	(mil yen)	Share (%)
Third sector (q_1)	1980	4547.9	6.04	132.3	18.45	2808.4	6.12
	1985	7494.6	8.23	272.0	23.28	4649.3	8.35
	1990	9621.5	8.60	380.4	21.22	5981.1	8.73
	1995	11334.4	8.67	607.0	27.58	7108.4	8.87
Second sector (q_2)	1980	70726.4	93.96	584.5	81.55	43094.7	93.88
	1985	83587.7	91.77	896.5	76.72	51012.4	91.65
	1990	102314.0	91.40	1412.6	78.78	62565.0	91.27
	1995	119394.3	91.33	1594.1	72.42	72988.2	91.13

Note: The table lists the mean values of each sample for 1980, 85, 90, and 95; the values for the other years are available upon request.

TABLE 5
Product Composition in 1995 (Sample Average, %)

	JPN20	F13
Second sector	91.31	72.36
Fire[a]	9.08	3.89
Hull	1.28	0.46
Cargo	2.22	1.61
Transit	0.93	0.14
Automobile	57.09	51.87
Compulsory Automobile Liability	10.14	8.13
General Liability	5.08	3.93
Movables Comprehensive[a]	2.05	1.47
Workers' Compensation[a]	1.21	0.12
Burglary	0.64	0.15
Other second sector[b]	1.59	0.60
Third sector	8.67	27.58
Personal Accident[a]	8.62	27.58
Nursing Care Expenses[a]	0.05	Not available
Total	100.00	100.00

Note: Third-sector consists of personal accident and nursing care expenses insurance.
[a]Includes savings-type insurance.
[b]Other second sector = fidelity & credit, aviation, plate glass, guarantee, windstorm & flood, livestock, machinery, nuclear energy, contractors' all risks, miscellaneous pecuniary loss, and ships' passengers accident liability combined. Each of these products constitutes less than 0.5% of the total output for each sample.

are far smaller than their Japanese counterparts, some of the largest foreign firms are larger in scale than the smallest Japanese companies. Alternatively, we divide the sample of 33 firms into two size stratified groups—15 large Japanese firms and the remaining 18 small firms (5 small Japanese plus 13 foreign). We define large firms as having at least 50 billion yen in real net premiums earned (the average for the

TABLE 6
Summary Statistics

	JPN20	F13	JPN15	J5F13	ALL33
			Benchmark Models		
Covariance matrix					
σ_η^2 ($\times$1000)	2.133	77.568	1.374	58.498	
SSR	0.683	16.134	0.330	16.848	
Adj R^2	0.998	0.967	0.995	0.982	
Log L	529.987	−29.253	450.236	0.127	
Regularity conditions (no. of obs. satisfied)					
R1 (MC_1)	320	195	240	274	
R1 (MC_2)	320	208	240	288	
R2 (r_L)	220	141	173	192	
R2 (r_A)	174	85	127	120	
No. of obs.	320	208	240	288	
			AR(1) Models		
Covariance matrix					
σ_η^2 ($\times$1000)	1.040	71.127	0.566	53.086	1.041
σ_ν^2 ($\times$1000)	0.452	5.248	0.470	2.457	0.511
ρ	0.952	−0.559	0.926	0.878	0.952
λ	—	—	—	—	74.494
SSR	1.683	16.301	0.849	18.197	17.832
Adj R^2	0.996	0.967	0.986	0.981	0.995
Log L	624.996	−26.330	534.477	7.173	594.692
Regularity conditions (no. of obs. satisfied)					
R1 (MC_1)	306	194	240	264	502
R1 (MC_2)	320	208	240	287	528
R2 (r_L)	320	136	234	187	465
R2 (r_A)	138	75	64	155	240
No. of obs.	320	208	240	288	528

Notes: σ_η^2 = the variance of the noise term in Equations (10) and (13); σ_ν^2 = the variance of the noise term in the AR(1) specification Equation (12); ρ = autocorrelation coefficient in the AR(1) specification in Equation (12); λ = the ratio of the noise variance of the group of 13 foreign firms relative to the noise variance of the 20 Japanese firms in Equation (13).

sample period) and small firms as those with less than 50 billion yen in average real net premiums earned. All of the foreign companies had average real net premiums earned of less than 50 billion yen and thus belong to the small firm group. We will compare group-wise estimates of cost functions for the 20 Japanese firms (JPN20) and 13 foreign insurers (F13); 15 large Japanese firms (JPN15) and the remaining 18 small firms (J5F13); and the pooled sample of 33 firms (ALL33).

ESTIMATION RESULTS

Table 6 summarizes the estimation results of the composite cost function (4) with the white noise disturbance (10) ("the benchmark models") and autocorrelated disturbances (12) ("the AR(1) models") for the two groupings, JPN20 & F13, and JPN15 &

TABLE 7
Likelihood Ratio Tests

Log Likelihood Values	JPN20	F13	JPN15	J5F13
Benchmark model (L)	529.987	−29.253	450.236	0.127
AR(1) model (L^*)	624.996	−26.330	534.477	7.173
LR statistic (LR)	190.018	5.846	168.482	14.093

Notes: Denoting the log likelihood of the benchmark model (10) by L, and the log likelihood of the AR(1) model (12) by L^*, the likelihood ratio statistic is $\text{LR} = 2(L^* - L)$. With two degrees of freedom, the critical chi-square values are 5.991 at the 5 percent significance level, and 9.210 at the 1 percent level.

J5F13, as well as the entire sample, ALL33. The cost function was estimated by the method of maximum likelihood. Asymptotic standard errors were calculated based on the formula derived in Magnus (1982), modified to fit our application. Iterative estimation was used, since the estimated model was nonlinear in parameters. The estimated coefficients of individual variables are not listed here for lack of space but are available upon request.

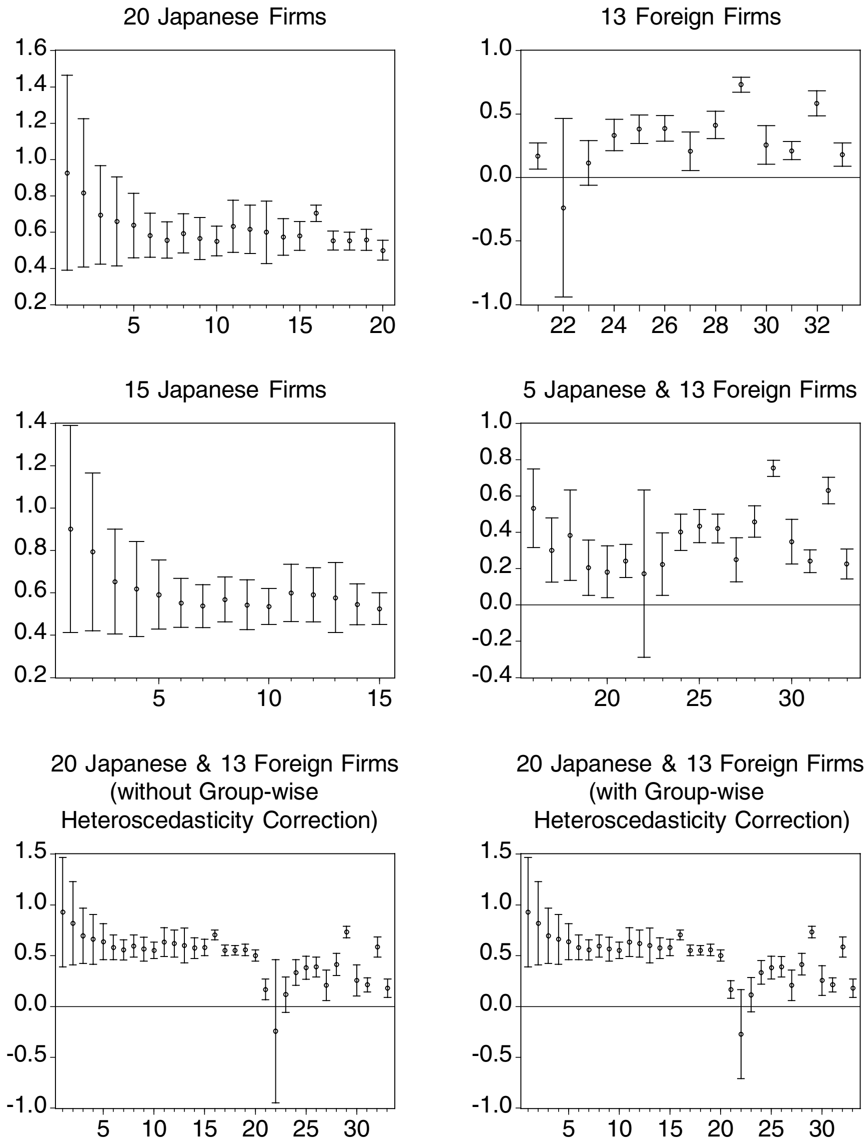
As mentioned in "Regularity Conditions," we did not impose regularity conditions in the estimation. It can be seen from Table 6 that the regularity condition of positive marginal cost (R1) is satisfied in the majority of observations, though monotonicity of costs with respect to input prices (R2) is satisfied less frequently. The percentages of violations are comparable to results in the previous studies such as PB (1992) and Pulley and Humphrey (1993).

Focusing first on the subsamples, the high values of ρ, the autocorrelation coefficient, for JPN20 and JPN15 also indicate that autocorrelation in the covariance matrix might be a problem for these subsamples. Because we employ the Magnus–Woodland type error components model, we follow their approach and test for autocorrelation in each subsample using the LR test. The LR statistics are reported in Table 7. The significant likelihood gains in autocorrelation specification over the benchmark model for JPN20, JPN15, and J5F13 indicate that the generalization is quite useful. The null hypothesis of no autocorrelation is rejected at the 1 percent significance level for all groups except F13.[20] The LR statistic is not significant at the 5 percent level for F13. Accordingly, we choose the AR(1) models for JPN20, JPN15, and J5F13, and the benchmark model for F13 as the best specification for each subsample. In what follows, we will examine only the best specifications for each subsamples.

Getting back to Table 6, the large values of σ_η^2, variance of the noise term in Equations (10) and (13), for F13 and J5F13 imply that the estimated cost function does not fit the foreign insurance companies very well. This was confirmed when economies of scale and economies of scope were calculated from the regression

[20] In the AR(1) model, the number of additional parameters over the benchmark model is two. With two degrees of freedom, the critical chi-square values are 5.991 at the 5 percent significance level, and 9.210 at the 1 percent level.

FIGURE 1
Scope Estimates



Note: The point estimates and their 95 percent confidence intervals are plotted.

results. As shown in Figure 1, the confidence intervals were quite large for some foreign insurers. This prompted us to estimate the pooled sample of 33 firms (ALL33) with the following modifications to better fit the foreign companies. (The following paragraph refers to the estimation of coefficients for ALL33, which are not shown here; only the summary statistics are given in Table 6.)

First, we estimated the coefficients separately for the 20 Japanese firms and for the 13 foreign insurers. Separate estimation of the coefficients amounts to checking for the differences in the slopes between the two groups. In other words, we used dummy variables that allow for differences in the slopes between the two groups. If the two groups indeed have different cost structures, the estimated coefficients for the Japanese firms will be different from the estimated coefficients for the foreign firms, with statistically significant *t*-statistics. Second, in light of the results of the LR tests in Table 7, we incorporated the AR(1) specification in the disturbance term for the 20 Japanese firms but not for the 13 foreign insurers. Third, we allowed for a possibility that the 13 foreign firms as a group have larger noise variance than the group of the 20 Japanese insurers. "λ" for ALL33 in Table 6 refers to the ratio of the noise variance of the 13 foreign firms relative to the noise variance of the 20 Japanese firms, where λ is the proportional factor of noise variance. The fact that the estimated value of λ is 74.49 means that the estimated variance of the noise term for the 13 foreign firms as a group is 74.49 times the estimated variance for the 20 Japanese firms (see Equation (13)), i.e., the error term is heteroscedastic between the two groups. The apparent presence of heteroscedasticity is in accord with our initial observation that the disturbance term for the foreign insurers seems to be more random than that for the Japanese firms. In Table 6, ALL33 is the estimation result incorporating these modifications. In other words, ALL33 is the pooled estimation of the AR(1) model for JPN20 and the benchmark model for F13.

Table 8 presents estimates of the expansion path scale economies, EPSE. We calculated asymptotic standard errors using the gradient approximation procedure.[21] From the asymptotic standard errors, the *t*-statistics for the EPSE were computed using the formula[22]

$$t_{\mathrm{EPSE}} = |\mathrm{EPSE\ estimate} - 1|/\mathrm{asymptotic\ standard\ error}.$$

The estimates of the EPSE depend on the choice of the two firms. Table 8 presents the EPSE estimates as P/C insurers change their scales from the smallest (33rd) firm in our data set to the 25th firm, from the 25th firm to the 17th firm, from the 17th firm to the 9th firm, and from the 9th firm to the largest firm, where the firm size is measured by the average value of their real net premiums earned. The largest, the 9th largest, and the 17th largest firms are Japanese insurers, and the 25th largest and the smallest firms are foreign insurers. The EPSE estimates less (greater) than one indicate economies (diseconomies) of scale.

It can be seen from Table 8 that there are statistically significant expansion path scale economies between two firms in all the subsamples. Note also that the EPSE estimates for the same set of firms are stable across different estimations. For example, the EPSE estimates from the 9th largest to the largest firm are 0.762 in JPN20, 0.789 in JPN15, and 0.762 in ALL33.

[21] The derivation of asymptotic standard errors follows the method described in Anderson and Thursby (1986). We thank an anonymous referee for showing us this method to calculate the asymptotic standard errors of economies of scale and scope.

[22] With 15 degrees of freedom (16 observations for each firm minus one degree of freedom), the critical *t*-value at the 5 percent level is 2.131 for a two-tailed test.

Table 8
EPSE Estimates

	JPN20 (AR(1) Model)		F13 (Benchmark Model)		JPN15 (AR(1) Model)		JPF13 (AR(1) Model)		ALL33 (Heterocorrected)	
Firms	EPSE	Std. Error	EPSE	Std. Error	EPSE	Std. Error	EPSE	Std. Error	EPSE	Std. Error
From 9th firm to largest firm	0.762	0.041**			0.789	0.037**			0.762	0.041**
From 17th firm to 9th firm	0.526	0.026**							0.525	0.026**
From 25th firm to 17th firm							0.387	0.279*	0.442	0.023**
From 33rd firm to 25th firm			0.779	0.079*			0.755	0.059**	0.779	0.079*

Notes: The largest, 9th largest, 17th, 25th, and the smallest firms are respectively, Tokio, Fuji, Asahi, New India, and L'Union. EPSE estimates less (greater) than one indicate economies (diseconomies) of scale.
*Statistically different from 1 at the 5 percent level for a two–tailed test. **Statistically different from 1 at the 1 percent level for a two-tailed test. With 15 degrees of freedom, the critical t-values are 2.131 at the 5 percent level, and 2.947 at the 1 percent level for two-tailed tests.

The QSCOPE estimates are provided in Figure 1 and Table 9. We evaluated QSCOPE for each firm using the sample medians of the output and input price data for the following values of ε: 0.0 (yielding the traditional SCOPE formula), 0.000001, 0.0001, 0.001, 0.01, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, and 0.5. For lack of space, only the estimates of the firms whose QSCOPE values are at 25, 50, and 75 percentile of each subsample for the selected values of ε are given in Table 9.[23]

In Figure 1, only the SCOPE estimates of each firm for $\varepsilon = 0$ are shown for the same reason. The horizontal axis in each panel has the firms in each subsample in the same order as in our data set (i.e., in the same order as the list of firms in Table B1 in Appendix B), and are ordered roughly, though not strictly, according to the size of premiums earned. For example, the first firm in JPN20 is Tokio Marine & Fire Insurance, the largest P/C insurer in Japan. And the last firm in JPN20 is Daido Fire & Marine Insurance, the smallest among the 20 Japanese P/C insurers included in our data set. The SCOPE estimates for $\varepsilon = 0$ are on the vertical axis. The dots in each panel plot the point estimates of each firm. There are scope economies (diseconomies) as SCOPE is greater (less) than zero. And the ceiling above and the floor below each dot plot the 95 percent confidence intervals. The t-statistics for the QSCOPE were obtained from

$$t_{\mathrm{SCOPE}} = \text{QSCOPE estimate/asymptotic standard error},$$

and the 95 percent confidence intervals were derived from the t-statistics.

The figure shows the scope economy estimates of the best specifications for each subsample—AR(1) models for JPN20, JPN15, and J5F13, and the benchmark model for F13. For the overall sample of 33 firms (ALL33), two panels, one with the group-wise heteroscedasticity correction (our preferred model) and one without, are shown. Not correcting for group-wise heteroscedasticity for ALL33 amounts to assuming that the noise variance is the same for the 20 Japanese and the 13 foreign firms.

It is apparent from Figure 1 that the SCOPE estimates are significantly greater than zero (implying economies of scope) for all of the Japanese firms. The SCOPE estimates and the lower bound of the confidence intervals exceed zero for most, though not all, of the foreign insurers as well. Note that the SCOPE estimates are generally larger for larger firms (the firms listed at the beginning of each subsample). At the same time, the SCOPE estimates of a given firm are stable across different subsamples. For example, the SCOPE estimates of, say, firm 19 are 0.556 in JPN20, and 0.557 in ALL33 (see Table 9). We also see from Table 9 that the QSCOPE estimates of a given firm vary steadily, not drastically, with changes in ε. Note also that for ALL33, the confidence intervals for at least one firm are tightened by correcting for group-wise heteroscedasticity (compare the bottom two panels in Figure 1).

Because firm estimates are robust to changes in sample group, the EPSE and the QSCOPE estimates calculated from the composite cost function are reliable. Overall, the composite cost function yields a good statistical fit, and the estimation results are stable with respect to small changes in the values of ε's. The good performance of

[23] A complete list of the QSCOPE estimates for all the sample firms is available upon request.

TABLE 9
QSCOPE Estimates

		JPN20 (AR(1) Model)		F13 (Benchmark Model)		JPN15 (AR(1) Model)		J5F13 (AR(1) Model)		ALL33 (Heterocorrected)	
	ε	QSCOPE	Std. Error	QSCOPE	Std. Error	QSCOPE	Std. Error	QSCOPE	Std. Error	QSCOPE	Std. Error
25 percentile		Firm 19 (Taiyo)		Firm 33 (QBE)		Firm 9 (Chiyoda)		Firm 33 (QBE)		Firm 25 (Hyundai)	
	0	0.5558	0.0275**	0.1789	0.0438**	0.5426	0.0560**	0.2241	0.0394**	0.3796	0.0534**
	0.0001	0.5558	0.0275**	0.1789	0.0438**	0.5426	0.0560**	0.2241	0.0394**	0.3796	0.0534**
	0.01	0.5556	0.0275**	0.1790	0.0438**	0.5377	0.0542**	0.2241	0.0394**	0.3796	0.0534**
	0.1	0.5535	0.0273**	0.1793	0.0438**	0.4975	0.0402**	0.2243	0.0394**	0.3802	0.0533**
	0.2	0.5517	0.0272**	0.1796	0.0437**	0.4624	0.0303**	0.2244	0.0394**	0.3807	0.0531**
	0.3	0.5504	0.0271**	0.1798	0.0436**	0.4374	0.0262**	0.2245	0.0393**	0.3810	0.0530**
	0.4	0.5496	0.0271**	0.1799	0.0436**	0.4224	0.0255**	0.2246	0.0393**	0.3812	0.0530**
	0.5	0.5493	0.0271**	0.1799	0.0436**	0.4173	0.0257**	0.2246	0.0393**	0.3813	0.0530**
50 percentile		Firm 8 (Koa)		Firm 30 (Royal Insurance)		Firm 13 (Dai-Tokyo)		Firm 30 (Royal Insurance)		Firm 19 (Taiyo)	
	0	0.5916	0.0518**	0.2544	0.0723**	0.5771	0.0792**	0.3470	0.0583**	0.5565	0.0276**
	0.0001	0.5915	0.0518**	0.2544	0.0723**	0.5770	0.0792**	0.3470	0.0583**	0.5565	0.0276**
	0.01	0.5874	0.0502**	0.2550	0.0721**	0.5696	0.0764**	0.3473	0.0582**	0.5563	0.0275**
	0.1	0.5542	0.0382**	0.2599	0.0707**	0.5091	0.0541**	0.3500	0.0575**	0.5542	0.0274**
	0.2	0.5252	0.0297**	0.2642	0.0696**	0.4562	0.0367**	0.3524	0.0569**	0.5524	0.0272**
	0.3	0.5044	0.0260**	0.2673	0.0688**	0.4184	0.0277**	0.3541	0.0565**	0.5511	0.0272**
	0.4	0.4920	0.0252**	0.2692	0.0683**	0.3957	0.0253**	0.3551	0.0562**	0.5503	0.0271**
	0.5	0.4878	0.0252**	0.2698	0.0682**	0.3882	0.0252**	0.3554	0.0562**	0.5501	0.0271**

(Continued)

TABLE 9
(Continued)

	ε	JPN20 (AR(1) Model) QSCOPE	JPN20 (AR(1) Model) Std. Error	F13 (Benchmark Model) QSCOPE	F13 (Benchmark Model) Std. Error	JPN15 (AR(1) Model) QSCOPE	JPN15 (AR(1) Model) Std. Error	J5F13 (AR(1) Model) QSCOPE	J5F13 (AR(1) Model) Std. Error	ALL33 (Heterocorrected) QSCOPE	ALL33 (Heterocorrected) Std. Error
75 percentile		Firm 4 (Sumitomo)		Firm 26 (Royal Exchange)		Firm 4 (Sumitomo)		Firm 25 (Hyundai)		Firm 12 (Fuji)	
	0	0.6576	0.1170**	0.3864	0.0475**	0.6174	0.1068**	0.4332	0.0429**	0.6161	0.0635**
	0.0001	0.6575	0.1170**	0.3864	0.0475**	0.6173	0.1068**	0.4332	0.0429**	0.6160	0.0635**
	0.01	0.6461	0.1125**	0.3866	0.0475**	0.6059	0.1028**	0.4333	0.0429**	0.6110	0.0614**
	0.1	0.5532	0.0767**	0.3877	0.0472**	0.5129	0.0706**	0.4335	0.0428**	0.5695	0.0450**
	0.2	0.4720	0.0478**	0.3887	0.0471**	0.4317	0.0444**	0.4338	0.0428**	0.5333	0.0327**
	0.3	0.4141	0.0321**	0.3894	0.0469**	0.3737	0.0298**	0.4339	0.0427**	0.5074	0.0268**
	0.4	0.3793	0.0284**	0.3899	0.0469**	0.3389	0.0258**	0.4340	0.0427**	0.4918	0.0252**
	0.5	0.3677	0.0286**	0.3900	0.0468**	0.3272	0.0257**	0.4340	0.0427**	0.4867	0.0251**

Notes: The estimates of firms whose QSCOPE values are at the 25 percentile, 50 percentile, and 75 percentile of each sample are presented. QSCOPE estimates greater (less) than zero indicate economies (diseconomies) of scope.
**Statistically different from 0 at the 1 percent level for a two-sided test.

the composite cost model is in line with the existing studies using the composite cost function such as PB, Pulley and Humphrey (1993), McKillop, Glass, and Morikawa (1996), and Berger et al. (2000). We therefore conclude that the composite cost function, together with our specification of the disturbance terms, fits the data well and that significant economies of scale and scope exist for most of the P/C insurance firms in Japan.

CONCLUSION

This article analyzed economies of scale and economies of scope for Japanese and foreign P/C insurance companies by fitting a composite cost function on a set of panel data and employing an error component model. We found statistically significant economies of scope between the second and third sector insurance lines for both Japanese and most of the foreign insurers operating in Japan. Expansion path scale economies were also observed between smaller and larger firms. Finally, efficiency in estimation was significantly improved by correcting for group-wise autocorrelation and heteroskedasticity in the disturbance term.

Our finding that economies of scope are greater for larger firms implies that the benefits of a merger would be greater for larger P/C insurers. In reality, most of the merger agreements up to date has taken place between large and medium-size companies, and among the firms whose main banks have merged with each other.

Empirical research on the cost structure of the P/C insurance industry is ever more important in the age of financial deregulation. As an agenda for future research, it would be important to delve into the sources of scale and scope economies. Hughes, Mester, and Moon (2001) examine the effect of diversification on scale economies. It would also be worthwhile to consider the temporal nature of the panel data and incorporate the effects of technological change into the model. Some authors who have analyzed panel data include time trend variables in the cost function to estimate technological change (see Kasuya, 1989; McKillop, Glass, and Morikawa, 1996). There are numerous studies, including the literature on nonparametric frontier approach (e.g., Fukuyama, 1997), that measure productivity growth of financial institutions. Finally, this article implicitly assumed that the P/C insurance companies are operating on the efficient cost frontier. It would clearly be desirable to analyze cost inefficiency of these firms.

APPENDIX A: DERIVATION OF EQUATIONS

Derivation of Equation (6)

From Equation (4),

$$\begin{aligned} C(r, q_{\mathrm{B}}) = {} & \left[\psi_{\mathrm{B}} + \sum \alpha_j q_{\mathrm{Bj}} + (1/2) \sum \sum \alpha_{jk} q_{\mathrm{B}j} q_{\mathrm{B}k} + \sum \sum \delta_{jh} q_{Bj} \ln r_h\right] \\ & \times \exp\left[\sum \beta_h \ln r_h + (1/2) \sum \sum \beta_{hl} \ln r_h \ln r_l\right] \equiv \Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta) \times \mathrm{E}(r; \beta) \end{aligned} \tag{A1}$$

for firm B. Thus,

$$
\begin{aligned}
\partial \ln C(r, q_{\mathrm{B}})/\partial q_j &= [\partial C(r, q_{\mathrm{B}})/\partial q_j][q_j/C(r, q_{\mathrm{B}})] \\
&= \left[\alpha_j + \sum_k \alpha_{jk} q_{\mathrm{B}k} + \sum_h \delta_{jh} \ln r_h\right] q_{\mathrm{B}j} \\
&\quad \Big/ \left[\psi_{\mathrm{B}} + \sum \alpha_j q_{\mathrm{B}j} + (1/2) \sum\sum \alpha_{jk} q_{\mathrm{B}j} q_{\mathrm{B}k} + \sum\sum \delta_{jh} q_{\mathrm{B}j} \ln r_h\right] \\
&= \left[\alpha_j + \sum_k \alpha_{jk} q_{\mathrm{B}k} + \sum_h \delta_{jh} \ln r_h\right] q_{\mathrm{B}j} \Big/ \Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta).
\end{aligned} \tag{A2}
$$

Using (A2),

$$
\begin{aligned}
&\sum_j [(q_{\mathrm{B}j} - q_{\mathrm{A}j})/q_{\mathrm{B}j}][\partial \ln C(r, q_{\mathrm{B}})/\partial \ln q_j] \\
&= \left[\sum_j (q_{\mathrm{B}j} - q_{\mathrm{A}j}) \left(\alpha_j + \sum_k \alpha_{jk} q_{\mathrm{B}k} + \sum_h \delta_{jh} \ln r_h\right)\right] \Big/ \Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta).
\end{aligned} \tag{A3}
$$

By defining $\Delta q_{\mathrm{BA}j} \equiv q_{\mathrm{B}j} - q_{\mathrm{A}j}$,

$$
\begin{aligned}
[C(r, q_{\mathrm{B}}) - C(r, q_{\mathrm{A}})]/C(r, q_{\mathrm{B}}) &= [\Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta) - \Gamma(r, q_{\mathrm{A}}; \psi_{\mathrm{A}}, \alpha, \delta)]/\,\Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta) \\
&= \left[(\psi_{\mathrm{B}} - \psi_{\mathrm{A}}) + \sum_j \Delta q_{\mathrm{BAj}} \left(\alpha_j + \sum_h \delta_{jh} \ln r_h\right)\right. \\
&\quad \left. + (1/2) \sum_j \sum_k \alpha_{jk} \Delta q_{\mathrm{BA}j} \Delta q_{\mathrm{BA}k}\right] \Big/ \Gamma(r, q_{\mathrm{B}}; \psi_{\mathrm{B}}, \alpha, \delta).
\end{aligned} \tag{A4}
$$

Dividing (A3) by (A4), we have

$$
\begin{aligned}
\mathrm{EPSE}_{\mathrm{AB}} &= \frac{\sum_j [(q_{\mathrm{BA}j} - q_{\mathrm{A}j})/q_{\mathrm{B}j}][\partial \ln C(r, q_{\mathrm{B}})/\partial \ln q_j]}{C(r, q_{\mathrm{B}}) - C(r, q_{\mathrm{A}})]/C(r, q_{\mathrm{B}})} \\
&= \frac{\sum_j \Delta q_{\mathrm{BA}j} \left(\alpha_j + \sum_k \alpha_{jk} q_{\mathrm{B}k} + \sum_h \delta_{jh} \ln r_h\right)}{(\psi_{\mathrm{B}} - \psi_{\mathrm{A}}) + \sum_j \Delta q_{\mathrm{BA}j} \left(\alpha_j + \sum_h \delta_{jh} \ln r_h\right) + (1/2) \sum_j \sum_k \alpha_{jk} \Delta q_{\mathrm{BA}j} \Delta q_{\mathrm{BA}k}},
\end{aligned} \tag{A5}
$$

as shown in Equation (6).

Derivation of Equation (9)
From Equation (4),

$$\begin{aligned} C((1-\varepsilon)q_1, \varepsilon; q_2; r) = \Bigg[\sum_i^N \psi_i D_i &+ (\alpha_1(1-\varepsilon)q_1 + \alpha_2 \varepsilon q_2) \\ &+ (1/2)\big(\alpha_{11}(1-\varepsilon)^2 q_1^2 + 2\alpha_{12}(1-\varepsilon)\varepsilon q_1 q_2 + \alpha_{22}\varepsilon^2 q_2^2\big) \\ &+ (\delta_{11} \ln r_1 + \delta_{12} \ln r_2)(1-\varepsilon)q_1 \\ &+ (\delta_{21} \ln r_1 + \delta_{22} \ln r_2)\varepsilon q_2 \Bigg] \times E(r;\beta), \end{aligned} \tag{A6}$$

and

$$\begin{aligned} C(\varepsilon q_1, (1-\varepsilon)q_2; r) = \Bigg[\sum_i^N \psi_i D_i &+ (\alpha_1 \varepsilon q_1 + \alpha_2(1-\varepsilon)q_2) \\ &+ (1/2)\big(\alpha_{11}\varepsilon^2 q_1^2 + 2\alpha_{12}(1-\varepsilon)\varepsilon q_1 q_2 + \alpha_{22}(1-\varepsilon)^2 q_2^2\big) \\ &+ (\delta_{11} \ln r_1 + \delta_{12} \ln r_2)\varepsilon q_1 \\ &+ (\delta_{21} \ln r_1 + \delta_{22} \ln r_2)(1-\varepsilon)q_2 \Bigg] \times E(r;\beta). \end{aligned} \tag{A7}$$

Combining (A6), (A7) and (4),

$$\begin{aligned} &C((1-\varepsilon)q_1, \varepsilon q_2; r) + C(\varepsilon q_1, (1-\varepsilon)q_2; r) - C(q_1, q_2, r) \\ &= \Bigg[\sum_i^N \psi_i D_i - \alpha_{11}(1-\varepsilon)\varepsilon q_1^2 - \alpha_{22}(1-\varepsilon)\varepsilon q_2^2 \\ &\quad - (1/2)(\alpha_{12} + \alpha_{21})(1 - 2\varepsilon + 2\varepsilon^2)q_1 q_2 \Bigg] \times E(r;\beta). \end{aligned} \tag{A8}$$

Hence,

$$\begin{aligned} \text{QSCOPE}_i &= (A8)/C(q_1, q_2, r) \\ &= \big[\psi_i - \alpha_{11}(1-\varepsilon)\varepsilon q_1^2 - \alpha_{22}(1-\varepsilon)\varepsilon q_2^2 - (1/2)(\alpha_{12} + \alpha_{21})(1 - 2\varepsilon + 2\varepsilon^2)q_1 q_2\big] \\ &\Big/ \Big[\psi_i + \sum \alpha_j q_j + (1/2)\sum\sum \alpha_{jk} q_j q_k + \sum\sum \delta_{jh} q_j \ln r_h\Big], \end{aligned} \tag{A9}$$

as shown in Equation (9).

APPENDIX B

TABLE B1
Names of the Firms Included in the Data Set

20 Japanese firms[a]
Tokio MFI, Yasuda FMI, Mitsui MFI, Sumitomo MFI, Nippon FMI, Dowa FMI, Nissan FMI, Koa FMI, Chiyoda FMI, Nisshin FMI, Nichido FMI, Fuji FMI, Dai-Tokyo FMI, Kyoei Mutual FMI, Taisei FMI, Daiichi Mutual FMI, Toyo FMI, Asahi FMI, Taiyo FMI, and Daido FMI.[b]

13 foreign-owned firms
Allstate Automobile and Fire,[c] AIU, American Home Assurance, British Insurance Group, Hyundai Marine and Fire, Royal Exchange Assurance, The New India Assurance, Assurance Generales De France, Ansvar Mutual, Royal Insurance Public, Federal, L'Union Des Assurances De Paris, and QBE Insurance International.

[a]The firms are listed in the same order as in our data set.
[b]MFI stands for Marine & Fire Insurance, and FMI stands for Fire & Marine Insurance.
[c]Allstate is now registered as a Japanese P/C insurance firm, but initially started its operation as a foreign-owned firm.

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