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Ownership Structure, Agency Costs, Specialization, and Efficiency: Analysis of Keiretsu and Independent Insurers in the Japanese Nonlife Insurance Industry

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Abstract

This article uses the nonparametric frontier method to examine differences in efficiency for three unique organizational forms in the Japanese nonlife insurance industry—keiretsu firms, nonspecialized independent firms (NSIFs), and specialized independent firms (SIFs). It is not possible to reject the null hypothesis that efficiencies are equal, with one exception. Keiretsu firms seem to be more cost-efficient than NSIFs. The results have important implications for the stakeholders of the NSIFs. An examination of the productivity changes across the different organizational forms reveals deteriorating efficiency for all three types of firms throughout the 1985–1994 sample period. Finally, the evidence also suggests that the value-added approach and the financial intermediary approach provide different but complementary results.

Introduction

Agency costs that arise from the separation of ownership and control increase total costs and thus make firms less efficient. Researchers examining agency costs usually analyze the rights of different parties in a firm and their effects on managerial and owner activities (e.g., Coase, 1960; Jensen and Meckling, 1976; Fama and Jensen, 1983a, 1983b). The insurance industry provides an interesting environment for studying agency hypotheses because of the different organizational forms in the industry (e.g., Boose, 1990; McNamara and Rhee, 1992; Lamm-Tennant and Starks, 1993).

Cummins, Weiss, and Zi (1999) study the efficiency of alternative organizational forms in US property-casualty insurers and focus on the inherent principal–agent problem. They test the managerial discretion hypothesis (Mayers and Smith, 1981, 1986, 1988,

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1994) and the expense preference hypothesis (Williamson, 1963) in analysis of the efficiency of stock and mutual organizational forms of insurers. Their results show that firms with different organizational forms are sorted into distinct market segments where they have comparative advantages in minimizing production and agency costs, an outcome consistent with the managerial discretion hypothesis.

Although the issue of efficiency and ownership structure in the US insurance industry has attracted some research attention, very few studies have examined these questions in the Japanese nonlife insurance industry. Our purpose is to examine differences in efficiency in the Japanese nonlife insurance industry.

We find this issue particularly interesting because of two unique characteristics of the Japanese insurance firms. First, there are two types of insurance firms in Japan: independent firms and keiretsu firms. Independent insurance firms in Japan are similar in organizational structure to insurance firms in the United States. The keiretsu structure is very different. It is characterized as a group of firms centered on affiliated banks and financial institutions (see Hoshi, Kashyap, and Scharfstein, 1990a, 1990b). The member firms in a keiretsu have close ties to a "main bank," which not only provides member firms with debt financing, but also owns a substantial amount of member firm equity (Nakatani, 1984). Companies in keiretsu groups have strong business ties with one another and significant levels of corporate reciprocal ownership (Prowse, 1992).

A substantial amount of research has examined the attributes of keiretsu firms (e.g., Nakatani, 1984; Kester, 1986; Hoshi et al., 1990b; Prowse, 1990). The creditor–shareholder relationship pertains in nearly every keiretsu group, and member firms have strong incentives to monitor one another's financial standings. Such monitoring significantly reduces information asymmetry and reduces the possibility that member firms will experience financial insolvency (Nakatani, 1984).

The second unique issue is that insurers in the independent ownership class are distinctive because they specialize in mainly one or two insurance product lines. Table 1 reports the average percentages of lines categorized by ownership structure (only lines representing more than 1 percent of policies are reported). The lines of business in eight keiretsu firms are generally evenly distributed. More interesting, Table 1 shows that 6 of 11 independent firms focus on only one or two lines. Specifically, the top lines of the six firms (Allstate, Asahi, Didoo, Koa, Taiyo, and Toyo) represent at least 70 percent of their business.

We examine whether the variances of distribution for individual lines are equal for the two ownership classes (independent firms vs. keiretsu firms). The hypothesis that the distributions for individual lines are equal is rejected at least at the 10-percent level in all the lines with higher than 6 percent of a business.

Table 2 reports the Herfindahl concentration index for independent firms and keiretsu firms. The Herfindahl indices of independent firms range from 23 percent to 78 percent, whereas the Herfindahl indices of keiretsu firms range from approximately 21 percent to 30 percent.

The Herfindahl indices of the 6 of 11 independent firms are higher than 50 percent; the indices of the other five firms are between 23 percent and 24 percent.

Table 1

Line Distribution by All Firms

This table reports the average percentage of line distribution categorized by ownership structure. Only lines representing policies accounting for more than 1 percent of the business are reported. Thus, lines excluded are hull, aviation, guarantee, machinery, movables, and savings-type movable policies.

	Earthquake	Fire	Cargo	Transit	Auto	Personal Account	Savings-Type Personal Account	Public Liability	Compulsory Auto Liability
Independent									
Allstate	14.46%	76.49%	0.14%	0.03%	4.91%	2.71%	0.20%	0.47%	0.54%
Asahi	1.27%	6.73%	0.08%	88.17%	1.16%	1.59%	0.01%	0.10%	0.72%
Chiyoda	4.78%	24.18%	3.00%	0.22%	28.03%	4.90%	1.17%	1.74%	30.80%
Daido	13.64%	71.74%	0.39%	0.13%	5.60%	0.90%	0.19%	0.41%	6.82%
Dai-Tokyo	5.32%	23.47%	0.58%	0.08%	31.64%	3.98%	1.56%	1.96%	30.39%
Dowa	5.76%	32.39%	3.45%	0.42%	26.26%	6.27%	1.33%	1.85%	20.89%
Fuji	8.47%	26.27%	1.14%	0.11%	31.81%	4.26%	1.62%	1.49%	23.46%
Koa	0.57%	6.56%	0.60%	80.78%	4.80%	1.48%	0.30%	0.30%	4.14%
Nissan	5.70%	28.58%	3.63%	0.43%	26.87%	3.72%	1.48%	1.45%	27.00%
Taiyo	14.22%	78.18%	0.60%	0.04%	2.23%	0.53%	0.12%	0.40%	1.58%
Toyo	13.34%	70.68%	0.23%	0.04%	6.77%	1.05%	0.13%	0.56%	6.21%
Average	7.96%	40.48%	1.26%	15.49%	15.46%	2.85%	0.74%	0.97%	13.87%

(continued)

TABLE 1
(Continued)

	Earthquake	Fire	Cargo	Transit	Auto	Personal Account	Savings-Type Personal Account	Public Liability	Compulsory Auto Liability
Keiretsu									
Nichido	7.61%	31.57%	1.00%	0.05%	27.30%	5.60%	1.21%	1.16%	23.20%
Nippon	5.49%	28.04%	5.04%	0.30%	27.04%	6.05%	1.44%	2.17%	22.06%
Nisshin	6.53%	36.90%	1.67%	0.20%	26.87%	3.50%	1.15%	1.67%	20.28%
Sumitomo	5.07%	26.35%	5.85%	0.69%	27.68%	6.76%	2.25%	2.22%	21.47%
Taisei	9.77%	50.10%	0.87%	0.09%	17.88%	5.55%	1.81%	1.49%	11.01%
Taisho	3.39%	16.29%	5.28%	21.63%	23.54%	4.89%	2.73%	2.40%	18.31%
Tokio	2.84%	15.48%	5.49%	0.41%	32.47%	6.16%	1.71%	3.23%	30.70%
Yasuda	2.37%	10.66%	1.87%	34.72%	19.57%	4.79%	0.97%	1.27%	22.66%
Average	5.38%	26.93%	3.38%	7.26%	25.29%	5.41%	1.66%	1.95%	21.21%
t-test	*	**		**	***				**

Note: Companies in bold represent specialized independent firms (SIFs).
***Statistically significant difference at the 1 percent level.
**Statistically significant difference at the 5 percent level.
*Statistically significant difference at the 10 percent level.

TABLE 2

Herfindahl Concentration Index of All Firms

The table reports the average Herfindahl concentration index of all Japanese insurers categorized by ownership structure. The Herfindahl Index is calculated for each firm as

$$H = \sum_{L=1}^{16} S_L^2,$$

where L stands for line of business, and $S_L = NP_L/TNP$. NP_L is the number of policies written in a particular line of business, and TNP is the total number of policies across all 16 lines of business.

Independent Firms		Keiretsu Firms	
Allstate	**0.6119**	Nichido	0.2383
Asahi	**0.7831**	Nippon	0.2122
Chiyoda	0.2391	Nisshin	0.2569
Daido	**0.5440**	Sumitomo	0.2053
Nissan	0.2340	Taisei	0.3099
Dai-Tokyo	0.2538	Taisho	0.2508
Dowa	0.2293	Tokio	0.2333
Fuji	0.2374	Yasuda	0.2396
Koa	**0.6615**	*Average*	0.2433
Taiyo	**0.6337**		
Toyo	**0.5268**		
Average	0.4504		

Note: Companies in bold represent specialized independent firms (SIFs).

According to the results in Tables 1 and 2, we classify the six independent firms with the highest Herfindahl indices as specialized independent firms (SIFs). The remainders are nonspecialized independent firms (NSIFs). This division of the independent insurers provides an additional perspective for analysis of the efficiency differences between groups of firms that have made different business line choices. Thus, we ultimately examine the efficiency differences among three organizational forms of the Japanese nonlife insurance industry: keiretsu firms, SIFs, and NSIFs.

Efficiency differences among the three organizational forms would be important to firm stakeholders. Stockholders and managers might choose to switch from one form such as keiretsu firms to another such as independent firms in the future if one organizational form is proven to be more efficient than another. Or, managers of a nonspecialized firm may decide to switch from a nonspecialized strategy to a specialized one if the latter is found to be more efficient. Finally, policyholders and regulators are interested in the efficiency of different organizational forms because, all else being equal, a firm is less likely to face the threat of bankruptcy if it is more efficient. In fact, society benefits if all firms are more efficient.

We use nonparametric frontier efficiency methods, such as data envelopment analysis (DEA), to examine whether the three distinct organizational forms are equally efficient.[1] Three of the approaches among others to measure outputs in the financial services sector are the value-added approach, the asset or financial intermediary approach, and the user-cost approach. We concentrate on the value-added and the financial intermediary approach.[2] Cummins et al. (1999) use the value-added approach, taking the present value of real losses incurred is used as a proxy for the amount of risk-pooling and real insurance services provided by insurers. Although we agree losses represent an important output for insurance firms, there are criticisms of using losses as a proxy. If a firm suffers unexpectedly large losses due to inappropriate underwriting practices, no one would interpret this firm is efficient. Yet, the value-added approach that uses losses as an output would interpret more losses indicating as more efficiency.

The second approach views an insurance company as a financial intermediary. As a financial intermediary, an insurer issues contingent claims to policyholders and uses the proceeds to purchase assets (see Brockett et al., 2000). Thus, the objective of an insurance firm is to maximize return on capital and maximize the value of the firm. Cummins et al. (1999) believe the financial intermediary approach is not appropriate for property-liability insurers because their services are not limited to financial intermediation. Given lack of agreement on the validity of a particular approach, we conduct the analysis using both the value-added approach and the financial intermediary approach. Under the financial intermediary approach, we further conduct the analyses using both the cross-frontier method and a range-adjusted measure (RAM) version of DEA.

This research extends the literature in several ways. First, let us investigate differences in efficiency between the keiretsu and independent (nonkeiretsu) firms' organizational structure. Second, coexistence of keiretsu firms, SIFs, and NSIFs provides additional insights on the efficiency issues in different organizational forms. Third, we improve on the value-added approach by using number of policies instead of losses as one output. Fourth, to our knowledge, this is the first article to examine the efficiency of different organizational forms in the Japanese nonlife insurance industry, the second-largest insurance market in the world.[3] Finally, we are the first to conduct DEA analyses using both value-added and financial intermediary approaches, including the cross-frontier method and a RAM version. We believe the results of the two approaches shed some light on an appropriate approach for conducting DEA analyses.

The overall results do not allow consistent rejection of the null hypotheses that one organization form is more efficient than another, with one exception. Keiretsu firms

[1] The traditional efficiency research on firms in the insurance industry focuses on economies of scale and scope. Only recently, there has been some research examining the efficiency of industry units. Cummins and Weiss (1993), Gardner and Grace (1993), and Yuengert (1993) study with the X-efficiency of insurers both in the life and the property-liability industries in the United States.

[2] The user-cost approach considers the opportunity cost of a proxy measure. If the return on an asset proxy is higher than the opportunity cost, the proxy is treated as an output; otherwise, it is treated as an input. We do not use the user-cost approach because it is difficult to obtain precise data on product revenues and opportunity costs. See Cummins et al. (1999).

[3] Fukuyama (1997) examines the efficiency issue for the Japanese life insurance companies.

seem to be more cost-efficient than NSIFs. The advantages of keiretsu firms, such as better monitoring, lower information costs, and lower cost of capital dominate the advantage of independent firms such as no obligation to cross-subsidize other member firms.

The evidence of productivity changes for different organizational forms is very interesting. The results of the value-added approach indicate that keiretsu firms have more severe technical regress than independent firms. Within independent firms, NSIFs define most of the regress. The results of productivity changes are strikingly different when we use the financial intermediary approach. Specifically, we find the net technical changes of SIFs contribute most of the regress.

The above results indicate that different inputs/outputs and methodologies provide different conclusions; thus, it may not be appropriate to use only one approach and base conclusions on that. Both approaches are useful together. The value-added approach provides insights into the technical efficiency (TE) and cost efficiency (CE) of different organizational forms (based on the number of policies and amount of invested assets), but the financial intermediary approach provides insight into efficiency based on return on assets and financial condition.

The remainder of this article is organized in the following manner. The section "Research Question and Hypotheses" discusses and develops the three hypotheses and the research questions to be investigated in this article. The section "Methodology and Data" presents the methodology and data applied in the article. The section "Value-Added Approach" discusses the input and output measurements and performs the analyses using the value-added approach. The results of the value-added approach are reported in the section "Results of the Value-Added Approach." The analyses of the financial intermediary approach and the results are presented in the sections "The Financial Intermediary Approach" and "Results of the Financial Intermediary Approach Using the Cross-Frontier Method," respectively. The section "Results of the Financial Intermediary Approach Using the RAM Method" reports the results of RAM version of DEA. Finally, the final section summarizes and concludes the article.

RESEARCH QUESTION AND HYPOTHESES

Organizational Forms and Efficiency

The first major research question is which form of ownership structure is the most efficient: keiretsu firms, SIFs, or NSIFs. This question is interesting not only for firm stakeholders but also for economics and finance theorists.

Efficiency of Keiretsu Firms vs. Independent Firms. We believe keiretsu firms are more efficient than independent firms in certain respects and that independent firms are in other respects. The efficiency advantages of keiretsu firms are discussed first. Some efficiency advantages for keiretsu firms include lower general expenses and fewer perquisites, lower information costs, lower cost of external capital, and lower commissions. We refer to these advantages as the "keiretsu effect." There is some information on this question. Lai and Limpaphayom (2003) provide discussion and literature review related to this issue. First, keiretsu firms may have lower general expenses and offer fewer perquisites to managers due to more strict monitoring. It is well documented that the largest lender of a keiretsu firm (usually a bank) generally is one of the five largest shareholders (see Sheard, 1989, 1994). The bank as a member of keiretsu has strong incentives to monitor member firms' managerial behavior because it is both main creditor and a major stockholder. Hoshi et al. (1991) suggest that group financial institution equity holdings play a monitoring purpose in a keiretsu group. Specifically, cross-ownership allows financial institutions to put key personnel in top managerial positions of group firms to monitor keiretsu members, thus mitigating some managerial agency costs such as expenses and perquisites. The expense preference hypothesis posits that managers have incentives to consume as many perquisites as possible (e.g., Williamson, 1963; Fields, 1988; Cummins et al., 1999). As the control of managers is more difficult in mutual firms, the hypothesis predicts mutual firms will have higher expenses than otherwise comparable stock firms. Applying the rationale of Hoshi et al. (1991) and the expense hypothesis to keiretsu firms, we predict keiretsu firms have lower expenses or fewer perquisites and thus are more efficient than independent firms.

Second, keiretsu firms may be more efficient because of low information costs. Prowse (1992) notes that keiretsu firms have strong business ties with one another as well as significant levels of corporate cross-ownership. The cross-holding of shares not only increases the degree of monitoring but also reduces information asymmetry (Kester, 1986; Sheard, 1989; Hoshi et al., 1990a; Gilson and Roe, 1993). The keiretsu structure may be able to mitigate some of the information cost insurers face in underwriting and claims handling. Applying the finance literature, we suggest that keiretsu insurers should be more efficient than independent insurers because keiretsu insurers have lower information costs. Lower information costs occur because cross-holding of shares better aligns the interests of keiretsu insurers and their member firm policyholders.

Third, keiretsu insurers may have advantages in obtaining external funding. Nakatani (1984) and Hoshi et al. (1990b) suggest that a main bank will immediately provide both financial and administrative assistance to a keiretsu firm encountering financial difficulty, so the costs of financial distress are lower. The fact that major debtholders and shareholders are the same in a keiretsu insurer mitigates agency conflicts between stockholders and fixed claimholders (Prowse, 1990).

Finally, additional efficiency may be gained in savings resulting from keiretsu firms' relationship with the rest of the members in the keiretsu. Savings may come, for example, from reduced commissions paid to other keiretsu members.

At the same time, one advantage for an independent firm over a keiretsu firm is that the independent firm does not have to cross-subsidize any failing keiretsu members. A keiretsu insurer may have an obligation to come to the aid of other members. When a keiretsu insurer cross-subsidizes a failing keiretsu member, it is less efficient. If a keiretsu insurer issues a policy to a keiretsu member at a below-market equilibrium premium, for instance, its efficiency suffers.

Efficiency of Specialized Firms vs. Nonspecialized Firms. We suggest that firms specializing in fewer lines have some advantages over firms that offer many different lines. We refer to this argument as the "specialization effect." Generally, firms have a choice of conducting business by entering into either a wide range or a narrow range of product lines. By producing fewer distinct products or providing fewer types of services, firms can be more efficient; they can develop more expertise in one or two lines and thereby reduce costs. Agents, adjusters, and actuaries would be more knowledgeable about one line of business rather than multiple lines of business, other things equal. Moreover, the training costs for these professionals would be lower if confined to one line of business rather than many different lines. Finally, specialization allows firms to develop efficient operations on both production and cost frontiers and reach economies of scale sooner, especially for a relatively small firm.

Although there are some advantages in specialization, there are also some advantages for firms that do not specialize and write policies over different lines. Nonspecialized firms may enjoy economies of scope in production and marketing (Comment and Jarrell, 1995). They may also enjoy more stable earnings because of the diversification effect resulting from noncorrelated loss experience across different lines.

For example, Table 1 indicates that 88.17 percent of business of the Asahi, a SIF, is in the transit line. If there was a bad year for the transit line, Asahi would suffer significantly. Nissan, a nonspecialized firm, has top three lines divided over fire (28.58 percent), auto (26.87 percent), and compulsory auto liability (27.00 percent). If any one of these top three lines has a bad year, Nissan would not suffer as much as Asahi.

It should be noted that keiretsu firms have the advantages of nonspecialization as well as the advantages of the keiretsu effect. SIFs have the advantages of both the specialization effect and the advantages of independence. Finally, the NSIFs have the advantages of both nonspecialization and independence.

Because each type of insurers has its own advantages, which type of insurer is the most efficient is an empirical question. We summarize the advantages of the three organizational forms in Table 3.

TABLE 3

Advantages of Different Organizational Form

This table reports the predicted efficiency differences among the three organizational forms in Japanese nonlife insurers and reports the effect of three hypotheses on these differences.

	Advantages
Keiretsu firms	Lower general expenses and perquisites; lower costs of information; lower costs of external capital; and lower commissions
Specialized independent firms	Efficient operation on both production and cost frontiers because of specialization effect; no need to subsidize other members
Nonspecialized independent firms	May enjoy economies of scope in production and marketing; stable earnings

Productivity Changes

The second research question regards changes in efficiency and productivity throughout the years for keiretsu firms and independent firms. By examining the productivity changes, we can study whether the evolution of the production frontiers of different organizational forms are different. We use the Malmquist index to measure productivity changes over time.[4] The Malmquist index can be decomposed into two components: TE change and technology change. We can thus distinguish improvements or deterioration in efficiency relative to the frontier (TE change) from shifts in the frontier (technology change). For example, if we find deteriorating productivity of one organizational form over time, we would like to know whether the reason is a worsening of TE or failure to update technology.

A by-product of this research is that we can decide whether the value-added approach or the financial intermediary approach would produce the same empirical results. More important, if the results are different, we will be able to make some meaningful interpretations.

In general, the value-added approach treats the proxy measures as important outputs if they add significant value to the operation of the firm (see Berger and Humphrey, 1992b). The second approach views an insurance company as a financial intermediary; an insurer issues contingent claims to policyholders and uses the proceeds to purchase assets (see Brockett et al., 2000). Thus, its objective is to maximize the return on capital and maximize the value of the firm. Results of the two approaches should provide some insights into the debate on which method is better.

Hypotheses Development and Hypotheses Testing

The first main null hypothesis related to the first research question states that (1) keiretsu and independent insurers are equally efficient. Within independent firms, we further compare the efficiency between SIFs and NSIFs. Thus, the second null hypothesis is that (2) keiretsu insurers and SIFs are equally efficient, and the third hypothesis is that (3) keiretsu insurers and NSIFs are equally efficient. Finally, the fourth hypothesis states that (4) SIFs and NSIFs are equally efficient.

To test these four main hypotheses, we follow a set of test procedures (Cummins et al., 1999). For example, if we want to test hypothesis (1) that keiretsu and independent insurers are equally efficient, then we need to first test the subnull hypothesis that keiretsu firms and independent insurers are operating on the same frontier against the alternative hypothesis that they operate on different frontiers. Rejection of the subnull hypothesis implies that a comparison of efficiency based on the pooled frontier is meaningless, because keiretsu firms and independent firms operate on different frontiers. Thus, if we reject the subnull hypothesis, we need to calculate the efficiency scores based on separate frontiers. The efficiency scores of keiretsu firms and independent firms can then be used for comparison purposes.

METHODOLOGY AND DATA

We provide the discussion of methodology and data in this section.

[4] See Malmquist (1953) for details.

Data Selection

We obtain our data from the Statistics of Japanese Non-Life Insurance Business from 1983 to 1994.[5]

Methodology

There are two principal types of efficiency methodologies among others—the econometric (parametric) approach and the mathematical programming (nonparametric) approach (see Cummins and Weiss, 2000). The econometric approach requires the specification of a production, cost, revenue, or profit function as well as assumptions about the error terms. The nonparametric programming approach requires less specification of the optimization problem. We choose the nonparametric programming approach because it makes the work less vulnerable to the specification errors that are common in the econometric approach.[6]

To save space, we do not discuss the detailed methodology. For the value-added approach, we follow Cummins and Zi (1998) very closely. Cummins and Weiss (2000) provide an excellent review of the frontier efficiency and productivity methods.[7] For the financial intermediary approach, we follow Brockett et al. (2004). We also provide some review in the Appendix.

VALUE-ADDED APPROACH

This section discusses the outputs and inputs of the value-added approach. Table 4 shows the descriptive statistics for both inputs and outputs for all firms by type of ownership structure.

A total of 21 firms represent the complete population of Japanese nonlife insurers with data available throughout 12 sample years. Nineteen are stock firms and two are mutuals, which we eliminate.[8] Of the stock firms, 8 are keiretsu firms and the other 11 are independent firms; the latter are further categorized into 5 NSIFs and 6 SIFs as we mentioned in the previous sections. Except for the number of policies and labor, all output and input quantities are deflated to 1985 Japanese yen.

Outputs

Following the insurance and banking literature, we first use the value-added approach to measure outputs (see Berger and Humphrey (1992b) and Cummins et al. (1999)). Cummins et al. (1999) suggest that property-liability insurers provide three principal services: real services relating to insured losses, risk-pooling and risk-bearing, and

[5] We focus on the time period because Japanese insurance industry went through many regulatory changes after 1995.

[6] See Cummins and Weiss (2000) for a detailed discussion of the pros and cons of the nonparametric programming approach.

[7] Farrell (1957), Shephard (1970), Charnes et al. (1978), Färe et al. (1985), Aly et al. (1990), Berger and Humphrey (1991), Elyasiani and Mehdian (1992), Berger et al. (1993), Berger et al. (1996), and Coelli (1996) provide more detailed methodology and implications in either the banking industry or the insurance industry.

[8] Since it is necessary to have more than two firms to construct the efficiency frontier using the DEA method, we are unable to construct the frontier for mutual firms in Japan.

TABLE 4

Descriptive Statistics for All Japanese Nonlife Insurers

The table reports the means of input and output variables, input price, and number of firms of different ownership structures in the Japanese insurance industry. Data source are from Statistics of Japanese Non-Life Insurance Business from 1983–1994. All output and input quantities are expressed in 1985 yen except numbers of policy and labor.

	All	Mutual	All Stock	Keiretsu	Independent	NSIF	SIF
Output							
Y_1 = number of policies in short-tail lines	6,831,706	2,364,424	7,301,946	7,406,070**	7,226,219	4,714,569**	9,319,260
Y_2 = number of policies in long-tail lines	2,020,881	677,379	2,162,302	3,285,371**	1,345,525	2,412,308**	456,539
Y_3 = number of policies in saving-type lines	158,151	231,456	150,434	224,389**	96,649	151,496**	50,943
Y_4 = total invested assets	656,959	510,662	672,359	1,115,490**	350,081	577,050**	160,941
Input							
X_1 = labor	3,202	2,051	3,323	4,900**	2,177	3,733**	879
X_2 = business services	67,697	30,517	71,611	113,633**	41,050	72,017**	15,244
X_3 = capital (debt + equity)	872,104	615,351	899,131	1,490,993**	468,686	788,109**	202,500
Input price							
P_1 = price of labor	10.264	8.882	10.409	10.787**	10.135	10.933**	9.469
P_2 = price of business service	0.00788	0.00913	0.00775	0.01051**	0.00574	0.01007**	0.00213
P_3 = price of total capital	0.01555	0.01118	0.01601	0.02084**	0.01249	0.01768**	0.00816
Number of firms	21	2	19	8	11	5	6

**Statistically significant difference at the1 percent level.

intermediation. We select number of policies as one output variable because it is a good proxy for the amount of risk-pooling and real insurance services. We further disaggregate number of policies into three categories: short-tailed lines, long-tailed lines, and savings-type lines, since underwriting intensity varies by line of business. We also select total invested assets as a output according to the intermediation function. Total invested assets are deflated to the base year 1985 using the Japan Consumer Price Index (CPI).

Inputs

We classify insurance inputs into three different groups: labor, business services, and capital. Labor input refers to total number of personnel for each firm, and its input price equals personnel expenses per person. Business services input consists of material costs (represented by nonpersonnel expenses) and outside service costs (represented by agents' commissions). The input price is the service expense per policy.

The capital input of insurers incorporates both debt and equity. The price of capital input, namely, the cost of capital, equals the ratio of ordinary profits to capital. We consider the ordinary profits as both underwriting profits and investment profits.[9] The entire input category is deflated by the 1985 CPI wherever appropriate.

The results for the differences in variables between keiretsu and independent firms and between NSIFs and SIFs reported in Table 4 indicate that input and output variables are greater for keiretsu firms than for independent firms, and differences are statistically significant. The same is true for all differences in variables for NSIFs and SIFs. Except for the short-tailed output, the input and output variables are greater for NSIFs than SIFs. Size appears to play a role in the difference between keiretsu and independent firms, and we examine the size issue further below.

RESULTS OF THE VALUE-ADDED APPROACH

This section provides the results of the value-added approach.

Average Efficiencies

We present two panels of results regarding efficiency based on the pooled frontiers in Table 5. Panel A reports the results of TE, and Panel B reports the results of CE. Although TE involves input and output quantities only, CE involves prices and allocation of inputs and outputs. In each panel we compare keiretsu and independent firms as well as SIFs and NSIFs. The pooled frontier of NSIFs and SIFs is formed using all the independent firms available. Note that X_k and Y_k refer to the input–output bundle for keiretsu firms, and the subscript on T (TE) or on C (CE) indicates the frontier upon which the firms measures are based. For example, $T_p(X_k, Y_k)$ refers to the TE of keiretsu firms relative to the pooled frontier. The subscript "*ns*" stands for NSIFs, and "*si*" stands for SIFs.

The results on TE in Panel A show that, on average, keiretsu and independent firms could have produced their outputs using 88.8 percent and 86.5 percent of the inputs

[9] The amount of investment profits used in the estimation is calculated as follows: interest & dividends + profit on securities − (investment expenses + tax + interest paid + depreciation + loss on securities).

that they actually consumed, respectively. NSIFs and SIFs could have produced their outputs using 86.1 percent and 91.1 percent of their inputs, respectively. The CE results shown in Panel B are in the opposite direction.

Overall, the results in Table 5 suggest that keiretsu firms on average are more technically efficient than independent firms, but less cost-efficient than independent firms. SIFs are on average more technically efficient but less cost-efficient than NSIFs.

Again, the results in Table 5 are based on the assumption that the organizational forms face the same technology and cost frontiers. If this assumption is not valid, the results in Table 5 are meaningless. Therefore, we further test whether the pooled and

TABLE 5

Technical and Cost Efficiency Based on Pooled Frontiers

The table reports the efficiency scores of Japanese nonlife insurers relative to the pooled frontiers in a sample period 1983–1994 and their average. Panel A reports the results of technical efficiency, whereas Panel B reports the results of cost efficiency.

Panel A: Technical Efficiency

Keiretsu vs. Independent			NSIF vs. SIF		
Year	$T_p(X_k, Y_k)$	$T_p(X_i, Y_i)$	Year	$T_i(X_{ns}, Y_{ns})$	$T_i(X_{si}, Y_{si})$
Mean	0.8879**	0.8645	Mean	0.8611***	0.9109
	(0.0838)	(0.0749)		(0.0779)	(0.0821)
1983	0.9244	0.9625	1983	0.9662	0.9598
	(0.0725)	(0.0639)		(0.0676)	(0.0602)
1984	0.9285	0.9588	1984	0.9658	0.953
	(0.0641)	(0.0638)		(0.0585)	(0.0674)
1985	0.9446	0.9703	1985	0.9828	0.9598
	(0.0593)	(0.0500)		(0.0344)	(0.0579)
1986	0.9274	0.9496	1986	0.9574	0.946
	(0.0708)	(0.0666)		(0.0703)	(0.0627)
1987	0.9091	0.9344	1987	0.9582	0.9145
	(0.0846)	(0.0958)		(0.0731)	(0.1073)
1988	0.9024	0.9349	1988	0.9312	0.938
	(0.0723)	(0.0640)		(0.0500)	(0.0735)
1989	0.8965	0.9156	1989	0.8932	0.9343
	(0.0607)	(0.0611)		(0.0446)	(0.0665)
1990	0.9253	0.9259	1990	0.9024	0.9455
	(0.0651)	(0.0486)		(0.0237)	(0.0549)
1991	0.9256	0.9311	1991	0.8936	0.9623
	(0.0599)	(0.0480)		(0.0255)	(0.0393)
1992	0.9280	0.9323	1992	0.8828	0.9735
	(0.0538)	(0.0525)		(0.0142)	(0.0337)
1993	0.9198	0.9381	1993	0.8932	0.9755
	(0.0626)	(0.0531)		(0.0324)	(0.0349)
1994	0.9519	0.9526	1994	0.9138	0.985
	(0.0445)	(0.0529)		(0.0469)	(0.0314)

(continued)

TABLE 5
(Continued)

Panel B: Cost Efficiency

Keiretsu vs. Independent			NSIF vs. SIF		
Year	$C_p(X_k, Y_k)$	$C_p(X_i, Y_i)$	Year	$C_i(X_{ns}, Y_{ns})$	$C_i(X_{si}, Y_{si})$
Mean	0.6938*	0.7670	Mean	0.7725***	0.6566
	(0.2868)	(0.1418)		(0.1103)	(0.3681)
1983	0.8815	0.7466	1983	0.9194	0.65
	(0.1103)	(0.3647)		(0.1025)	(0.4609)
1984	0.8666	0.7287	1984	0.909	0.6352
	(0.1094)	(0.3610)		(0.1021)	(0.4541)
1985	0.8831	0.8057	1985	0.9026	0.7812
	(0.1081)	(0.2869)		(0.0988)	(0.3635)
1986	0.8763	0.8169	1986	0.9186	0.7752
	(0.1150)	(0.2862)		(0.0875)	(0.3622)
1987	0.8550	0.8225	1987	0.9212	0.7627
	(0.1396)	(0.2854)		(0.1019)	(0.3640)
1988	0.8274	0.8052	1988	0.868	0.7658
	(0.1284)	(0.2783)		(0.0722)	(0.3602)
1989	0.7970	0.7515	1989	0.806	0.7342
	(0.1302)	(0.2667)		(0.0611)	(0.3492)
1990	0.8216	0.7595	1990	0.8076	0.7507
	(0.1416)	(0.2705)		(0.0597)	(0.3566)
1991	0.8221	0.6241	1991	0.7104	0.5615
	(0.1617)	(0.3114)		(0.0421)	(0.4094)
1992	0.7925	0.6928	1992	0.6882	0.7263
	(0.1537)	(0.2534)		(0.0471)	(0.3408)
1993	0.8134**	0.5654	1993	0.6958	0.4682
	(0.1627)	(0.2892)		(0.0693)	(0.3597)
1994	0.8390	0.7941	1994	0.735	0.8445
	(0.1418)	(0.1401)		(0.0748)	(0.1602)

Notes: Numbers in parentheses are standard deviations. X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (technical efficiency) or on C (cost efficiency) indicates the frontier on which the firms are based. Subscript p = pooled frontier; k = keiretsu frontier; i = independent frontier.
***Statistically significant difference at the 1 percent level.
**Statistically significant difference at the 5 percent level.
*Statistically significant difference at the 10 percent level.

separate frontiers are identical between keiretsu and independent firms as well as between NSIFs and SIFs. The results are reported in Table 6.

The comparisons in Panel A between the keiretsu and the pooled frontier can be examined in two ways. First, we compare the efficiency scores of the 8 keiretsu firms to the keiretsu's own frontiers and the scores of all 19 firms to the frontier of all firms. Second, we compare the efficiency scores of eight keiretsu firms to their own frontiers

TABLE 6

Tests of the Null Hypothesis That the Pooled and Separate Frontiers Are Identical

This table reports the test results of null hypothesis that the pooled and separate frontiers are identical. Panel A reports the results of technical efficiency and Panel B reports the results of cost efficiency.

Population Comparison	ANOVA F (Prob > F)	Wilcoxon Z (Prob > Z)	Median Z (Prob > Z)	Van Der Waerden Z (Prob > Z)	Savage Z (Prob > Z)
Panel A: Technical Efficiency					
Keiretsu vs. Independent Firms					
8 keiretsu frontier efficiencies vs. 19 pooled frontier efficiencies	282.731 (0.0001)	11.65 (0.0001)	11.6619 (0.0001)	10.95 (0.0001)	10.89 (0.0001)
11 independent frontier efficiencies vs. 19 pooled frontier efficiencies	0.766 (0.3821)	0.6656 (0.5057)	0.073 (0.9417)	0.878 (0.38)	0.976 (0.33)
8 keiretsu frontier efficiencies vs. 8 keiretsu scores from pooled frontier	202.91 (0.0001)	9.6159 (0.0001)	9.78936 (0.0001)	9.2162 (0.0001)	8.2322 (0.0001)
11 independent frontier efficiencies vs. 11 independent scores from pooled frontier	6.416 (0.0119)	2.69 (0.007)	2.214 (0.027)	2.679 (0.007)	2.213 (0.0269)
NSIFs vs. SIFs					
5 NSIF frontier efficiencies vs. 11 independent frontier efficiencies	61.284 (0.0001)	6.19734 (0.0001)	6.8329 (0.0001)	5.827 (0.0001)	4.7976 (0.0001)
6 SIF frontier efficiencies vs. 11 independent frontier efficiencies	3.497 (0.0629)	2.0604 (0.0394)	1.5378 (0.0795)	2.0488 (0.0405)	1.7995 (0.0719)
5 NSIF frontier efficiencies vs. 5 NSIF scores from independent frontier	113.205 (0.0001)	7.1 (0.0001)	6.496 (0.0001)	6.7947 (0.0001)	5.769 (0.0001)
6 SIF frontier efficiencies vs. 6 SIF scores from independent frontier	0.9848 (0.35)	0.3629 (0.971)	0.1117 (0.911)	0.0307 (0.9755)	0.0311 (0.9752)

Panel B: Cost Efficiency					
Keiretsu vs. Independent Firms					
8 keiretsu frontier efficiencies vs. 19 pooled frontier efficiencies	95.39	9.31	8.529	8.782	7.797
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
11 independent frontier efficiencies vs. 19 pooled frontier efficiencies	0	0.475	1.09	0.4123	0.9577
	(0.9921)	(0.6346)	(0.2748)	(0.68)	(0.3382)
8 keiretsu frontier efficiencies vs. 8 keiretsu scores from pooled frontier	67.288	7.322	6.046	7.267	6.0128
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
11 independent frontier efficiencies vs. 11 independent scores from pooled frontier	0.241	1.178	1.965	0.913	1.1916
	(0.623)	(0.2386)	(0.049)	(0.36)	(0.233)
NSIFs vs. SIFs					
5 NSIF frontier efficiencies vs. 11 independent frontier efficiencies	34.235	6.4037	6.4	5.9323	4.6813
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
6 SIF frontier efficiencies vs. 11 independent frontier efficiencies	1.196	0.1456	0.8768	0.0225	0.8962
	(0.2755)	(0.8842)	(0.3805)	(0.982)	(0.3701)
5 NSIF frontier efficiencies vs. 5 NSIF scores from independent frontier	90.248	6.9208	6.417	6.5594	5.2984
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
6 SIF frontier efficiencies vs. 6 SIF scores from independent frontier	0.9828	0.0644	0.1672	0.0581	0.0636
	(0.35)	(0.9486)	(0.8672)	(0.9536)	(0.9493)

and to the frontiers of all firms. We follow an analogues procedure for the independent firm frontiers.

By the two different methods, the results in Panel A of Table 6 overwhelmingly reject the subnull hypothesis that the keiretsu technical frontier is the same as the pooled technical frontier, but not that the independent frontiers differ from the pooled frontiers. Rather, the results suggest that independent firms primarily define the pooled frontier. The tests for NSIFs and SIFs lead to rejection of the subnull hypothesis that NSIF frontiers are different from the pooled (all independent firms) frontier, but not the subnull hypothesis that SIF frontiers are different from the pooled frontier. Thus, the SIFs primarily define the frontier of all independent firms. The results regarding the cost frontier, reported in Panel B of Table 6, are similar to the TE results.

We thus conclude that we should base both technical and CE comparisons on separate frontiers when we compare either keiretsu and independent firms or NSIFs and SIFs. What is more important is that these results show the two groups of firms in each comparison use distinctive technologies to produce their particular outputs. Table 7 thus bases the analysis on separate frontiers. For the whole sample period, Panel A shows that keiretsu TE averaged 97.2 percent, whereas independent TE averaged 88.8 percent. NSIF TE averaged 97.6 percent, and SIF TE averaged 91.1 percent. These results imply that keiretsu firms could have produced the same amount of output by reducing the inputs that were actually consumed by 2.8 percentage points; independent firms could have produced the same outputs by reducing inputs by 11.2 percentage points. The same is true for the NSIFs and SIFs, by different amounts.

We cannot interpret these results as that independent insurers would produce the outputs of keiretsu insurers more efficiently, nor that NSIFs would produce the outputs of SIFs more efficiently. The results in Table 7 are based on the assumption that the firms use different technologies. Thus, the results say only that firms have different efficiency performance according to different production frontiers.

Cross-Frontier Results

To examine whether independent insurers (NSIFs) could produce the outputs of keiretsu insurers (SIFs) more efficiently, we perform cross-frontier analysis. Table 8 shows cross-frontier efficiencies based on the cross-frontier distance function. We calculate the efficiency scores of one organizational form relative to the frontier of the other in both production and cost schemes. Panel A reports the cross-frontier results between keiretsu firms and independent firms, and Panel B reports the results of comparison between keiretsu firms and NSIFs. The results for NSIFs and SIFs are in Panel C and the results for keiretsu firms and SIFs in Panel D. In each panel we report results for TE in the first four columns and the results for CE in the last four columns.[10]

Keiretsu Firms vs. Independent Firms. The cross-frontier TE scores for keiretsu firms and independent firms are presented in the second and fourth columns of Panel A. First,

[10] To facilitate comparison, we repeat each group's efficiency scores relative to its own frontier (e.g., $T_k(X_k, Y_k)$) in the odd-numbered columns of each panel (columns 1, 3, 5, and 7).

the mean of keiretsu relative-to-independent-frontier scores ($T_i(X_k, Y_k)$) are less than the mean of the keiretsu score relative to their own frontier, $T_k(X_k, Y_k)$, implying it may be feasible to replicate keiretsu input–output combinations using the independent firm technology. Because $T_i(X_k, Y_k)$ is greater than 1 in 7 of the 12 years in the sample period, we must be very careful about the results. In other words, the keiretsu technology dominates the independent firm technology for producing keiretsu outputs in those 7 years. The independent firm technical efficiencies, with respect to the keiretsu frontier ($T_k(X_i, Y_i)$), however, are higher than 1 in all the sample years. This implies that the independent firms' technology is better than the keiretsu technology in producing the independent firms' output vectors.

TABLE 7

Technical and Cost Efficiency Based on Separate Frontiers

The table reports the efficiency scores of Japanese nonlife insurers relative to the separate frontiers in a sample period 1983–1994 and their average. Panel A reports the results of technical efficiency, whereas Panel B reports the results of cost efficiency.

Panel A: Technical Efficiency

Keiretsu vs. Independent			NSIF vs. SIF		
Year	$T_k(X_k, Y_k)$	$T_i(X_i, Y_i)$	Year	$T_{ns}(X_{ns}, Y_{ns})$	$T_{si}(X_{si}, Y_{si})$
Mean	0.9720***	0.8883	Mean	0.9758	0.9113
	(0.0371)	(0.0840)		(0.0278)	(0.0821)
1983	0.9815	0.9627	1983	1.0000	0.9598
	(0.0394)	(0.0637)		(0.0000)	(0.0602)
1984	0.9796	0.9588	1984	0.9964	0.9530
	(0.0401)	(0.0638)		(0.0072)	(0.0674)
1985	0.9859	0.9703	1985	0.9994	0.9612
	(0.0362)	(0.0500)		(0.0012)	(0.0566)
1986	0.9920	0.9512	1986	0.9972	0.9542
	(0.0212)	(0.0665)		(0.0056)	(0.0659)
1987	0.9924	0.9344	1987	0.9968	0.9170
	(0.0202)	(0.0958)		(0.0064)	(0.1079)
1988	0.9934***	0.9349	1988	1.0000	0.9380
	(0.0138)	(0.0640)		(0.0000)	(0.0735)
1989	0.9975***	0.9156	1989	1.0000	0.9343
	(0.0066)	(0.0611)		(0.0000)	(0.0665)
1990	1.0000***	0.9259	1990	1.0000	0.9455
	(0.0000)	(0.0486)		(0.0000)	(0.0550)
1991	0.9976***	0.9311	1991	1.0000	0.9623
	(0.0063)	(0.0480)		(0.0000)	(0.0393)
1992	1.0000***	0.9323	1992	1.0000	0.9735
	(0.0000)	(0.0525)		(0.0000)	(0.0337)
1993	0.9980***	0.9381	1993	1.0000	0.9755
	(0.0053)	(0.0531)		(0.0000)	(0.0349)
1994	1.0000***	0.9526	1994	1.0000	0.9850
	(0.0000)	(0.0529)		(0.0000)	(0.0314)

(continued)

TABLE 7
(Continued)

Panel B: Cost Efficiency

Keiretsu vs. Independent			NSIF vs. SIF		
Year	$C_k(X_k, Y_k)$	$C_i(X_i, Y_i)$	Year	$C_{ns}(X_{ns}, Y_{ns})$	$C_{si}(X_{si}, Y_{si})$
Mean	0.8350***	0.7093	Mean	0.9302	0.6580
	(0.1307)	(0.2877)		(0.0641)	(0.3690)
1983	0.9223	0.7725	1983	0.9422	0.6500
	(0.1098)	(0.3724)		(0.0765)	(0.4610)
1984	0.9293	0.7596	1984	0.9462	0.6352
	(0.1037)	(0.3685)		(0.0716)	(0.4541)
1985	0.9263	0.8364	1985	0.9304	0.7812
	(0.1092)	(0.2831)		(0.0741)	(0.3635)
1986	0.9291	0.8404	1986	0.9380	0.7855
	(0.0996)	(0.2831)		(0.0679)	(0.3666)
1987	0.9211	0.8347	1987	0.9624	0.7643
	(0.0900)	(0.2885)		(0.0463)	(0.3648)
1988	0.9373	0.8123	1988	0.9816	0.7658
	(0.0693)	(0.2752)		(0.0368)	(0.3602)
1989	0.9478**	0.7668	1989	0.9736	0.7342
	(0.0686)	(0.2636)		(0.0412)	(0.3492)
1990	0.9461**	0.7765	1990	0.9816	0.7507
	(0.0590)	(0.2679)		(0.0348)	(0.3566)
1991	0.8910**	0.6292	1991	0.9988	0.5615
	(0.1235)	(0.3126)		(0.0024)	(0.4094)
1992	0.9041*	0.7090	1992	1.0000	0.7263
	(0.1189)	(0.2544)		(0.0000)	(0.3408)
1993	0.9458***	0.5716	1993	1.0000	0.4682
	(0.0763)	(0.2926)		(0.0000)	(0.3597)
1994	0.9967***	0.7947	1994	1.0000	0.8445
	(0.0060)	(0.1397)		(0.0000)	(0.1602)

Notes: Numbers in parentheses are standard deviations. X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (technical efficiency) or on C (cost efficiency) indicates the frontier on which the firms are based. Subscript k = keiretsu frontier; i = independent frontier; ns = NSIF frontier; si = SIF frontier.
***Statistically significant difference at the 1 percent level.
**Statistically significant difference at the 5 percent level.
*Statistically significant difference at the 10 percent level.

The cross-frontier CE scores between keiretsu firms and independent firms are presented in columns 6 and 8 in Panel A. The keiretsu relative-to-independent-frontier scores ($C_i(X_k, Y_k)$) are less than 1 in every sample period, but are not statistically significant. Thus, we are not able to reject the first main hypothesis that independent firms are more efficient than keiretsu firms.

The independent firm relative-to-keiretsu-frontier scores ($C_k(X_i, Y_i)$) are greater than 1 in every sample period, implying it is not feasible to replicate the independent firm input–output combinations using the keiretsu technology. In other words, the independent firm technology dominates the keiretsu technology for producing the particular output vectors. Combining all the results, we are not able to reject the hypothesis that keiretsu firm and independent firm efficiencies are equal.

Again, we need to treat these results with caution because the evidence in Table 6 suggests that NSIFs and SIFs operate on different frontiers and should be analyzed separately even though they are both independent firms. We provide additional evidence based on analysis that treats NSIFs and SIFs separately.

Keiretsu Firms vs. NSIFs. The cross-frontier TE comparisons for keiretsu firms and NSIFs are presented in the second and fourth columns of Panel B of Table 8. These results provide some interesting findings. First, the keiretsu relative-to-NSIF-frontier scores ($T_{ns}(X_k, Y_k)$) are higher than 1 in every sample period, implying it is not feasible

TABLE 8

Cross-Frontier Results

The table reports the cross-frontier efficiency scores among three ownership structures in Japanese nonlife insurers. Panel A reports the results between keiretsu firms and NSIFs; Panel B reports the results between SIFs and NSIFs, whereas Panel C reports the results between keiretsu firms and SIFs.

Panel A: Comparison of Keiretsu Firms and Independent Firms

Year	(1) $T_k(X_k, Y_k)$	(2) $T_i(X_k, Y_k)$	(3) $T_i(X_i, Y_i)$	(4) $T_k(X_i, Y_i)$	(5) $C_k(X_k, Y_k)$	(6) $C_i(X_k, Y_k)$	(7) $C_i(X_i, Y_i)$	(8) $C_k(X_i, Y_i)$
Mean	0.9720***	0.9037	0.8883***	3.0947	0.8350	0.8180	0.7093***	1.9727
	(0.0371)	(0.1279)	(0.0840)	(3.7481)	(0.1307)	(0.1513)	(0.2877)	(2.7804)
1983	0.9815	1.0260	0.9627***	3.7227	0.9223	0.9364	0.7725	1.9955
	(0.0394)	(0.1684)	(0.0637)	(4.1061)	(0.1098)	(0.1184)	(0.3724)	(2.6187)
1984	0.9796	1.0181	0.9588***	4.0773	0.9293	0.9285	0.7596	2.2045
	(0.0401)	(0.1655)	(0.0638)	(5.1679)	(0.1037)	(0.1197)	(0.3685)	(3.4134)
1985	0.9859	1.0575	0.9703***	3.9227	0.9263	0.9446	0.8364	2.4045
	(0.0362)	(0.1771)	(0.0500)	(5.1961)	(0.1092)	(0.1340)	(0.2831)	(3.5593)
1986	0.9920	1.0590	0.9512***	3.7545	0.9291	0.9345	0.8404*	2.3773
	(0.0212)	(0.1896)	(0.0665)	(4.7160)	(0.0996)	(0.1327)	(0.2831)	(3.4564)
1987	0.9924	1.0148	0.9344***	5.1727	0.9211	0.8839	0.8347**	3.3636
	(0.0202)	(0.1893)	(0.0958)	(6.7786)	(0.0900)	(0.1396)	(0.2885)	(5.0232)
1988	0.9934	0.9990	0.9349***	5.1773	0.9373	0.8711	0.8123**	3.5136
	(0.0138)	(0.1893)	(0.0640)	(6.5861)	(0.0693)	(0.1396)	(0.2752)	(5.1881)
1989	0.9975	1.0069	0.9156***	4.7773	0.9478	0.8779	0.7668***	3.2636
	(0.0066)	(0.1958)	(0.0611)	(5.3539)	(0.0686)	(0.1560)	(0.2636)	(4.4804)
1990	1.0000	1.0223	0.9259***	4.8500	0.9461	0.9030	0.7765***	3.0773
	(0.0000)	(0.1769)	(0.0486)	(5.3820)	(0.0590)	(0.1741)	(0.2679)	(4.2534)
1991	0.9976	0.9653	0.9311***	4.5955	0.8910	0.8584	0.6292**	2.5682
	(0.0063)	(0.0994)	(0.0480)	(4.8762)	(0.1235)	(0.1736)	(0.3126)	(4.0848)
1992	1.0000	0.9814	0.9323***	4.4818	0.9041	0.8756	0.7090***	2.7727
	(0.0000)	(0.1193)	(0.0525)	(4.3971)	(0.1189)	(0.1775)	(0.2544)	(3.6391)
1993	0.9980*	0.9390	0.9381***	4.3091	0.9458	0.8318	0.5716***	1.5409
	(0.0053)	(0.0861)	(0.0531)	(4.2852)	(0.0763)	(0.1668)	(0.2926)	(1.3397)
1994	1.0000***	0.9585	0.9526***	4.6364	0.9967***	0.8396	0.7947***	4.0864
	(0.0000)	(0.0511)	(0.0529)	(4.8624)	(0.0060)	(0.1414)	(0.1397)	(4.6589)

(continued)

TABLE 8
(Continued)

Panel B: Comparison of Keiretsu Firms and NSIFs

Year	(1) $T_k(X_k, Y_k)$	(2) $T_{ns}(X_k, Y_k)$	(3) $T_{ns}(X_{ns}, Y_{ns})$	(4) $T_k(X_{ns}, Y_{ns})$	(5) $C_k(X_k, Y_k)$	(6) $C_{ns}(X_k, Y_k)$	(7) $C_{ns}(X_{ns}, Y_{ns})$	(8) $C_k(X_{ns}, Y_{ns})$
Mean	0.9720***	1.2393	0.9758*	1.0028	0.8350***	1.1144	0.9302***	0.8053
	(0.0371)	(0.2746)	(0.0278)	(0.0735)	(0.1307)	(0.2540)	(0.0641)	(0.0947)
1983	0.9815**	1.3118	1.0000***	1.1620	0.9223*	1.2008	0.9422	0.9100
	(0.0394)	(0.3362)	(0.0000)	(0.0972)	(0.1098)	(0.3513)	(0.0765)	(0.1226)
1984	0.9796**	1.3136	0.9964**	1.1160	0.9293*	1.2143	0.9462	0.8980
	(0.0401)	(0.3636)	(0.0072)	(0.0768)	(0.1037)	(0.3842)	(0.0716)	(0.1187)
1985	0.9859***	1.3440	0.9994*	1.0820	0.9263***	1.2113	0.9304	0.8740
	(0.0362)	(0.3394)	(0.0012)	(0.0703)	(0.1092)	(0.3626)	(0.0741)	(0.0965)
1986	0.9920***	1.3616	0.9972*	1.1880	0.9291**	1.2236	0.9380	0.9400
	(0.0212)	(0.3587)	(0.0056)	(0.1155)	(0.0996)	(0.3603)	(0.0679)	(0.1339)
1987	0.9924***	1.2653	0.9968***	1.1940	0.9211**	1.1010	0.9624	0.9500
	(0.0202)	(0.1982)	(0.0064)	(0.0885)	(0.0900)	(0.1452)	(0.0463)	(0.0932)
1988	0.9934***	1.3740	1.0000***	1.2260	0.9373***	1.1576	0.9816	0.9940
	(0.0138)	(0.2566)	(0.0000)	(0.1071)	(0.0693)	(0.1586)	(0.0368)	(0.1167)
1989	0.9975***	1.3781	1.0000**	1.1880	0.9478**	1.1520	0.9736	0.9820
	(0.0066)	(0.)2658	(0.0000)	(0.1158)	(0.0686)	(0.1866)	(0.0412)	(0.1235)
1990	1.0000***	1.4156	1.0000***	1.2220	0.9461***	1.2098	0.9816	0.9860
	(0.0000)	(0.2335)	(0.0000)	(0.1105)	(0.0590)	(0.1931)	(0.0348)	(0.1322)
1991	0.9976***	1.4306	1.0000***	1.2340	0.8910***	1.2413	0.9988***	0.8840
	(0.0063)	(0.1971)	(0.0000)	(0.1291)	(0.1235)	(0.2190)	(0.0024)	(0.0436)
1992	1.0000***	1.4925	1.0000**	1.2000	0.9041***	1.3159	1.0000*	0.8860
	(0.0000)	(0.2547)	(0.0000)	(0.1322)	(0.1189)	(0.2411)	(0.0000)	(0.1224)
1993	0.9980***	1.4606	1.0000*	1.1420	0.9458***	1.2799	1.0000***	0.8940
	(0.0053)	(0.1132)	(0.0000)	(0.1141)	(0.0763)	(0.1621)	(0.0000)	(0.0602)
1994	1.0000***	1.3815	1.0000*	1.1340	0.9967***	1.2101	1.0000	0.9520
	(0.0000)	(0.0868)	(0.0000)	(0.1184)	(0.0060)	(0.0833)	(0.0000)	(0.0621)

(continued)

to replicate the keiretsu input–output combination using the NSIF technology. In other words, the keiretsu technology dominates the NSIF technology for producing the keiretsu firm output vectors. The NSIF technical efficiencies, with respect to the keiretsu frontier ($T_k(X_{ns}, Y_{ns})$), are also higher than 1 in all sample years, similarly implying that NSIF technology is superior to keiretsu technology in producing the NSIF output vectors.

Second, we compare the keiretsu efficiency score relative to the NSIF frontier, $T_{ns}(X_k, Y_k)$, with the keiretsu score relative to its own frontier, $T_k(X_k, Y_k)$. The keiretsu-relative-to-NISF-frontier scores are higher than $T_k(X_k, Y_k)$ in every sample year, overwhelmingly rejecting the hypothesis that they are equal. The keiretsu technology thus tends to dominate the NSIF technology for producing the keiretsu firm output combinations. A similar comparison for NSIFs ($T_{ns}(X_{ns}, Y_{ns})$) and ($T_k(X_{ns}, Y_{ns})$) shows that the NSIF technology is dominant for producing the NSIF output vectors in every sample year.

These TE results imply that keiretsu firms and NSIFs use different technologies. Keiretsu technology is found to dominate the NSIF frontier for producing keiretsu outputs, and NSIF technology similarly dominates the keiretsu frontier for producing

TABLE 8
(Continued)

Panel C: Comparison of NSIFs and SIFs

Year	(1) $T_{ns}(X_{ns}, Y_{ns})$	(2) $T_{si}(X_{ns}, Y_{ns})$	(3) $T_{si}(X_{si}, Y_{si})$	(4) $T_{ns}(X_{si}, Y_{si})$	(5) $C_{ns}(X_{ns}, Y_{ns})$	(6) $C_{si}(X_{ns}, Y_{ns})$	(7) $C_{si}(X_{si}, Y_{si})$	(8) $C_{ns}(X_{si}, Y_{si})$
Mean	0.9758***	0.8908	0.9113***	8.1326	0.9302***	0.7898	0.6580***	5.9993
	(0.0278)	(0.1203)	(0.0821)	(7.2942)	(0.0641)	(0.1319)	(0.3690)	(7.0876)
1983	1.0000	1.0480	0.9598***	9.4250	0.9422	1.0120	0.6500***	5.8167
	(0.0000)	(0.1181)	(0.0602)	(7.0232)	(0.0765)	(0.1338)	(0.4610)	(6.6217)
1984	0.9964	1.0880	0.9530***	10.8250	0.9462	1.0500	0.6352***	6.9750
	(0.0072)	(0.1184)	(0.0674)	(9.5098)	(0.0716)	(0.1438)	(0.4541)	(9.1498)
1985	0.9994	1.1140	0.9612***	10.6333	0.9304	1.0380	0.7812***	7.5917
	(0.0012)	(0.0801)	(0.0566)	(9.8279)	(0.0741)	(0.1259)	(0.3635)	(9.1026)
1986	0.9972	1.0940	0.9542***	10.4917	0.9380	1.0660	0.7855***	7.5083
	(0.0056)	(0.1652)	(0.0659)	(9.6569)	(0.0679)	(0.1614)	(0.3666)	(9.1483)
1987	0.9968	0.9820	0.9170***	9.8000	0.9624	0.9400	0.7643***	7.0333
	(0.0064)	(0.0900)	(0.1079)	(8.3975)	(0.0463)	(0.1108)	(0.3648)	(8.0832)
1988	1.0000***	0.9320	0.9380***	9.5250	0.9816**	0.8660	0.7658***	7.0167
	(0.0000)	(0.0479)	(0.0735)	(7.9318)	(0.0368)	(0.0720)	(0.3602)	(8.1078)
1989	1.0000***	0.8940	0.9343***	8.4583	0.9736***	0.8080	0.7342***	6.1000
	(0.0000)	(0.0427)	(0.0665)	(6.0462)	(0.0412)	(0.0624)	(0.3492)	(6.5332)
1990	1.0000***	0.9020	0.9455***	9.2083	0.9816***	0.8080	0.7507***	6.6750
	(0.0000)	(0.0232)	(0.0550)	(7.1136)	(0.0348)	(0.0591)	(0.3566)	(7.5658)
1991	1.0000***	0.8920	0.9623***	9.8250	0.9988***	0.7100	0.5615***	6.6917
	(0.0000)	(0.0248)	(0.0393)	(7.7413)	(0.0024)	(0.0415)	(0.4094)	(9.0158)
1992	1.0000***	0.8820	0.9735***	10.1917	1.0000***	0.6880	0.7263***	7.7917
	(0.0000)	(0.0133)	(0.0337)	(7.6324)	(0.0000)	(0.0462)	(0.3408)	(8.5577)
1993	1.0000***	0.8920	0.9755***	9.5667	1.0000***	0.6960	0.4682***	3.2833
	(0.0000)	(0.0319)	(0.0349)	(6.8365)	(0.0000)	(0.0709)	(0.3597)	(2.5441)
1994	1.0000***	0.9140	0.9850***	9.2250	1.0000***	0.7360	0.8445***	7.6250
	(0.0000)	(0.0488)	(0.0314)	(5.6677)	(0.0000)	(0.0763)	(0.1602)	(5.8860)

(continued)

NSIF outputs. These results suggest that neither keiretsu firms nor NSIF are dominant in TE.

The cross-frontier CE scores for keiretsu firms and NSIFs are presented in columns 6 and 8 in Panel B. The keiretsu relative-to-NSIF-frontier scores ($C_{ns}(X_k, Y_k)$) are higher than 1 for every sample period. In addition, $C_{ns}(X_k, Y_k)$, the keiretsu efficiencies relative to the NSIF frontier, are higher than $C_k(X_k, Y_k)$ in every sample year. These results imply that the keiretsu cost frontier dominates the NSIF cost frontier for the keiretsu firm input–output vectors. The scores of NSIFs relative to the keiretsu frontier ($C_k(X_{ns}, Y_{ns})$) are lower than the scores of NSIFs relative to their own frontier ($C_{ns}(X_{ns}, Y_{ns})$), however, implying that the keiretsu frontier tends to lie to the left of the NSIF frontier for the NSIF input–output vectors.

Combining these two results, we find that the keiretsu cost frontier dominates the NSIF cost frontier not only for keiretsu outputs but also for NSIF outputs. Although the results of the TE tests show that NSIFs and keiretsu firms use distinct technologies to produce their particular outputs, NSIFs do not pursue their technological advantages to necessarily gain cost advantages. Keiretsu insurers have some advantages in input prices, such as a lower cost of capital because of their relationship with the main bank

TABLE 8
(Continued)

Panel D: Comparison of Keiretsu Firms and SIFs

Year	(1) $T_k(X_k, Y_k)$	(2) $T_{si}(X_k, Y_k)$	(3) $T_{si}(X_{si}, Y_{si})$	(4) $T_k(X_{si}, Y_{si})$	(5) $C_k(X_k, Y_k)$	(6) $C_{si}(X_k, Y_k)$	(7) $C_{si}(X_{si}, Y_{si})$	(8) $C_k(X_{si}, Y_{si})$
Mean	0.9720***	0.9132	0.9113***	4.8396	0.8350	0.8287	0.6580***	2.9451
	(0.0371)	(0.1365)	(0.0821)	(4.3649)	(0.1307)	(0.1557)	(0.3690)	(3.4762)
1983	0.9815	1.0616	0.9598**	5.8500	0.9223	0.9675	0.6500	2.8917
	(0.0394)	(0.1981)	(0.0602)	(4.5765)	(0.1098)	(0.1331)	(0.4610)	(3.2854)
1984	0.9796	1.0703	0.9530***	6.5417	0.9293	0.9855	0.6352	3.3000
	(0.0401)	(0.1977)	(0.0674)	(5.9663)	(0.1037)	(0.1501)	(0.4541)	(4.3256)
1985	0.9859	1.1119	0.9612***	6.2917	0.9263	0.9930	0.7812**	3.6833
	(0.0362)	(0.2028)	(0.0566)	(6.0949)	(0.1092)	(0.1575)	(0.3635)	(4.4293)
1986	0.9920	1.1168	0.9542***	5.8917	0.9291	0.9701	0.7855**	3.5833
	(0.0212)	(0.2100)	(0.0659)	(5.5423)	(0.0996)	(0.1432)	(0.3666)	(4.3231)
1987	0.9924	1.0148	0.9170***	8.5000	0.9211	0.8861	0.7643**	5.3750
	(0.0202)	(0.1844)	(0.1079)	(7.7381)	(0.0900)	(0.1458)	(0.3648)	(6.1117)
1988	0.9934	0.9990	0.9380***	8.4667	0.9373	0.8711	0.7658**	5.6167
	(0.0138)	(0.1893)	(0.0735)	(7.4640)	(0.0693)	(0.1396)	(0.3602)	(6.2933)
1989	0.9975	1.0069	0.9343***	7.7667	0.9478	0.8779	0.7342**	5.1583
	(0.0066)	(0.1958)	(0.0665)	(5.7339)	(0.0686)	(0.1560)	(0.3492)	(5.3749)
1990	1.0000	1.0223	0.9455***	7.8667	0.9461	0.9030	0.7507**	4.8167
	(0.0000)	(0.1769)	(0.0550)	(5.7510)	(0.0590)	(0.1741)	(0.3566)	(5.1475)
1991	0.9976	0.9653	0.9623***	7.3917	0.8910	0.8584	0.5615	3.9667
	(0.0063)	(0.0944)	(0.0393)	(5.1359)	(0.1235)	(0.1736)	(0.4094)	(5.1269)
1992	1.0000	0.9814	0.9735***	7.2250	0.9041	0.8756	0.7263**	4.3417
	(0.0000)	(0.1193)	(0.0337)	(4.3448)	(0.1189)	(0.1775)	(0.3408)	(4.3420)
1993	0.9980	0.9390	0.9755***	6.9583	0.9458	0.8318	0.4682	2.0833
	(0.0053)	(0.0861)	(0.0349)	(4.2679)	(0.0763)	(0.1668)	(0.3597)	(1.6250)
1994	1.0000***	0.9585	0.9850***	7.5417	0.9967***	0.8396	0.8445***	6.6917
	(0.0000)	(0.0511)	(0.0314)	(4.9764)	(0.0060)	(0.1414)	(0.1602)	(4.9857)

Notes: Numbers in parentheses are standard deviations. X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (technical efficiency) or on C (cost efficiency) indicates the frontier on which the firms are based. Subscript k = keiretsu frontier; i = independent frontier; ns = NSIF frontier; si = SIF frontier.
***Statistically significant difference at the 1 percent level.
**Statistically significant difference at the 5 percent level.
*Statistically significant difference at the 10 percent level.

and other keiretsu member firms. These results suggest that keiretsu firms may be more successful than NSIFs in minimizing costs.

NSIFs vs. SIFs. Panel C of Table 8 provides cross-frontier efficiency comparisons for NSIFs and SIFs. Both the TE and the CE results provide strong evidence for the specialization hypothesis in that SIFs are more efficient than NSIFs for producing either the SIF or the NSIF outputs. In the TE results, the NSIF scores to the SIF frontier $T_{si}(X_{ns}, Y_{ns})$ are on average lower than the NSIF scores relative to their own frontier, $T_{ns}(X_{ns}, Y_{ns})$. The SIF scores relative to the NSIF frontier $T_{ns}(X_{si}, Y_{si})$ are far higher than the SIF scores relative to their own frontier, $T_{si}(X_{si}, Y_{si})$, and are also higher than 1. The results regarding cross-frontier CE between NSIFs and SIFs are similar. These results suggest that the specialization effect dominates the advantages of nonspecialization.

Keiretsu Firms vs. SIFs. Panel D shows the cross-frontier efficiency comparisons for the keiretsu firms and SIFs. The keiretsu firm scores relative to the SIF frontier, $T_{si}(X_k, Y_k)$, are found on average to be lower than $T_k(X_k, Y_k)$, the keiretsu firm scores relative to their own frontier. Thus, the SIF technology is more efficient for producing the keiretsu firm outputs than the keiretsu technology. The SIF advantage of specialization thus apparently outweighs comparative advantage of keiretsu firms in producing their outputs.

We also find the scores of SIFs relative to the keiretsu frontier ($T_k(X_{si}, Y_{si})$) are far higher than the scores of SIFs relative to their own frontier ($T_{si}(X_{si}, Y_{si})$) and are also much higher than 1. This implies that SIF technology dominates the keiretsu technology frontier for producing SIF outputs.

In terms of the CE, the keiretsu firm scores relative to the SIF frontier in Panel C, $C_{si}(X_k, Y_k)$, on average, are lower than the keiretsu firm scores relative to their own frontier, $C_k(X_k, Y_k)$, but the values are not statistically significant. In other words, the hypothesis suggest that the two scores or the efficiencies are equal cannot be rejected.

We summarize the results of cross-frontier tests as follows. Comparison of keiretsu firms and independent firms does not support rejection of the hypothesis that keiretsu firm efficiency of is equal to independent firm efficiency. The comparisons of keiretsu firms and NSIFs in terms of production technology suggest that neither organizational form dominates. The CE results, though, suggest that the keiretsu effect dominates.

Comparison of SIFs and NSIFs suggests that the specialization effect dominates. Specifically, SIFs dominate NSIFs on both production and cost frontiers. In the comparison of keiretsu firms and SIFs, the TE results suggest that the specialization effect dominates the keiretsu effect. We do not interpret these results as invalidating the presence of the keiretsu effect. Apparently, the specialization effect dominates the keiretsu effect. Finally, the SIF cost advantages may surpass the keiretsu firm advantages in monitoring control, but the results are not statistically significant. Thus, we cannot reject the null hypothesis that SIF and NSIF CE is equal.

Regression Analysis

The cross-frontier results in Table 8 indicate SIFs dominate the other two organizational forms for the SIF outputs, and we conjecture that such results are an outcome of SIFs' advantage in specialization over keiretsu firms' advantage in monitoring control. Whether this dominance is due to SIF line specialization or any other factors (such as size) remains a question. We use a regression model to further examine this issue.

First, we follow the literature (such as Cummins et al., 1999) and calculate an F-score to measure the dominance of SIFs. The F-score is intended to evaluate the frontier difference between SIF efficiency relative to their own frontier and SIF efficiency relative to other groups' frontier.

We define the F-score of SIFs relative to the keiretsu frontier as follows:

$$F_k(X_{si}, Y_{si}) = 1 - \frac{T_k(X_{si}, Y_{si})}{T_{si}(X_{si}, Y_{si})} \quad \text{for technical efficiency.} \tag{1}$$

The F-score of SIFs relative to the NSIF frontier is defined as follows:

$$F_{ns}(X_{si}, Y_{si}) = 1 - \frac{T_{ns}(X_{si}, Y_{si})}{T_{si}(X_{si}, Y_{si})} \quad \text{for technical efficiency.} \tag{2}$$

A value of $F(X_{si}, Y_{si}) < 0$ implies that the SIF technology is dominant for the SIF input–output vectors (X_{si}, Y_{si}). For example, when $F_k(X_{si}, Y_{si}) < 0$ this implies that the SIF technology dominates the keiretsu technology for producing the SIF outputs, whereas $F_k(X_{si}, Y_{si}) > 0$ implies that the keiretsu technology dominates the SIF technology for producing the SIF outputs. Likewise, a negative $F_{ns}(X_{si}, Y_{si})$ shows that the SIF technology dominates the NSIF technology for producing the SIF outputs, whereas a positive $F_{ns}(X_{si}, Y_{si})$ implies that the NSIF technology dominates SIF technology for producing the SIF outputs.

To analyze the comparative advantage of SIF ownership over other groups, we regress the vector of frontier difference $F(X_{si}, Y_{si})$ for technical and CE on two independent variables: size and the Herfindahl index. Recall that a negative F-score suggests that the SIF form dominates the other group for the SIF outputs. A negative coefficient for the Herfindahl index implies that the more specialized the SIF, the greater the dominance of the SIF. In addition, if the coefficient of size is positive, this implies that the smaller the SIF, the greater the SIF's dominance. A negative coefficient of size indicates that the larger the SIF, the greater the dominance of the SIF.

We present the regression results in Table 9. Panel A provides the F-score values for SIF relative to the keiretsu frontier; Panel B provides score value for SIF relative to the NSIF frontier. The TE results in Panel A suggest the SIFs tend to have a comparative advantage over the other groups in producing the SIF outputs when the SIF is more specialized or when the SIF is smaller. The Herfindahl index *per se* explains most of the dominance of SIFs because adding the second variable (size) increases the R^2 by only 4 percent (not reported). The CE results also indicate that SIFs tend to have a comparative advantage over the other groups by the SIF cost frontier when the SIF is more specialized. Although the coefficient of size is negative, it is not significant. The results in Panel B are similar to those in Panel A. The SIF dominance in efficiency over NSIFs is explained mostly by SIF high specialization in one or two business lines, not by size. These results provide supplementary evidence that the specialization effect dominates the advantages of nonspecialization.

Specialization Effect

We can provide additional evidence of the specialization effect using an economies of scope approach. To show that SIFs have advantages over NSIFs and keiretsu firms, we need to provide evidence that NSIFs and keiretsu firms are subject to diseconomies of scale.

TABLE 9
Regression Analysis of Technical and Cost Efficiency

Model 1: $F_{it} = \beta_0 + \beta_1 H_{it}$.
Model 2: $F_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 S_{it}$.
Using technical efficiency, for example, $F_k(X_{si}, Y_{si}) = 1 - \frac{T_k(X_{si}, Y_{si})}{T_{si}(X_{si}, Y_{si})}$ and

$$F_{ns}(X_{si}, Y_{si}) = 1 - \frac{T_{ns}(X_{si}, Y_{si})}{T_{si}(X_{si}, Y_{si})},$$

S_{it} refers to size, and H_{it} refers to the Herfindahl index.

	S	H	Adjusted R^2
Panel A: $F_k(X_{si}, Y_{si})$			
Technical efficiency	1.0034***	−41.67***	0.69
	−4.141	(−12.77)	
Cost efficiency	−0.0378	−23.81***	0.45
	(−0.156)	(−7.27)	
Panel B: $F_{ns}(X_{si}, Y_{si})$			
Technical efficiency	1.4486***	69.91***	0.70
	(−3.656)	(−13.11)	
Cost efficiency	−0.264	−47.35***	0.42
	(−0.505)	(−6.73)	

Note: Numbers in parentheses are t-statistics.

We follow Grace and Timme (1992) and examine economies of scope by calculating pairwise cost complementarities between outputs for keiretsu firms and NSIFs. There are cost complementarities (thus, economies of scope) when joint production reduces aggregate costs. For example, if a firm changes the sole production of one output to the production of two outputs so that the aggregate costs are lower than those of separate production of the two outputs, cost complementarities are present.

We define the estimate of the cost complementarity between the pair of outputs i and j, CC_{ij} for the output vector Q as:

$$CC_{ij} = \sum_i \partial^2 C(Q) / \partial q_i \partial q_j,$$

where $C(\cdot)$ is a cost function, and q_i is the quantity of output for the ith product. Cost complementarities imply economies of scope if $CC_{ij} < 0$. These would be diseconomies of scope if $CC_{ij} > 0$. A value of $CC_{ij} = 0$ is consistent with the presence of additive costs.

The empirical results show that all the output pairs in keiretsu firms are greater than zero ($CC_{ij} > 0$) and are all significantly different from zero at least at the 5 percent level.[11] The results for NSIFs are similar to those for keiretsu firms, and are significantly different from zero at the percent level. Our findings suggest there are diseconomies

[11] The economy of scope analysis is based on a parametric approach, whereas elsewhere we use a nonparametric approach. Thus, detailed analyses and results are not reported here.

of scope in the outputs of keiretsu firms and NSIFs, thus, implying that SIFs enjoy some advantages through specialization.

Productivity Changes

We use the Malmquist index to measure productivity changes over the years (see Malmquist (1953) and Färe and Grosskopf (1992)). The results are presented in Table 10.

TABLE 10

Malmquist Index Summary of Annual Means

The table presents the results of Malmquist productivity analysis. Malmquist indices and components for alternative ownership groups are presented in two panels. Panel A compares the results between keiretsu and independent firms, and Panel B presents the results between NSIFs and SIFs. The first section of each panel presents year-to-year Malmquist index and its components, and the cumulative changes from year to year are in the last section. The cumulative change for a given year is the product of the year-to-year indices from the beginning of the period to the end of that year, e.g., for 1985, the cumulative index is the product of the 1983–1984 and 1984–1985 indices.

Panel A: Keiretsu vs. Independent Firms

Keiretsu				Independent			
Year	Total Change	Tech Eff Change	Technology Change	Year	Total Change	Tech Eff Change	Technology Change
1984	1.081	0.998	1.083	1984	1.055	0.996	1.059
1985	1.077	1.007	1.07	1985	0.997	1.013	0.985
1986	0.968	1.007	0.962	1986	0.982	0.979	1.002
1987	0.92	1	0.92	1987	0.922	0.979	0.942
1988	0.957	1.001	0.955	1988	0.994	1.004	0.99
1989	0.98	1.004	0.976	1989	0.958	0.98	0.978
1990	0.971	1.003	0.969	1990	0.993	1.012	0.981
1991	0.944	0.998	0.946	1991	0.992	1.006	0.986
1992	1.02	1.002	1.018	1992	1	1.001	0.999
1993	1.008	0.998	1.01	1993	1.007	1.006	1.001
1994	0.971	1.002	0.969	1994	1.009	1.015	0.994
Mean	0.991	1.002	0.989	Mean	0.992	0.999	0.992
Cumulative Result							
1985	1.1642	1.0050	1.1588	1985	1.0518	1.0089	1.0431
1986	1.1270	1.0120	1.1148	1986	1.0329	0.9878	1.0452
1987	1.0368	1.0120	1.0256	1987	0.9523	0.9670	0.9846
1988	0.9922	1.0130	0.9794	1988	0.9466	0.9709	0.9747
1989	0.9724	1.0171	0.9559	1989	0.9069	0.9515	0.9533
1990	0.9442	1.0201	0.9263	1990	0.9005	0.9629	0.9352
1991	0.8913	1.0181	0.8763	1991	0.8933	0.9687	0.9221
1992	0.9091	1.0201	0.8921	1992	0.8933	0.9696	0.9212
1993	0.9164	1.0181	0.9010	1993	0.8996	0.9754	0.9221
1994	0.8898	1.0201	0.8730	1994	0.9077	0.9901	0.9166

(continued)

TABLE 10
(Continued)

Panel B: Nonspecialized vs. Specialized Independent Firms

NSIFs				SIFs			
Year	Total Change	Tech Eff Change	Technology Change	Year	Total Change	Tech Eff Change	Technology Change
1984	1.026	0.996	1.03	1984	1.055	0.993	1.063
1985	0.997	1.003	0.994	1985	1.003	1.009	0.993
1986	0.951	0.998	0.953	1986	1.004	0.992	1.012
1987	0.9	0.999	0.9	1987	0.926	0.956	0.968
1988	0.959	1.003	0.956	1988	1.017	1.028	0.99
1989	0.982	1	0.982	1989	0.978	0.997	0.982
1990	0.974	1	0.974	1990	0.998	1.013	0.985
1991	0.938	1	0.938	1991	0.996	1.018	0.978
1992	0.988	1	0.988	1992	1.012	1.012	1
1993	1.01	1	1.01	1993	1.018	1.002	1.016
1994	1.002	1	1.002	1994	1.01	1.01	1
Mean	0.975	1.000	0.975	Mean	1.002	1.003	0.999
Cumulative Result							
1985	1.0229	0.9990	1.0238	1985	1.0582	1.0019	1.0556
1986	0.9728	0.9970	0.9757	1986	1.0624	0.9939	1.0682
1987	0.8755	0.9960	0.8781	1987	0.9838	0.9502	1.0340
1988	0.8396	0.9990	0.8395	1988	1.0005	0.9768	1.0237
1989	0.8245	0.9990	0.8244	1989	0.9785	0.9739	1.0053
1990	0.8031	0.9990	0.8029	1990	0.9765	0.9865	0.9902
1991	0.7533	0.9990	0.7532	1991	0.9726	1.0043	0.9684
1992	0.7442	0.9990	0.7441	1992	0.9843	1.0163	0.9684
1993	0.7517	0.9990	0.7516	1993	1.0020	1.0184	0.9839
1994	0.7532	0.9990	0.7531	1994	1.0120	1.0285	0.9839

Panel A compares results for keiretsu and independent firms, whereas Panel B compares the results for NSIFs and SIFs. The first section in each panel presents the year-to-year Malmquist index and its components, and the second section the cumulative changes from year-to-year. The cumulative change for a given year is the product of the year-to-year indices from the beginning of the period to the end of that year, e.g., for 1985, the cumulative index is the product of the 1983–1984 and 1984–1985 indices.

The Malmquist index can be further decomposed into two components: TE change and technology change. Favorable efficiency change is interpreted as evidence of "catching-up" to the frontier, whereas favorable technical change is interpreted as innovation (Färe et al., 1994). It would also be possible to observe firms falling behind, i.e., becoming less efficient, as well as technical regress, interpreted as unfavorable shifts in the production frontier.

In Panel A of Table 10, the year-to-year Malmquist indices for both keiretsu and independent firms are approximately 1 or below 1 (except for the first 1 or 2 years). The geometric means of the year-to-year changes in the Malmquist index (total productivity change) for the two different groups are close, at about 0.99. The cumulative results, however, imply that the production frontiers of both keiretsu and independent firms shift over the years in an unfavorable direction, and keiretsu firms drop more (24 percent) than independent firms (14 percent).

The results regarding the technology changes further show that technology changes (in this case, regress) throughout the years explain the loss in the Malmquist index more than TE changes. In fact, keiretsu firms show a slight evidence (1.02) of catching up to their frontier as their TE change increases.

Panel B of Table 10 shows the changes in NSIFs and SIFs. Cumulative TE changes for the two groups are very close (0.9999 vs. 1.0285), whereas the geometric means for both groups are close to 1. The technology change results for the two groups are strikingly different, however. Although the net technology change in SIFs was only a loss of 6.7 percent (from 1.0556 to 0.9839), the technology change in NSIFs dropped 26 percent (from 1.0238 to 0.7531). This huge loss for NSIFs also explains why the total productivity index of NSIFs dropped 26 percent whereas the SIFs dropped only 5 percent.

Table 10 indicates overall keiretsu firms have more serious technology regress than independent firms, and among independent firms, NSIFs are responsible for most of the regress. The regress of keiretsu firms may be due to a difficulty that keiretsu firms have had in adapting to new technology. The minimal decline in technology change for SIFs might be attributable to the flexibility they gain from specializing in fewer lines. This flexibility can best be demonstrated by the technology efficiency change from 1990 to 1991 (the period when the Japanese economy crashed). Although the technology change in SIFs posted a loss of only 2.2 percent, the technology change measures in NSIFs (keiretsu firms) dropped 6.19 percent (5.4 percent) during the period.

THE FINANCIAL INTERMEDIARY APPROACH

We also use the financial intermediary approach to examine the efficiency performance of the Japanese nonlife insurance firms.

Outputs

The financial intermediary approach views an insurance company as a financial intermediary. In offering insurance, managers invest firm assets by borrowing from policyholders. A critical objective for the managers is therefore maximization of the profits of the firm. Brockett et al. (2000) suggests that insurance firms are different from other financial institutions, such as banks, in that their debtholder (policyholder) returns are contingent on loss experiences. The policyholders in an insurance firm are in fact "purchasing a long-term financial commitment" from the insurer (see Brockett et al., 2000). Other than maximizing profit, paying ability and financial health are also important goals for an insurance firm.

We choose return on assets as an output and a proxy for firm value maximization which is the objective of ordinary business firms. As a proxy for a firm's financial situation, we adopt the variables selected in Brockett et al. (2000) and a system of performance ratios known as the Insurance Regulatory Information System (IRIS) ratio. The IRIS system, developed by the National Association of Insurance Commissioners, is used by regulatory agencies to evaluate company performance.

We list the six variables in Panel A of Table 11, but because our population size is small (19 firms each year), it may not be appropriate to include all six variables as outputs. We instead conduct principal components analysis and use the important components as our proxy for financial condition. The results in Panel B show that the first three components combined explain 79 percent of the total variances of the

TABLE 11

Descriptive Statistics for All Japanese Nonlife Insurers

The table reports the input and output variables, input price, and number of firms in different ownership strucutre in the Japanese insurance industry. Data source are from Statistics of Japanese Non-Life Insurance Business in the period of 1983–1994. We exclude the firm Allstate from the sample because of appropriateness of input use.

Panel A: Variables Selected for Financial Conditions of the Firm

	Variable
1	Change in policyholder surplus
2	Capitalization ratio
3	Change in invested assets
4	Investment yield
5	Change in net premiums
6	Liquid assets to liabilities

Panel B: Principal Component Analysis

	Eigenvalue	Difference	Proportion	Cumulative
Eigenvalue of the Correlation Matrix				
Prin1	2.2310	0.5990	0.3718	0.3718
Prin2	1.6320	0.7639	0.2720	0.6438
Prin3	0.8681	0.2124	0.1447	0.7885
Prin4	0.6557	0.2910	0.1093	0.8978
Prin5	0.3647	0.1162	0.0608	0.9586
Prin6	0.2485	0.0414	1.0000	

	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6
Eigenvectors						
var1	0.3689	−0.5682	−0.1322	0.2174	0.2061	0.6586
var2	0.4642	−0.4451	0.1478	0.2965	−0.0875	−0.6848
var3	0.3449	0.4655	−0.4996	0.2320	0.5816	−0.1505
var4	0.3612	0.2408	0.7799	−0.2158	0.3787	0.1148
var5	0.4583	−0.0572	−0.3183	−0.8045	−0.1902	−0.0449
var6	0.4347	0.4484	0.0383	0.3424	−0.6572	0.2437

(continued)

TABLE 11
(Continued)

Panel C: Descriptive Statistics of Inputs/Outputs					
(On Average)	All Stock	Keiretsu	Independent	NSIF	SIF
Output					
Y_1 = return on assets	0.0060	0.0069**	0.0054	0.0065**	0.0042
Y_2 = principal component 1 of financial conditions	0.2024	0.2153*	0.1921	0.2103*	0.1739
Y_3 = principal component 2 of financial conditions	0.1885	0.1879	0.1889	0.1916	0.1862
Y_4 = principal component 3 of financial conditions	0.1075	0.0983*	0.1149	0.0996**	0.1302
Input					
X_1 = surplus previous year/assets	0.0203	0.0244**	0.0170	0.0245**	0.0095
X_2 = change in surplus/assets	0.0016	0.0015	0.0016	0.0021	0.0011
X_3 = underwriting + investment expenses/assets	0.1154	0.1072**	0.1219	0.1319**	0.1120
X_4 = policyholders debt capital/assets	0.8433	0.8249**	0.8581	0.8246**	0.8916
Input price					
$P_1 = D/E$ ratio for previous year	19.3275	11.2745**	25.7699	11.3832**	40.1567
$P_2 = D/E$ ratio for current year	18.4012	11.2564**	24.1171	11.3035**	36.9306
P_3 = expenses per policy	12.7792	16.2457**	10.0061	16.4585**	3.5537
P_4 = investment income attributed to debt	0.0226	0.0228	0.0225	0.0228	0.0222
Number of firms	18	8	10	5	5

**Statistically significant difference at the 1 percent level.
*Statistically significant difference at the 5 percent level.

original six variables. Henceforth, we use the first three components in Panel B as proxies for the financial condition of an insurance firm.

Inputs

Following Brockett et al. (2000), we define four different variables as our inputs. The first two inputs represent equity capital, the amount of the owners' stake in the firm. Because the amount of equity acquired by the firm can be invested at different times, we further separate the equity capital into surplus in the previous year and change in capital and surplus. The third input consists of underwriting and investment expenses. This reflects the expenses involved in the two important functions of an insurance company—underwriting against contingent losses, and investing the proceeds borrowed from policyholders and owners. The last input is the debt capital supplied by policyholders, which consists primarily of funds borrowed from policyholders.

The prices of the first two inputs, P_1 and P_2, are equal to the debt–equity ratio of the previous year and the current year, respectively.[12] The price for the third input is expenses per policy, derived by taking the third input divided by total expenses (X_3). The price of the debt input is equal to investment income attributed to debt divided by total debt capital (X_4). All input categories are deflated by the 1985 CPI when appropriate.

Descriptive Statistics of Inputs and Outputs

Panel C of Table 11 shows descriptive statistics for both inputs and outputs for all firms by their ownership structure. We test the differences in variables between keiretsu and independent firms and also between NSIFs and SIFs. To standardize comparisons, all the inputs are divided by the total assets of the firm.

We find that most of the input and output variables of keiretsu firms are significantly different from those of independent firms, and most of the variables for NSIFs and SIFs are significantly different from each other. To save space, we report only the final results, because the analysis is very similar to that reported already.

RESULTS OF THE FINANCIAL INTERMEDIARY APPROACH USING THE CROSS-FRONTIER METHOD

There are major differences in output between the value-added approach and the financial intermediary approach, so we further examine the effect of output differences in firms' efficiency performances. To save space, we report only the final results, because the analysis is very similar to that of the value-added approach.

Average Efficiencies

Table 12 includes two panels of results regarding efficiency based on the pooled frontiers. Overall, the results suggest that keiretsu firms on average are both more technically efficient and more cost-efficient than independent firms. SIFs are also on average more technically efficient and more cost-efficient than NSIFs although the differences are not significant.

The results in Table 12 are based on the assumption that each different organizational form faces the same technology and cost frontier. Follow Cummins et al. (1999), we further test whether the pooled and separate frontiers are identical between keiretsu and independent firms as well as between NSIFs and SIFs. The results are shown in Table 13. We conclude that both TE and CE comparisons should be based on separate frontiers for either comparison.

The TE and CE scores on separate frontiers reported in Table 14 indicate that the organizational forms have distinct efficiency performances using different production frontiers.

[12] In the context of corporate finance we know $r_E = r_A + D/E\ (r_A - r_D)$, where r_E is the return on equity, r_A equals return on assets, r_D equals return on debt, and D/E is the debt–equity ratio. We often assume the return on assets is equal across firms in the same industry. If we further assume the return on debt capital (r_D) is the same across firms, we should observe the price of equity (r_E) to be a function of a firm's debt–equity ratio.

TABLE 12
Technical and Cost Efficiency Based on Pooled Frontiers

The table reports the efficiency scores of Japanese nonlife insurers relative to the pooled frontiers in a sample period 1983–1994 and their average. Panel A reports the results of technical efficiency, whereas Panel B reports the results of cost efficiency.

Keiretsu vs. Independent			NSIF vs. SIF		
Panel A: Technical Efficiency					
Year	$T_p(X_k, Y_k)$	$T_p(X_i, Y_i)$	Year	$T_i(X_{ns}, Y_{ns})$	$T_i(X_{si}, Y_{si})$
Mean	0.9856	0.9815	Mean	0.9909	0.9984
Panel B: Cost Efficiency					
Year	$C_p(X_k, Y_k)$	$C_p(X_i, Y_i)$	Year	$C_i(X_{ns}, Y_{ns})$	$C_i(X_{si}, Y_{si})$
Mean	0.9057	0.8303	Mean	0.8946	0.9066

Notes: X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (technical efficiency) or on C (cost efficiency) indicates the frontier on which the firms are based. Subscript p = pooled frontier; k = keiretsu frontier; i = independent frontier.

Cross-Frontier Results

Table 15 presents the cross-frontier efficiencies.

Keiretsu Firms vs. NSIFs. The cross-frontier TE scores between keiretsu firms and NSIFs are presented in Panel A. Keiretsu technology is found to dominate the NSIF frontier for producing the keiretsu outputs, and the NSIF technology also dominates the keiretsu frontier for producing the NSIF outputs. These results suggest that neither keiretsu firms nor NSIFs dominate in TE.

We find the keiretsu cost frontier dominates the NSIF cost frontier not only for keiretsu outputs but also for NSIF outputs. The evidence suggests the keiretsu effect dominates the advantages of nonspecialization.

NSIFs vs. SIFs. In contrast to the results in Table 8, the findings in Panel B of Table 15 do not show that highly SIFs perform more efficiently than firms that are not highly specialized. Our TE results thus imply that each group selects the most efficient way to operate its businesses. Our CE results do not allow us to reject the hypothesis that CE is the same for both SIFs and NSIFs. Therefore, the CE results suggest that neither SIFs nor NSIFs dominate.

Keiretsu Firms vs. SIFs. Neither the TE nor the CE results indicate that SIF frontiers dominate keiretsu firms or vice versa.

We summarize and compare our results as follows. In the case of TE performance, we do not find the strong dominance of SIF efficiency performance in Table 15 that

TABLE 13

Tests of the Null Hypothesis That the Pooled and Separate Frontiers Are Identical

This table reports the test results of null hypothesis that the pooled and separate frontiers are identical. Panel A reports the results of technical efficiency, and Panel B reports the results of cost efficiency.

Panel A: Technical Efficiency

Population Comparison	ANOVA F (Prob > F)	Wilcoxon Z (Prob > Z)	Median Z (Prob > Z)	Van Der Waerden Z (Prob > Z)	Savage Z (Prob > Z)
Keiretsu vs. Independent Firms					
8 keiretsu frontier efficiencies vs. 18 pooled frontier efficiencies	54.48 (0.0001)	6.6276 (0.0001)	5.4739 (0.0001)	6.5564 (0.0001)	5.9178 (0.0001)
10 independent frontier efficiencies vs. 18 pooled frontier efficiencies	10.3332 (0.0014)	3.0378 (0.0012)	3.0787 (0.001)	3.137 (0.0009)	2.6107 (0.0045)
8 keiretsu frontier efficiencies vs. 8 keiretsu scores from pooled frontier	39.8722 (0.0001)	5.2411 (0.0001)	3.743 (0.0001)	5.4163 (0.0001)	4.5518 (0.0001)
10 independent frontier efficiencies vs. 10 independent scores from pooled frontier	12.9289 (0.0004)	3.3043 (0.0005)	3.0919 (0.001)	3.4413 (0.0003)	2.7393 (0.0031)
NSIFs vs. SIFs					
5 NSIF frontier efficiencies vs. 10 independent frontier efficiencies	26.516 (0.0001)	5.2091 (0.0001)	4.7302 (0.0001)	5.1647 (0.0001)	4.9852 (0.0001)
5 SIF frontier efficiencies vs. 10 independent frontier efficiencies	2.1711 (0.1424)	2.0387 (0.0207)	2.2452 (0.0124)	1.8755 (0.0304)	2.1015 (0.0178)
5 NSIF frontier efficiencies vs. 5 NSIF scores from independent frontier	40.1561 (0.0001)	5.7162 (0.0001)	4.9096 (0.0001)	5.691 (0.0001)	5.4391 (0.0001)
5 SIF frontier efficiencies vs. 5 SIF scores from independent frontier	0.1891 (0.6645)	0.6762 (0.2495)	0.7272 (0.2335)	0.657 (0.2556)	0.7147 (0.2374)

(continued)

TABLE 13
(Continued)

Panel B: Cost Efficiency

Population Comparison	ANOVA F (Prob > F)	Wilcoxon Z (Prob > Z)	Median Z (Prob > Z)	Van Der Waerden Z (Prob > Z)	Savage Z (Prob > Z)
Keiretsu vs. Independent Firms					
8 keiretsu frontier efficiencies vs. 18 pooled frontier efficiencies	33.683 (0.0001)	5.5426 (0.0001)	4.8987 (0.0001)	5.4399 (0.0001)	4.9615 (0.0001)
10 independent frontier efficiencies vs. 18 pooled frontier efficiencies	0.0845 (0.7715)	0.4179 (0.338)	0.4547 (0.3246)	0.4307 (0.3333)	0.3409 (0.3666)
8 keiretsu frontier efficiencies vs. 8 keiretsu scores from pooled frontier	7.6406 (0.0063)	2.9818 (0.0014)	2.4602 (0.0069)	3.022 (0.0013)	3.052 (0.0011)
10 independent frontier efficiencies vs. 10 independent scores from pooled frontier	5.4049 (0.0209)	2.4913 (0.0064)	2.0613 (0.0196)	2.2959 (0.0108)	1.7953 (0.0363)
NSIFs vs. SIFs					
5 NSIF frontier efficiencies vs. 10 independent frontier efficiencies	29.1982 (0.0001)	5.0848 (0.0001)	4.7302 (0.0001)	4.9233 (0.0001)	4.131 (0.0001)
5 SIF frontier efficiencies vs. 10 independent frontier efficiencies	0.1835 (0.6689)	0.4356 (0.3315)	0 (0.5)	0.4631 (0.3216)	1.0557 (0.1456)
5 NSIF frontier efficiencies vs. 5 NSIF scores from independent frontier	35.956 (0.0001)	5.2566 (0.0001)	3.9999 (0.0001)	5.2521 (0.0001)	4.7366 (0.0001)
5 SIF frontier efficiencies vs. 5 SIF scores from independent frontier	0 (1.0000)	0 (0.5)	0 (0.5)	0 (0.5)	0 (0.5)

TABLE 14
Technical and Cost Efficiency Based on Separate Frontiers

The table reports the efficiency scores of Japanese nonlife insurers relative to the separate frontiers in a sample period 1983–1994 and their average. Panel A reports the results of technical efficiency, whereas Panel B reports the results of cost efficiency.

Keiretsu vs. Independent			NSIF vs. SIF		
Panel A: Technical Efficiency					
Year	$T_k(X_k, Y_k)$	$T_i(X_i, Y_i)$	Year	$T_{ns}(X_{ns}, Y_{ns})$	$T_{si}(X_{si}, Y_{si})$
Mean	0.9969	0.9946	Mean	1.0000	0.9987
Panel B: Cost Efficiency					
Year	$C_k(X_k, Y_k)$	$C_i(X_i, Y_i)$	Year	$C_{ns}(X_{ns}, Y_{ns})$	$C_{si}(X_{si}, Y_{si})$
Mean	0.9351	0.9006	Mean	0.9700	0.9069

Notes: X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (technical efficiency) or on C (cost efficiency) indicates the frontier on which the firms are based. Subscript k = keiretsu frontier; i = independent frontier; ns = NSIF frontier; si = SIF frontier.

we saw in Table 8. In fact, comparisons among the three different groups suggest that neither group dominates. Each group chooses either to focus on specific lines or to write evenly across different lines where it can enjoy the comparative advantages in maximizing outputs.

In the case of CE, the results of the comparisons between keiretsu firms and NSIFs suggest the keiretsu effect dominates the advantages of NSIFs, consistent with the results in Table 8. The results for comparisons of SIFs and NSIFs and keiretsu firms and SIFs are different from the results in Table 8, however. Our results in Table 15 should not be interpreted as invalidating the existence of the keiretsu effect. Instead, we believe that firms with different organizational forms sort themselves into market segments where they have comparative advantages.

Regression Analysis

Some of the cross-frontier results using the financial intermediary approach are different from the results using the value-added approach, although the only difference between the two approaches is the outputs and inputs. The value-added approach uses the number of polices and the total invested assets as outputs, whereas the financial intermediary approach uses return on assets and financial condition as outputs. Since financial health is not considered in the value-added approach, we suspect financial output variables may play a role in the diminished dominance of the SIFs' efficiency performance.

To examine this question we conduct the regression analyses and consider the relationship between dominant performance and the financial condition of the SIFs.

TABLE 15
Cross-Frontier Results

The table reports the cross-frontier efficiency scores among three ownership structures in Japanese nonlife insurers. Panel A reports the results between keiretsu firms and NSIFs, Panel B reports the results between SIFs and NSIFs, whereas Panel C reports the results between keiretsu firms and SIFs.

Panel A: Results Between Keiretsu Firms and NSIFs

Year	(1) $T_k(X_k, Y_k)$	(2) $T_{ns}(X_k, Y_k)$	(3) $T_{ns}(X_{ns}, Y_{ns})$	(4) $T_k(X_{ns}, Y_{ns})$	(5) $C_k(X_k, Y_k)$	(6) $C_{ns}(X_k, Y_k)$	(7) $C_{ns}(X_{ns}, Y_{ns})$	(8) $C_k(X_{ns}, Y_{ns})$
Mean	0.9969***	1.4638	1.0000*	1.1560	0.9351***	1.3034	0.9700***	0.7865
1983	0.9956***	1.4138	1.0000	1.1580	0.9175**	1.3013	0.9654***	0.7680
1984	0.9870***	1.4138	1.0000	1.1760	0.9163*	1.2750	0.9770**	0.8280
1985	0.9870***	1.6088	1.0000	1.0800	0.9100**	1.4400	0.9830***	0.7620
1986	1.0000***	1.6125	1.0000**	1.1640	0.9544	1.3538	0.9956***	0.7500
1987	1.0000***	1.4850	1.0000**	1.1040	0.9416	1.2900	0.9622**	0.8160
1988	1.0000***	1.4700	1.0000	1.1820	0.9508*	1.3275	0.9862***	0.8280
1989	1.0000***	1.5975	1.0000	1.3680	0.9379***	1.3538	0.9990***	0.7980
1990	1.0000***	1.4700	1.0000*	1.1280	0.9466***	1.3200	0.9734***	0.7860
1991	0.9990***	1.4325	1.0000	1.0860	0.9435***	1.3200	0.9790***	0.7560
1992	0.9989***	1.3725	1.0000**	1.1280	0.9260***	1.2225	0.9482***	0.7560
1993	0.9951***	1.3538	1.0000**	1.1400	0.9430***	1.2300	0.9470**	0.7920
1994	1.0000***	1.3350	1.0000***	1.1580	0.9341***	1.2075	0.9234**	0.7980

(continued)

TABLE 15
(Continued)

Panel B: Results Between NSIFs and SIFs

Year	(1) $T_{ns}(X_{ns}, Y_{ns})$	(2) $T_{si}(X_{ns}, Y_{ns})$	(3) $T_{si}(X_{si}, Y_{si})$	(4) $T_{ns}(X_{si}, Y_{si})$	(5) $C_{ns}(X_{ns}, Y_{ns})$	(6) $C_{si}(X_{ns}, Y_{ns})$	(7) $C_{si}(X_{si}, Y_{si})$	(8) $C_{ns}(X_{si}, Y_{si})$
Mean	1.0000***	1.1920	0.9987***	5.5420	0.9700	0.9600	0.9069***	2.7787
1983	1.0000**	1.2540	1.0000***	7.8120	0.9654	1.0200	0.9402***	4.2420
1984	1.0000*	1.1820	1.0000***	7.6020	0.9770	0.9360	0.9674***	4.0560
1985	1.0000***	1.2300	1.0000***	9.7980	0.9830	0.9780	0.9496***	5.1840
1986	1.0000***	1.1220	0.9910***	10.8360	0.9956**	0.8340	0.9090***	4.6680
1987	1.0000***	1.1640	1.0000***	9.6300	0.9622**	0.8400	0.9292***	2.4660
1988	1.0000	1.1460	1.0000***	5.5860	0.9862*	0.8760	0.9126***	2.0280
1989	1.0000***	1.4220	1.0000***	3.1980	0.9990	1.0980	0.9194***	2.0400
1990	1.0000***	1.2240	0.9978***	2.4300	0.9734	0.9960	0.9004***	1.9140
1991	1.0000*	1.1040	0.9958***	2.6580	0.9790	0.9360	0.8716***	2.0940
1992	1.0000***	1.1400	1.0000***	2.3340	0.9482	0.9120	0.8698**	1.8600
1993	1.0000	1.0920	1.0000***	2.3280	0.9470	0.9660	0.8818***	1.8720
1994	1.0000**	1.2240	1.0000***	2.2920	0.9234**	1.1280	0.8318***	0.9200

(continued)

TABLE 15
(Continued)

Panel C: Results Between Keiretsu Firms and SIFs

Year	(1) $T_k(X_k, Y_k)$	(2) $T_{si}(X_k, Y_k)$	(3) $T_{si}(X_{si}, Y_{si})$	(4) $T_k(X_{si}, Y_{si})$	(5) $C_k(X_k, Y_k)$	(6) $C_{si}(X_k, Y_k)$	(7) $C_{si}(X_{si}, Y_{si})$	(8) $C_k(X_{si}, Y_{si})$
Mean	0.9969***	1.3459	0.9987***	4.7250	0.9351***	1.1750	0.9069***	2.1870
1983	0.9956***	1.4325	1.0000***	5.1600	0.9175**	1.2675	0.9402***	2.7480
1984	0.9870***	1.3013	1.0000***	4.8960	0.9163*	1.1213	0.9674***	2.5740
1985	0.9870***	1.3463	1.0000***	4.9740	0.9100**	1.1513	0.9496***	2.4840
1986	1.0000***	1.2750	0.9910***	10.4040	0.9544	1.0950	0.9090**	4.4880
1987	1.0000***	1.2825	1.0000***	9.0420	0.9416	1.0275	0.9292***	2.2380
1988	1.0000***	1.3388	1.0000***	5.6100	0.9508*	1.1663	0.9126**	1.9260
1989	1.0000***	1.7175	1.0000***	4.1460	0.9379***	1.3200	0.9194**	1.5600
1990	1.0000***	1.3688	0.9978**	2.2800	0.9466***	1.2525	0.9004**	1.4580
1991	0.9990***	1.3013	0.9958**	2.5080	0.9435***	1.1400	0.8716**	1.6680
1992	0.9989***	1.2263	1.0000***	2.5080	0.9260***	1.1625	0.8698**	1.6920
1993	0.9951***	1.2713	1.0000***	2.7960	0.9430***	1.1925	0.8818**	1.7640
1994	1.0000***	1.2900	1.0000***	2.3760	0.9341***	1.2038	0.8318**	1.6440

Notes: X_k, Y_k = input and output for keiretsu firms, respectively. X_i, Y_i = input and output for independent firms, respectively. X_{ns}, Y_{ns} = input and output for NSIFs, respectively. X_{si}, Y_{si} = input and output for SIFs, respectively. Subscript on T (implying technical efficiency) or on C (implying cost efficiency) indicates the frontier on which the firms are based. Subscript k = keiretsu frontier; i = independent frontier; ns = NSIF frontier; si = SIF frontier.

***Statistically significant difference at the 1 percent level.

**Statistically significant difference at the 5 percent level.

*Statistically significant difference at the 10 percent level.

The dependent variable is the frontier difference $F(X_{si}, Y_{si})$ for both TE and CE. We include three independent variables: size, Herfindahl index, and the first principal component of a firm's financial situation (the second output in the financial intermediary approach, Y_2). No other financial condition variables are used because they are highly correlated with Y_2.

A negative coefficient for Y_2 (a financial condition variable) would imply that the poorer the financial condition of the SIFs, the less is the dominance. A positive coefficient implies otherwise. All the predicted signs for the remaining independent variables follow those in the section "Regression Analysis."

We present the regression results in Table 16. Panel A provides the results when *F*-scores for the SIFs relative to the keiretsu frontier is the dependent variable; Panel B provides the results when *F*-scores for the SIFs relative to the NSIF frontier is the dependent variable.

The TE results in Panel A show that the coefficients of both size and financial condition variables are significant, but the Herfindahl index is not significant. The positive coefficient on size implies that SIFs tend to dominate keiretsu firms when SIFs are smaller. The negative coefficient on financial situation implies that the poorer the financial condition of SIFs, the less is the dominance of SIFs.

This result and the fact that financial conditions of SIFs are not as strong as keiretsu firms prompt us to conclude that the diminished dominance of SIFs compared to other groups is related to the weaker financial condition of SIFs. In addition, it seems that the specialization effect does not dominate in the TE results. The TE results in Panel B are similar to those in Panel A except that the coefficient of Herfindahl index is negative and significant.

The CE results, however, indicate that adding Y_2 the regression does not help explain the dominance of SIFs in CE performance. In addition, the coefficient of the Herfindahl index is negative and significant in the CE analysis.

Contrary to the results based on the value-added approach that the SIFs dominate keiretsu firms and NSIFs in their TE and CE performance, the financial intermediary approach does not show dominance of SIFs. The TE results in Table 16 suggest that this may be because the value-added approach does not consider the financial situation of individual firms. Thus, the reduced dominance of SIFs is due to other input and output variables.

Productivity Changes

Results of the Malmquist productivity analysis are presented in Table 17, year-to-year indices in the first section, and the cumulative changes in second. Panel A shows the year-to-year Malmquist indices for both keiretsu and independent firms fluctuate year by year, but the geometric mean of the year-to-year change for keiretsu firms is higher than the mean for independent firms. The cumulative results show that the production frontiers for both keiretsu and independent firms shift in an unfavorable direction. Independent firms drop much more (45 percent, from 1.1694 to 0.64) than keiretsu firms (14 percent, from 1.0675 to 0.9129). The results further show that technology

TABLE 16

Regression Analysis of Technical and Cost Efficiency

Model 1: $F_{it} = \beta_0 + \beta_1 H_{it}$.

Model 2: $F_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 S_{it}$.

Model 3: $F_{it} = \beta_0 + \beta_1 H_{it} + \beta_2 S_{it} + \beta_3 Y_2$.

Using technical efficiency, for example, $F_k(X_{si}, Y_{si}) = 1 - \frac{T_k(X_{si}, Y_{si})}{T_{si}(X_{si}, Y_{si})}$ and

$$F_{ns}(X_{si}, Y_{si}) = 1 - \frac{T_{ns}(X_{si}, Y_{si})}{T_{ns}(X_{si}, Y_{si})}$$

S_{it} refers to size, and H_{it} refers to the Herfindahl index. $Y2$ is the second output (first principal component of financial situation).

		S	H	$Y2$	Adjusted R^2
Panel A: $F_k(X_{si}, Y_{si})$					
Technical efficiency	Model 1:		−0.978		0.01
			(−0.18)		
	Model 2:	1.639***	−8.364		0.19
		(3.62)	(−1.54)		
	Model 3:	1.58***	−6.52	−13.48***	0.36
		(3.94)	(−1.36)	(−2.71)	
Cost efficiency	Model 1:		−9.32***		0.27
			(−4.66)		
	Model 2:	0.589***	−11.97***		0.41
		(3.59)	(−6.09)		
	Model 3:	0.628***	−11.1***	0.42	0.44
		(3.95)	(−5.82)	(0.22)	
Panel B: $F_{ns}(X_{si}, Y_{si})$					
Technical efficiency	Model 1:		−5.98		0.012
			(−0.83)		
	Model 2:	2.122***	−15.54**		0.19
		(3.61)	(−2.21)		
	Model 3:	2.078***	−13.11**	−14.77**	0.31
		(3.85)	(−2.03)	(−2.15)	
Cost efficiency	Model 1:		−13.18***		0.25
			(−4.4)		
	Model 2:	0.915***	−17.31***		0.4
		(3.76)	(−5.93)		
	Model 3:	0.97***	−16.40***	1.88	0.41
		(3.98)	(−5.59)	(0.66)	

Note: Numbers in parentheses are t-statistics.

changes (in this case, regress) throughout the years explain more of the loss in the Malmquist index than efficiency changes.

The results of independent firms are further examined in Panel B of Table 17. The technology change results between the two groups are strikingly different, and the huge difference between keiretsu firms and independent firms is mostly due to the drop of SIFs. Although the technology change in NSIFs represents a loss of only

TABLE 17
Malmquist Index Summary of Annual Means

The table presents the results of Malmquist productivity analysis. The Malmquist indices and its components for alternative ownership groups are presented in two panels. Panel A compares the results between keiretsu and independent firms, and Panel B presents the results between NSIFs and SIFs. The top section of each panel presents year-to-year Malmquist index and its components, and the cumulative changes from year to year are in the lower section. The cumulative change for a given year is the product of the year-to-year indices from the beginning of the period to the end of that year, e.g., for 1985, the cumulative index is the product of the 1983–1984 and 1984–1985 indices.

Panel A: Keiretsu vs. Independent Firms

	Keiretsu				Independent		
Year	Total Change	Tech Eff Change	Technology Change	Year	Total Change	Tech Eff Change	Technology Change
1984	0.993	0.991	1.002	1984	1.066	1.003	1.063
1985	1.075	1	1.075	1985	1.097	1.008	1.088
1986	1.019	1.013	1.005	1986	1.001	0.986	1.015
1987	0.856	1	0.856	1987	0.837	1.015	0.825
1988	0.928	1	0.928	1988	0.856	0.991	0.864
1989	1.077	1	1.077	1989	0.888	1.009	0.88
1990	1.011	1	1.011	1990	0.97	0.999	0.971
1991	0.927	0.999	0.928	1991	0.909	0.996	0.913
1992	1.074	1	1.074	1992	1.012	1.005	1.007
1993	0.964	0.996	0.967	1993	0.963	0.989	0.974
1994	1.011	1.005	1.006	1994	1	1.006	0.994
Mean	0.994	1.000	0.994	Mean	0.964	1.001	0.963
Cumulative Result							
1985	1.0675	0.9910	1.0772	1985	1.1694	1.0110	1.1565
1986	1.0878	1.0039	1.0825	1986	1.1706	0.9969	1.1739
1987	0.9311	1.0039	0.9267	1987	0.9798	1.0118	0.9685
1988	0.8641	1.0039	0.8599	1988	0.8387	1.0027	0.8368
1989	0.9306	1.0039	0.9261	1989	0.7447	1.0117	0.7363
1990	0.9409	1.0039	0.9363	1990	0.7224	1.0107	0.7150
1991	0.8722	1.0029	0.8689	1991	0.6567	1.0067	0.6528
1992	0.9367	1.0029	0.9332	1992	0.6645	1.0117	0.6574
1993	0.9030	0.9989	0.9024	1993	0.6400	1.0006	0.6403
1994	0.9129	1.0039	0.9078	1994	0.6400	1.0066	0.6364

(continued)

15 percent (from 0.9934 to 0.8482), the technology change in SIFs falls 60 percent (from 1.2667 to 0.5096).

The results in Table 17 are considerably different from those in Table 10, where we find SIFs to have in the least technology change of all three groups. Again, we believe this large difference is likely due to different inputs and outputs such as the financial condition of the SIFs.

TABLE 17
(Continued)

Panel B: Nonspecialized vs. Specialized Independent Firms							
NSIFs				SIFs			
Year	Total Change	Tech Eff Change	Technology Change	Year	Total Change	Tech Eff Change	Technology Change
1984	1.022	1	1.022	1984	1.128	1	1.128
1985	0.972	1	0.972	1985	1.123	1	1.123
1986	0.88	1	0.88	1986	1.107	0.991	1.117
1987	1.068	1	1.068	1987	0.688	1.009	0.682
1988	0.996	1	0.996	1988	0.756	1	0.756
1989	0.987	1	0.987	1989	0.794	1	0.794
1990	0.97	1	0.97	1990	1.002	0.998	1.004
1991	0.928	1	0.928	1991	0.938	0.998	0.94
1992	1.066	1	1.066	1992	1.002	1.004	0.997
1993	0.965	1	0.965	1993	0.963	1	0.963
1994	0.998	1	0.998	1994	0.971	1	0.971
Mean	0.987	1.000	0.987	Mean	0.952	1.000	0.952
Cumulative Result							
1985	0.9934	1.0000	0.9934	1985	1.2667	1.0000	1.2667
1986	0.8742	1.0000	0.8742	1986	1.4023	0.9910	1.4150
1987	0.9336	1.0000	0.9336	1987	0.9648	0.9999	0.9650
1988	0.9299	1.0000	0.9299	1988	0.7294	0.9999	0.7295
1989	0.9178	1.0000	0.9178	1989	0.5791	0.9999	0.5793
1990	0.8903	1.0000	0.8903	1990	0.5803	0.9979	0.5816
1991	0.8262	1.0000	0.8262	1991	0.5443	0.9959	0.5467
1992	0.8807	1.0000	0.8807	1992	0.5454	0.9999	0.5450
1993	0.8499	1.0000	0.8499	1993	0.5252	0.9999	0.5249
1994	0.8482	1.0000	0.8482	1994	0.5100	0.9999	0.5096

RESULTS OF THE FINANCIAL INTERMEDIARY APPROACH USING THE RAM METHOD

RAM Version of DEA

We can also use a RAM version of DEA and the same inputs and outputs to investigate the insurance company efficiency issue. The RAM version of DEA is used by Cooper et al. (1999) and Brockett et al. (2000). Two advantages of a RAM version are that we can rank firms by efficiency and a uniform set of weights (see Brockett et al. (2000) for details).

We first calculate the efficiency scores for keiretsu firms, SIFs, and NSIFs (not reported). We then perform some nonparametric tests based on the efficiency scores, examining only TE because Brockett et al. (2000) investigate only TE.

Empirical Results

Table 18 reports the results of the RAM analyses. The results of various nonparametric tests including Wilcoxon, Van Der Median, Waerden, Savage, and Mann–Whitney are

TABLE 18

Test Results of Efficiency Performances Using the RAM Method

This table uses the Range-Adjusted Measure Version (RAM) of DEA and the same input and output of the financial intermediary approach to calculate efficiency. Test results of null hypothesis that efficiency between different organizational forms are identical are then reported.

	Wilcoxon Z (Prob > Z)	Median Z (Prob > Z)	Van Der Waerden Z (Prob > Z)	Savage Z (Prob > Z)	Mann–Whitney Z (Prob > Z)
Keiretsu vs. NSIFs	1.5463	0.9843	1.6999	−0.0717	1.5281
	(0.061)	(0.1625)	(0.0446)	(0.4714)	(0.0631)
NSIFs vs. SIFs	−0.9753	−0.7272	−1.2378	0.2548	−1.4443
	(0.1647)	(0.2335)	(0.1075)	(0.3994)	(0.0749)
Keiretsu vs. SIFs	7.5124	6.5617	7.3347	7.2535	7.0061
	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)	(<0.0001)

TABLE 19

Summary Results of the Efficiency Performances

This table reports the summary results of efficiency differences among the three organizational forms of Japanese nonlife insurers. Panel A reports the results using the value-added approach, Panel B reports the results using the financial intermediary approach, and Panel C reports the (overall) results of the financial intermediary approach using the RAM version of the DEA method.

	Cross-Frontier Technical Efficiency	Cross-Frontier Cost Efficiency
Panel A: Value-Added Approach		
Keiretsu vs. NSIFs	Neither form dominates	Keiretsu firms dominate
NSIFs vs. SIFs	SIFs dominate	SIFs dominate
Keiretsu vs. SIFs	SIFs dominate	Neither form dominates
Panel B: Financial Intermediary Approach		
Keiretsu vs. NSIFs	Neither form dominates	Keiretsu firms dominate
NSIFs vs. SIFs	Neither form dominates	Neither form dominates
Keiretsu vs. SIFs	Neither form dominates	Neither form dominates

	Technical Efficiency
Panel C: RAM Approach	
Keiretsu vs. NSIFs	Neither form dominates
NSIFs vs. SIFs	Neither form dominates
Keiretsu vs. SIFs	Keiretsu firms dominate

consistent. In essence, we cannot reject the hypothesis that the efficiency of keiretsu firms is equal to NSIFs, nor can we reject the hypothesis that the efficiency of NSIFs is equal to that of SIFs. All the test statistics, however, show that keiretsu firms dominate SIFs in terms of TE.

SUMMARY AND CONCLUSIONS

We use several methods to examine the efficiency differences among the three unique organizational forms of the Japanese nonlife insurance industry. First, we use both the value-added approach and the financial intermediary approach. Under the financial intermediary approach, we conduct analysis using both the cross-frontier method and the RAM version of DEA. We summarize the results of the three different approaches in Table 19.

In comparison of keiretsu firms and independent firms, we cannot reject the null hypothesis that keiretsu firms and independent firms are equally efficient. In comparison of NSIFs and keiretsu firms, the TE comparison results obtained from all approaches suggest that the keiretsu technology dominates the NSIF technology in producing the keiretsu output factors (and vice versa). In other words, we cannot reject the hypothesis that NSIFs and keiretsu firms are equally efficient. The results of both the value-added approach and the financial intermediary approach, however, suggest that the keiretsu cost frontier dominates the NSIF cost frontier for both keiretsu and NSIF outputs. We believe these two results are not contradictory. Although TE involves only input and output quantity, CE involves prices and allocations of input and output. Keiretsu insurers definitely have advantages in input prices such as a lower cost of capital because of their relationship with the main bank and other keiretsu member firms. Moreover, the technological advantage of NSIFs does not translate as a cost advantage, which leads NSIFs to be less successful than keiretsu firms in choosing a cost combination of inputs. Finally, NSIFs also lack any advantages of the specialization effect.

In comparison of SIFs and NSIFs, the results of the value-added approach suggest SIFs dominate NSIFs on both technology and cost frontiers. Regression analyses provide supplementary evidence that the specialization level explains most of the SIFs' dominance in TE, although, the advantages of specialization disappear when we include financial condition and return on assets in the analysis. These two seemingly contradictory results seem partly attributable to the relatively weak financial condition of SIFs and to different inputs and outputs. Our argument about the weak financial condition regarding TE of the SIFs is supported by the regression analyses (see Table 16).

In comparison of SIFs and keiretsu firms, the value-added approach indicates that SIFs dominate keiretsu firms in technology efficiency. Apparently, the specialization advantage inherent in SIF operation allows them to enjoy superior technology in their production frontier and to reach economies of scale faster. The regression analyses also confirm the dominance of SIFs in terms of different independent variables. The financial intermediary method, however, does not produce results indicating SIF dominance in terms of TE. Again, we believe that the stronger financial condition of keiretsu insurers might be the main reason for the different results. The results of the RAM version suggest that the keiretsu effect dominates the specialization effect. These different results must be attributable to the different methodologies of the cross-frontier method and RAM method, as the inputs and the outputs are the same. For example, the RAM approach uses a uniform set of weights. Using the value-added approach and the financial intermediary approach, the CE results in comparison of the

SIFs and keiretsu firms do not allow us to reject the null hypothesis that the efficiency of SIFs is different from the efficiency of keiretsu firms.

With all of the approaches, we are not able to consistently reject the null hypotheses that one form of organization structure is more efficient than another with one exception: Keiretsu firms seem to be more efficient than NSIFs in terms of CE. The advantages of keiretsu firms such as better monitoring, reduced information costs, and lower cost of capital dominate the advantage of independent firms such as no obligation to cross-subsidize other member firms.

The overall evidence seems to suggest that neither regulators nor stakeholders of keiretsu firms and SIFs need to worry about switching from one organizational form to another. The stakeholders of NSIFs, however, may want to pay more attention to their efficiency and reconsider their nonspecialization strategy.

Our examination of the productivity changes for different organizational forms shows that overall efficiencies of keiretsu firms, NSIFs, and SIFs deteriorate throughout our sample period (1985–1994). This is not a surprising finding for a sample over time when Japan suffered a financial crisis beginning in the late 1980s. The value-added approach provides results showing that keiretsu firms have more serious technical regress than independent firm, and within the independent firms, NSIFs define most of the regress. The results of productivity changes are strikingly different under the financial intermediary approach. This time we find that net technical changes of SIFs contribute most of the regress, likely because of the financial intermediary approach considers financial conditions.

When different inputs/outputs and methodologies provide different conclusions, researchers need to be careful about interpreting results. It may not be appropriate to use only one approach and to draw the conclusion from the results of that approach. We find both value-added and financial intermediary approaches are useful. The value-added approach provides insights into the TE and CE of different organizational forms in terms of number of policies and size of invested assets, and the financial intermediary approach provides insight into efficiency in terms of return on assets and the financial condition of the Japanese nonlife insurers.

APPENDIX

The nonparametric approach used in this article is based on the work of Farrell (1957) as well as Färe, Grosskopf, and Lovell (1985), Färe et al. (1994), and Cummins et al. (1999). The literature suggests that the efficiency of a firm consists of two components: "TE," which reflects the ability of a firm to obtain maximal output from a given set of inputs; and "allocative efficiency," (AE) which reflects the ability of a firm to use the inputs in optimal proportions given their prices. These two measures are then combined to provide a measure of "CE" (Coelli, 1996). All the three efficiency measures vary between 0 and 1 with an efficiency score of 1 implying full efficiency.

Technical Efficiency

The previous measures can be further illustrated in Figure A1 using a simple example involving a firm using two inputs (x_1 and x_2) to produce a single output (y). In an

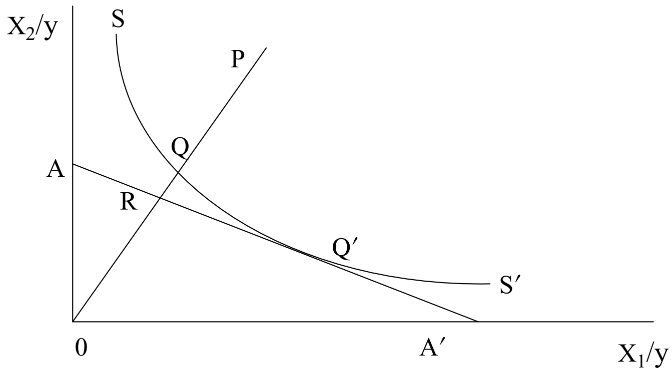

FIGURE A1
Technical Efficiency

input-oriented framework, the isoquant SS′ in Figure A1 represents the various combinations of the two inputs required to produce a fixed amount of the output. As firms using the best available technology are located on the isoquant, they are considered to be technically efficient. The TE of a firm always takes a value between 0 and 1, and a value of 1 indicates the firm to be fully technically efficient. If a given firm has input–output bundle defined by point P, the technical inefficiency of that firm is defined as the ratio of QP/0P, which stands for the percentage by which the firm could reduce its input by adopting the best technology. The TE then is represented by the ratio

$$\mathrm{TE} = 0Q/0P,$$

which equals to $1 - QP/0P$. Point Q is used as a technically efficient point as it lies on the efficient isoquant.

Allocative and Cost Efficiency

The input price ratio, represented by the isocost line AA′ in Figure A1, is also known as the AE of the firm operating at P is defined to be the ratio

$$\mathrm{AE} = 0R/0Q.$$

The distance RQ represents the reduction in production costs that would occur if the firm had operated at allocatively efficient point Q′, rather than at point Q. The total CE is then defined to be the ratio 0R/0P, and it turns out to be the product of TE and AE:

$$\begin{aligned}&\text{Technical Efficiency} * \text{Allocative Efficiency}\\&\quad = (0Q/0P) * (0R/0Q) = 0R/0P = \text{Cost Efficiency}.\end{aligned} \tag{A1}$$

In order to determine the CE, the linear programming (LP) technique is used. The first step is to calculate the minimum cost, MC, of producing the output of a particular firm. Specifically, for the multiple input–output situation the following LP problem is solved:

$$\begin{aligned} &\text{Min} && px_i^* \\ &\text{Subject to} && y_i \le \lambda Y \\ &&& x_i \ge \lambda X \\ &&& \lambda \in R_+. \end{aligned} \tag{A2}$$

In this problem, y is the m-dimensional vector of output produced by a particular firm; x_i is the n-dimensional vector of inputs used by a particular firm; Y is the $(k \times m)$ matrix of outputs where k represents the number of firms; X is the $(k \times n)$ matrix of inputs; λ is a $(m \times 1)$ vector of intensity parameters or weights attached to each observations in the determination of minimum cost; and p is the n-dimensional vector of input prices. The input values generated by the solution to the above problem (x_i^*) represent the minimum cost vector of input for the ith firm. The total CE of ith firm would then be calculated as

$$\text{CE} = px_i^*/px_i,$$

which is the ratio of minimum cost to observed cost. This ratio corresponds to 0R/0P in Figure A1.

A measure of TE is also developed using a second LP problem. The LP problem is stated as

$$\begin{aligned} &\text{Min TE} && y_i \le \lambda Y \\ &\text{subject to TE}* && x_i \ge \lambda X \\ &&& \lambda \in R_+. \end{aligned} \tag{A3}$$

In this problem, TE is a scalar with all of the other symbols as defined previously. For instance, in Figure A1 TE of point P responds to 0Q/0P. After TE and CE are calculated, AE is derived through Equation (1) as AE = CE/TE.

Cross-Frontier Distance Function

In this section, we review an approach called "cross-frontier efficiency method" which was advanced by Cummins et al. (1999). Through the estimation of cross-frontier distance function, this approach allows us to compute the efficiency of the firms in each ownership group with reference to the other group's production or cost frontier. The purpose of this approach is to help us examine whether each group's output vector could be produced with equal efficiency using the other group's technology.

We begin our discussion of cross-frontier distance function with the introduction of input-oriented distance function (Shephard, 1970). To illustrate the distance function, consider the firm operating at point (x_k, y_k) in Figure A2. Alhough x_k represents input of the keiretsu firm, y_k represents the output of the firm in period t, and V_k and V_i are the frontier of keiretsu and independent firms, respectively. Subscripts on D in the

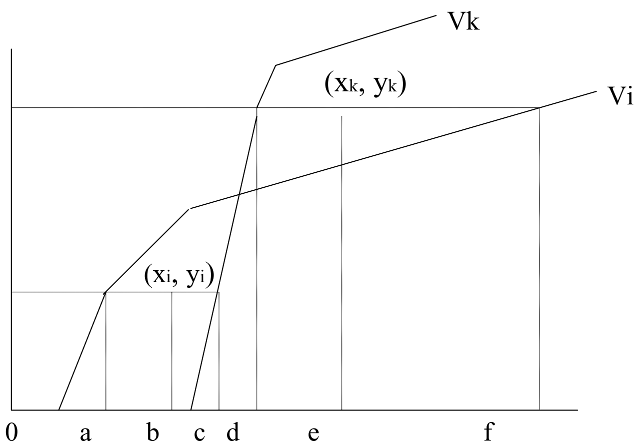

FIGURE A2
Keiretsu and Independent Frontiers

following distance functions indicate the reference set of firms used to construct the frontier. For example, $D_k(x_k, y_k)$ denotes the production point (x_k, y_k) with respect to the keiretsu frontier V_k. The distance function value for this firm relative to the keiretsu frontier is given by $D_k(x_k, y_k) = 0e/0d$. One can see that the measure of Farrell's TE of point $(x_k, y_k) = 0d/0e$, which happens to be the reciprocal of the input distance function of the specific point. Although TE of a production point is always ≥ 1, input distance function value is always ≤ 1.

However, input distance function "relative to the other group's function" is not necessarily always ≥ 1. This is the so-called "cross-frontier" distance function, and we illustrate it using the example of input distance function of a keiretsu firm (x_k, y_k) relative to the independent frontier V_i, $D_i(x_k, y_k)$ in Figure A2. For the specific production point (x_k, y_k), the distance value with respect to the independent frontier V_i is $0d/0c$, which is smaller than 1 as the independent frontier lies to the right of the point. It implies that this keiretsu firm has a technological advantage in producing in its output range. If the whole keiretsu group performs in the same way, it means the keiretsu firms are dominant in producing their outputs using their own technologies.

Evolution of Technical Efficiency and Technical Change

The concept of cross-frontier distance function originates from the Malmquist index approach (Malmquist, 1953). The Malmquist index is proposed to measure productivity change and becomes more applicable after extended by Färe and Grosskopf (1992). We illustrate the Malmquist index in Figure A3. Consider a firm operating at point (x^t, y^t), the distance function value for this firm relative to the frontier in time period t is $D^t(x^t, y^t) = 0a/0b$. The superscripts of the distance function (D) represent the time period of the frontier, whereas superscripts of input and output represent time of production. We compute the input distance function with respect to both time periods, t and $t+1$ to determine whether productivity change has occurred between

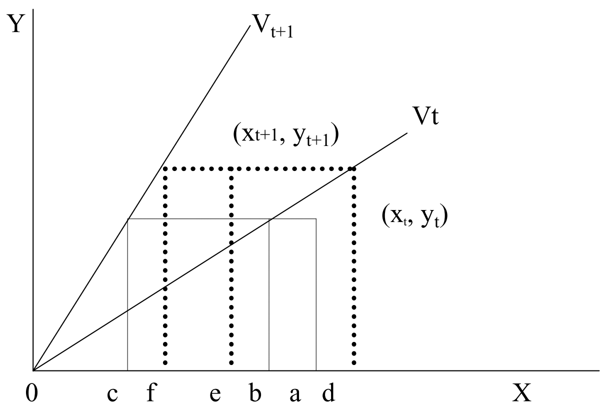

FIGURE A3
Productivity and Efficiency Change

periods t and $t + 1$. An input-oriented Malmquist productivity index with respect to the period t frontier (V^t) can be defined as

$$M^t = \frac{D^t(x^t, y^t)}{D^t(x^{t+1}, y^{t+1})}. \tag{A4}$$

And the input-oriented Malmquist productivity index with respect to the period $t + 1$ frontier (V^{t+1}) is

$$M^{t+1} = \frac{D^{t+1}(x^t, y^t)}{D^{t+1}(x^{t+1}, y^{t+1})}. \tag{A5}$$

To avoid arbitrarily choosing one frontier to compute the index, the input-oriented Malmquist productivity index is defined as the geometric mean of M^t and $M^{t\ +1}$:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D^t(x^t, y^t)}{D^t(x^{t+1}, y^{t+1})} \times \frac{D^{t+1}(x^t, y^t)}{D^{t+1}(x^{t+1}, y^{t+1})}\right]^{1/2}. \tag{A6}$$

This productivity index can be decomposed into two components, representing TE change, i.e., "change in Farrell TE between two periods," and technology change, i.e., "the shift in the frontier between the two periods." Efficiency change is the ratio of the distance from the frontier in period t to the distance in period $t + 1$, i.e., ((0a/0b)/(0e/0f)) in Figure A3. If the firm is closer to the present frontier in period $t + 1$ than it was in period t, as we see in Figure A3, the TE has improved between t and $t + 1$. The technology change, on the other hand, is a geometric mean of shifts in the frontier between periods t and $t + 1$, and is computed as follows:

Technology y Change

$$= \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^{t+1}, y^{t+1})} \times \frac{D^{t+1}(x^t, y^t)}{D^t(x^t, y^t)}\right]^{1/2} = \left[\left(\frac{0e/0f}{0e/0d}\right) \times \left(\frac{0a/0c}{0a/0b}\right)\right]^{1/2}. \tag{A7}$$

If technical improvement occurs, the frontier will shift to the left, and both ratios constituting the geometric mean will exceed 1. Thus, technical change value >1 implies technical progress and value <1 implies technical regress. A similar analysis can be conducted based on the cost frontier, leading to Malmquist indices for costs. All of the distance functions are measured by solving mathematical programming problems similar to Equation (A3).

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