

Studies on the Determinants of Efficiency in Taiwanese Life Insurance Industry - Application of Bootstrapped Truncated Model

Kuan-Chen Chen¹ and Chung-I Lin²

Abstract

Using 2009–2017 Taiwanese insurance company data from the database of Taiwan Economic Journal, we employ Simar–Wilson bootstrapping to prevent efficiency overestimation in data envelopment analysis (DEA) and then regress the factors on these efficiency scores by using a truncated rather than traditional Tobit model. Evidence shows that the companies' modified average efficiency score is 0.8784 (0.9068 using DEA). Meanwhile, domestic insurers outperform foreign insurers, and larger companies perform more poorly. Market share positively affects operational performance; performance improves over time. However, irrespective of whether insurer is a subsidiary of financial holding company or domestic company in Taiwan, operational performance is not statistically different. Finally, we find that traditional Tobit regression underestimates the marginal effects of explanatory variables.

JEL classification numbers: C34, D24, G22

Keywords: data envelopment analysis, bootstrap procedure, truncated regression model, technical efficiency

¹ Assistant Professor, Department of Health Care Management, National Taipei University of Nursing and Health Sciences, Taipei City, Taiwan.

² Assistant Professor, Department of International Business, Providence University, Taichung City, Taiwan, Correspondent Author.

1. Introduction

According to the most recent insurance market index of Taiwan, published by the Insurance Bureau of the Financial Supervisory Commission in October 2018, the total assets of the Taiwanese life insurance industry soared after the global financial crisis, from approximately NT\$ 10 trillion in 2009 to NT\$ 24 trillion in 2017. The life insurance industry now contributes more to the total assets of all financial institutions, increasing from 23.99% of all assets in 2009 to 33.11% in 2017. Moreover, the insurance penetration rate (the total insurance premium as a percentage of the gross domestic product) greatly increased from 15.48% in 2009 to 19.62% in 2017, which is the highest of all countries and much higher than that of the countries with the second and third highest rates—Hong Kong (14.58%) and South Africa (11.02%). Furthermore, the insurance density (insurance premium per capita) has increased from NT\$86,790 in 2009 to NT\$145,105 in 2017, the third highest density worldwide. Global interest rate declines and an aging population have caused the most common life insurance products in Taiwan to change from high-return policies to investment-linked and various annuity policies (Lee, Shyu, and Chiu 2017). The insurance industry is different from other financial service industries³ in that its risk is shared with policyholders and that it enhances the social safety net. The economic growth of Taiwan has made its citizens more aware of the importance of having a comprehensive insurance plan tailoring to their individual needs on top of having a basic insurance plan. Because of the uniqueness of the life insurance industry in Taiwan, there is value in investigating its operational performance and determinants for the benefit of concerned authorities, industries, and academia worldwide. Such investigations might aid decision making in institutions and enable governments to establish more comprehensive regulations and more friendly environments for relevant industries.

The diversity of financial products has changed how scholars analyze the efficiency and productivity of financial institutions; specifically, traditional methods, which involve a single type of financial ratio analysis, have been replaced by frontier analyses, which incorporate multiple outputs and inputs. An efficient frontier is determined using the operational performance of all sample companies and indicates the highest achieved efficiency. This frontier can be employed to assess the efficiency of companies that are behind the frontier, and the assessment may serve as a reference for improving future production decisions. The most widely used analyses in relevant studies are the nonparametric (linear programming) data

³Genetay and Molyneux (1998) suggest that banks and insurers share various characteristics and supplement each other but have differences in operational activities, particularly fund management and risk retention. Banks actively attract deposits from the public, provide general payment and foreign exchange services, loan idle funds to individuals or enterprises that have short- or medium-term funding needs, and provide hedge fund management services. By contrast, insurers gain insurance premiums, use these funds to make medium- and long-term investments, and assume the risk of possible loss of life and asset insurance policyholders, thus forming part of the social safety net.

envelopment analysis (DEA) and parametric (statistical computing) stochastic frontier analysis (SFA). Because DEA does not require the assumption of production functions or calculation of combined errors, it is more frequently used. However, for subsequent studies on efficiency scores and their determinants, Simar and Wilson (2007) asserted that the use of a Tobit regression model can lead to biased estimates of operational efficiency because the efficiency scores generated using DEA do not have characteristics of the latent variables and because the values are autocorrelated. Therefore, Simar and Wilson recommend that the bootstrap approach, called SW bootstrap, is first used to generate bias-corrected efficiency scores, after which a truncated regression model is employed to identify possible determinants. Efficiency scores generated using the combination of a Simar and Wilson bootstrap method and truncated models have been applied mostly in studies discussing the banking industry but rarely in studies related to the insurance industry. To fill this research gap, the present study uses an SW bootstrap approach to calculate modified DEA efficiency scores and employs a truncated regression model to identify the determinants of operational efficiency.

This paper is organized as follows. Section 1 explains the research background and motives; Section 2 reviews the domestic and foreign studies discussing the efficiency of the life insurance industry; Section 3 presents the study's research methods; Section 4 elaborates upon the data and variable selections; Section 5 presents the empirical results and analyses; and Section 6 concludes.

2. Literature Review on the Efficiency of Life Insurance Providers

Berger and Humphrey (1997), Eling and Luhn (2010), Cummins and Weiss (2013), and Wise (2017) have provided comprehensive and clear research frameworks in international journals for analyzing the insurance industry's efficiency. Recently, Kaffash et al. (2019) further survey 132 insurance performance related articles published in the period spanning from 1993 to 2018 and they classified them into 18 distinct study fields for future studies. Initially, foreign studies predominantly focused on the efficiency of insurance industry in developed Western countries. In studies on American insurance providers, Cummins and Zi (1998) use SFA and DEA to determine the efficiency of 445 American life insurance companies from 1988 to 1992 and discover that the efficiency rankings obtained using the two analysis approaches are not substantially different. Cummins, Tennyson, and Weiss (1999) employ DEA to discuss changes in the relationship between the efficiency and size of American life insurance companies after mergers and acquisitions from 1988 to 1995, and they use the Malmquist index to determine the productivity change of these companies over the research period. Greene and Segal (2004) adopt SFA to simulate the management performance of 136 American life insurance companies from 1995 to 1998 and reveal that cost inefficiency is negatively correlated with indicators of profitability (e.g., return on assets). Regarding studies on European insurance companies,

Hardwick (1997) use SFA to investigate the cost efficiency performance of 54 British life insurance companies under a competitive industrial environment from 1992 to 1996. Fenn et al. (2008) employ the Fourier flexible cost function, which uses few constraints, in SFA to simulate the cost efficiency of 14 European life insurance and asset insurance companies from 1995 to 2001; the returns to scale increased for most of the European insurance companies, and increases in an insurance company's size and domestic market share significantly increased its cost inefficiency. Barros, Nektarios, and Assaf (2010) integrate two-stage DEA with a modified approach proposed by Simar and Wilson (2007) to investigate the effect of liberalization on the efficiency of Greek insurance companies in 1994–2003; increasing company size and market share through mergers was the main determinant of efficiency improvement, and life insurance companies which were large, listed on the stock exchange, and had undergone a merger did demonstrate higher management efficiency.

In research related to the efficiency of insurance companies and conducted over the last decade, scholars have begun to assess the performance of insurance industries in developing countries. For example, Gaganis, Hasan, and Pasiouras (2013) use SFA to discuss the effect of efficiency on stock returns in 399 insurance companies listed on the stock exchange or traded over-the-counter in 52 countries between 2002 and 2008. Stock returns were positively correlated with company profitability but not with stock returns. Huang and Eling (2013) employ bootstrap DEA to examine the management performance of asset insurance companies in the BRIC countries (namely Brazil, Russia, India, and China) from 2000 to 2008; asset insurance companies in Brazil had the highest technical efficiency, pure technical efficiency, and scale efficiency. Lu, Wang, and Kweh (2014) apply a slack-based measure (SBM) to discuss the operational performance of 34 Chinese life insurance companies in 2006–2010; their empirical results suggest that investments in intellectual capital (comprising human, structural, and financial capital) improved the overall operational performance of the asset insurance companies.

The operational performance of the life insurance industry in Taiwan, which is also a developing country, has been discussed predominantly in domestic journals⁴ but rarely in international journals. Hwang and Kao (2006) and Kao and Hwang (2008) employ two-stage DEA to investigate the management efficiency of Taiwanese life insurance companies. Other studies assessing the performance of the Taiwanese life insurance industry are as follows. Hao and Chou (2005) investigate the average cost efficiency of Taiwanese life insurance companies in 1977–1999. The following

⁴These studies are as follows: Liu (1994), Liu and Lee (1995), Chang (1999), Yeh and Chen (2000), Lee (2001), Hwang and Wu (2001), Hao and Chou (2003), Wang, Peng, and Chang (2006), Huang et al. (2010), Lu, Wang, and Lee (2011), Shyu and Hsu (2011), Hu, Yu, and Lin (2012), and Peng, Chen, and Liu (2014). In particular, studies related to the determinants of insurance company efficiency have focused on how such efficiency is influenced by the following factors: ownership, bancassurance involvement, market share type, product concentration, whether a company is a financial holding company, company type (domestic or foreign), total assets, and year dummies (Wang, Peng, and Chang 2006; Peng, Cheng, and Liu 2014).

findings are obtained: the companies had an average cost efficiency of 0.66; an increase in company market share resulted in an increase in profits; and product diversity was uncondusive to improving cost efficiency. Huang, Hsiao, and Lai (2007), Wang, Jeng, and Peng (2007), and Jeng and Lai (2008) explore the effects of liberalization and company operation on the operational performance of Taiwanese insurance companies. The findings reveal that the old and family-owned insurance companies had higher operational efficiency; moreover, higher ownership centralization was associated with lower performance, and company size was not related to performance. Studies related to liberalization have revealed that new insurance companies initially have high efficiency, but their cost efficiency and profitability do not improve significantly in the following years. These studies recommend that future market entry strategies in the Taiwanese insurance industry focus on the merging and acquisition of existing companies rather than the establishment of new companies.

Studies reinvestigating the efficiency of Taiwanese insurance companies have begun to be published in international journals, in particular, discussions of market structure, risk management, and management performance. Chuang and Tang (2015) use data on life insurance companies in Taiwan for 1976–2010 as their research data set and identify a nonlinear relationship between the market share and efficiency of these companies, arguing that increases in market share did not improve company performance. Chuang and Tang also find that the domestic life insurance companies with large market share had higher efficiency than the foreign life insurance companies with small market share. Hu and Yu (2015) employ the data of 27 Taiwanese life insurance companies in 2004–2009 and stochastic cost frontier analysis to determine the relationships between asset risk, product risk, capital, and management performance. The following findings are obtained by Hu and Yu: Taiwanese life insurance companies had an average cost efficiency of 0.67; companies with lower efficiency were more likely to invest in products with high risk; companies with higher efficiency were more likely to maintain a high capital level as capital buffers; and asset risk had negative effects on capital and management inefficiency. Lee, Shyu, and Chiu (2017) emphasize the importance of an insurance company's solvency and use a dynamic network SBM to discuss the efficiency of Taiwanese insurance companies from 2006 to 2013. Insurance claims are used as inputs, investments are categorized as high or low risk, and return on assets is employed as a carryover variable. The empirical results of Lee, Shyu, and Chiu (2017) show that the overall performance of the Taiwanese insurance companies was higher than that of the foreign insurance companies located in Taiwan, but that these foreign companies had more favourable performance in insurance underwriting, fund management, and claim management; moreover, the efficiency of the insurance companies was predominantly achieved through merging with financial holding companies (FHCs).

3. Research Methods

DEA does not require assumptions regarding production, cost, or profit functions or calculation of combined errors. Linear programming is employed to calculate the optimal solutions and obtain the efficient frontier, against which gap analyses are conducted for assessing the performance of companies. Therefore, DEA has become one of the most frequently used frontier analysis tools. Farrell (1957) proposes the simplest concept of technical efficiency, which is that for a single input or output. Charnes, Cooper, and Rhodes (1978) and Banker, Charnes, and Cooper (1984) develop multi-input–multioutput analysis models assuming constant returns to scale (CCR model) and variable returns to scale (BCC model), respectively. In particular, the BBC model loosens the CCR model’s constraints of constant returns to scale (with a convexity constraint added, namely $\sum \lambda = 1$) and separates technical efficiency into pure technical efficiency and scale efficiency. The BCC model comprises output-oriented and input-oriented models, the choice between which is determined by a manager’s power to adjust and control either output or input. When a manager controls or adjusts the level of output for a given level of input, an output-oriented model should be used; by contrast, when a manager controls or adjusts the level of input during the production process, an input-oriented model should be used.

Because an insurance company’s management has much greater control over input resources than the company’s target output and we are investigating companies without the constraint of constant returns to scale, the conventional BCC model is used in this study to assess the efficiency of Taiwanese life insurance companies. Moreover, to prevent the efficiency overestimation that can occur using the conventional method, an algorithm developed by Simar and Wilson (2007) is employed to correct biased efficiency scores. Subsequently, we construct a bootstrap truncated regression model; maximum likelihood estimation (MLE) is used to estimate parameters, and the bootstrap method is employed to establish a confidence interval for the regression coefficients, thus reducing the estimation errors and obtaining efficiency values closer to the actual values. The following presents an overview of two-stage DEA:

Step 1: The linear programming setting of the input-oriented DEA-BCC model (with a convexity constraint) is used to obtain the uncorrected efficiency scores.

$$\min_{\theta, \lambda} \theta,$$

Such that

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\sum \lambda = 1$$

$$\lambda \geq 0,$$

Step 2: Bootstrap truncated regression model

This study uses a bootstrap truncated regression model to determine how the environmental factors (X_i) of the second stage affect the efficiency scores.

Let $TE_i^* = constant + \beta_i X_i + \epsilon_i$,
 where $i = 1, 2, \dots, n$; $\epsilon_i \sim N(0, \sigma^2)$;
 and $TE_i = TE_i^*$ for all TE_i^* .

The likelihood function is as follows:

$$L = \prod_i^n \frac{1}{\sigma} \phi\left(\frac{TE_i - \beta_i X_i}{\sigma}\right) \left[1 - \Phi\left(\frac{TE_i - \beta_i X_i}{\sigma}\right)\right],$$

where $i = 1, 2, \dots, n$ and $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability and cumulative distribution functions, respectively.

The maximum likelihood function is used to obtain an estimate:

$$\widehat{TE}_i = constant + \widehat{\beta}_i X_i, \text{ where } i = 1, 2, \dots, n$$

Simar and Wilson (2007) suggest that efficiency scores estimated using conventional DEA to conduct determinant analysis in the Tobit regression model may be biased because DEA-obtained efficiency scores do not exhibit the characteristics of latent variables (data-generating process excessively concentrated at 1) and the scores are autocorrelated. Therefore, the authors recommend the use of the bootstrap approach to modify the estimates and thus obtain unbiased efficiency scores before using the truncated regression model to investigate the various determinants of the efficiency. We use the second algorithm developed by Simar and Wilson (2007) to modify the biased efficiency scores that can be obtained using conventional methods. We then establish a bootstrap truncated regression model; parameters are estimated using MLE and a confidence interval is determined for the regression coefficients by using a bootstrap method.

Step 3: Procedure of the bootstrap method for efficiency score modification

1. The inputs and outputs of all decision-making units (DMUs) are used to estimate \widehat{TE}_i ($i = 1, 2, \dots, n$).
2. The inefficient DMUs are input to the MLE function to obtain a regression model $\widehat{TE}_i = \beta' X_i + \epsilon_i$. The model is left-truncated at $(1 - \beta' X_i)$; $\widehat{\beta}$ and $\widehat{\sigma}_\epsilon$ are parameters; and ϵ_i is a random residual equal to $N(0, \sigma_\epsilon^2)$.
3. The following four steps (3.1–3.4) are performed L_1 times to obtain N bootstrap estimates ($\xi_i = \{\widehat{TE}_{ib}^*\}_{b=1}^{L_1}$):

- 3.1 An ε_i^* is randomly selected for each DMU (represented by i ; $i = 1, 2, \dots, n$) under a normal distribution $N(0, \hat{\sigma}_\varepsilon^2)$, with left-truncation at $(1 - \hat{\beta}'X_i)$.
- 3.2 $TE_i^* = \hat{\beta}'X_i + \varepsilon_i^*$ is calculated for each DMU i .
- 3.3 $I_i^* = I_i \times (TE_i^*/\widehat{TE}_i)$ and $O_i^* = O_i$ is constructed for each DMU i .
- 3.4 The $I^* = (I_1^*, \dots, I_n^*)$ and $O^* = (O_1^*, \dots, O_n^*)$ constructed in (3.3) is employed to estimate $\widehat{TE}_i^*(I_n, O_n)$.
4. For each DMU i , a corrected estimate $\widehat{TE}_i = \widehat{TE}_i - \widehat{BIAS}(\widehat{TE}_i)$ is calculated, where $\widehat{BIAS}(\widehat{TE}_i) = E(\widehat{TE}_i) - TE_i$ is the bootstrap estimate ($\{\widehat{TE}_{ib}^*\}_{b=1}^{L_1}$) obtained in (3.4) and \widehat{TE}_i is the initial estimate.
5. MLE is employed to estimate the parameters $\widehat{\beta}'$ and $\widehat{\sigma}_\varepsilon^*$ of the left-truncated regression model $\widehat{TE}_i = \widehat{\beta}'X_i + \omega_i$.
6. The following three steps (6.1–6.3) are performed L_2 times to generate a set of bootstrap estimates $\Lambda = \{(\hat{\beta}^*, \hat{\sigma}_\varepsilon^*)_b\}_{b=1}^{L_2}$.
- 6.1 An ε_i^{**} is randomly selected for each DMU i under a normal distribution $N(0, \widehat{\sigma}_\varepsilon^2)$, with left-truncation at $(1 - \hat{\beta}'X_i)$.
- 6.2 $TE_i^{**} = \hat{\beta}'X_i + \varepsilon_i^{**}$ is calculated for each DMU i .
- 6.3 MLE is employed to estimate the parameters $\hat{\beta}^*$ and $\hat{\sigma}_\varepsilon^{**}$ of the left-truncated regression model $TE_i^{**} = \hat{\beta}'X_i + \omega_i$.
7. A confidence interval is constructed for the parameters with the set of bootstrap estimates $\{(\hat{\beta}^*, \hat{\sigma}_\varepsilon^{**})_b\}_{b=1}^{L_2}$ obtained in Step 6 and the initial estimates $(\hat{\beta}, \hat{\sigma}_\varepsilon)$.

4. Selection of Data and Variables

This study employs data covering the period 2009–2017 and extracted from the Taiwan Economic Journal database and Annual Report of Life Insurance published by the Life Insurance Association of the Republic of China. After excluding life insurance companies that provide limited information, we select 29 insurance companies and obtain a total of 189 observation values for empirical analysis. The most suitable inputs and outputs for use in institutional efficiency assessment have been highly debated and strongly affect the results of such assessments. The most widely used methods of variable selection are the asset (or intermediation), production (or value-added), and user–cost approaches. Cummins and Weiss (2013) argue that the production (value-added) approach is the most recognized and accepted approach in studies related to the efficiency of insurance companies. Accordingly, we select the production approach for our analysis.

Human resources are among the most crucial inputs in life insurance companies because such companies depend on their back-office staff to design insurance policies and on their salespeople to sell policies; therefore, this study uses number

of staff as an input variable. In accordance with Cummins, Tennyson, and Weiss (1999), we also employ debts and owner’s equity as input variables, because the life insurance industry is underpinned by debt-oriented business models and a company owner’s equity can offset insurance claims that exceed the expected amount. In summary, this study adopts three input variables: number of employees, debt, and owner’s equity. Regarding output variables, Cummins and Weiss (2013) recommend replacing income from premiums with incurred benefits and addition to reserves as output variables. The addition to reserves is negative when the reserves in the present year are lower than those in the preceding year, and negative values should be disregarded to proceed with estimation. However, to prevent any useful information being overlooked when disregarding values, we follow Fukuyama (1997) and combine incurred benefits and addition to reserves into one single output. Moreover, insurance companies boost their assets by investing their premium income in domestic or foreign investment products, profiting from the difference between the assumed interest rate and market interest rate; investments are thus also an essential output of insurance companies (Cummins and Xie 2008; Leverty and Grace 2010). Accordingly, the present study adopts two output variables: insurance benefits and addition to reserves (Y1) and total investment value (Y2).

This study incorporates the aforementioned input and output variables into the two-stage DEA approach proposed by Simar and Wilson (2007); we correct biased DEA estimates and use a two-stage bootstrap truncated regression model to further assess the determinants of the operational performance of our sample companies. The determinants are whether a company is a subsidiary under an FHC or an independent company (Z1), whether it is a domestic or foreign company (Z2), its market share (Z3), and its total assets (Z4). Market share refers to the percentage of a company’s premium income to the total premium income of the market in a given year.

5. Empirical Results

Table 1 presents the inputs, outputs, and basic statistics of regression outputs of the sample companies. The nominal inputs and outputs are deflated by the consumer price index, using 2016 as the base year, to eliminate the effects of price fluctuations on the price-related variables. We categorized our sample companies into life insurance companies that are an FHC subsidiary or not and domestic or foreign. The descriptive statistics of the sample companies are displayed in Tables 2 and 3. For the data spanning 2009–2017, 61 observation values come from subsidiaries of FHCs and 128 from subsidiaries of non-FHCs; 136 observation values are obtained for domestic and 53 for foreign life insurance companies. The Taiwanese life insurance subsidiaries under FHCs are larger than those under non-FHCs or independent life insurance companies. Moreover, the domestic life insurance companies are far larger than the foreign life insurance companies. Regarding the regression coefficients, the life insurance subsidiaries of FHCs have higher average

market share (20.99%) than those of non-FHCs (5.7%); the domestic life insurance companies have higher market share (14.25%) than the foreign life insurance companies (1.53%). Additionally, the insurance subsidiaries of FHCs have much greater total assets than the independent life insurance companies, and the domestic life insurance companies have substantially greater total assets than the foreign life insurance companies.

Table 1. Statistics of input and output variables for all sample life insurance companies.

Variable	Mean	Standard error	Minimum	Maximum
Input variables				
Number of employees	5960	9304	44	39822
Debt	708,000,000	1,100,000,000	4,854,673	5,590,000,000
Owner's equity	117,000,000	74,300,000	1	513,000,000
Output variables				
Incurred benefits and addition to reserves	111,000,000	174,000,000	66,842	777,000,000
Total investments	549,000,000	886,000,000	77,882	4,460,000,000
Regression variables				
Market share	0.1069	0.1652	0.0002	0.7864
Total assets	745,000,000	1,180,000,000	5,384,896	6,020,000,000
Note: A total of 189 observation values are extracted for the sample companies.				

Table 2. Statistics of input and output variables for life insurance subsidiaries of FHCs and non-FHCs.

Variable	FHCs		Non-FHCs	
	Mean	Standard error	Mean	Standard error
Input variables				
Number of employees	10728	13546	3688	5033
Debt	1,380,000,000	1,500,000,000	389,000,000	646,000,000
Owner's equity	162,000,000	106,000,000	95,100,000	36,600,000
Output variables				
Incurred benefits and addition to reserves	218,000,000	228,000,000	60,200,000	110,000,000
Total investments	1,080,000,000	1,170,000,000	298,000,000	569,000,000
Regression variables				
Market share	0.2099	0.2241	0.0577	0.0955
Total assets	1,460,000,000	1,610,000,000	404,000,000	680,000,000
Notes:				
1. A total of 61 observation values are collected for life insurance subsidiaries of FHCs				
2. A total of 61 observation values are collected for life insurance subsidiaries of non-FHCs				

Table 3. Statistics of input and output variables of domestic and foreign life insurance companies

Variable	Domestic		Foreign	
	Mean	Standard error	Mean	Standard error
Input variables				
Number of employees	7598	10458	1758	2009
Debt	918,000,000	1,230,000,000	171,000,000	232,000,000
Owner's equity	129,000,000	84,500,000	85,600,000	6,237,504
Output variables				
Incurred benefits and addition to reserves	146,000,000	190,000,000	21,800,000	67,400,000
Total investments	723,000,000	984,000,000	102,000,000	205,000,000
Regression variables				
Market share	0.1425	0.1823	0.0153	0.0220
Total assets	967,000,000	1,310,000,000	177,000,000	238,000,000
Notes:				
1. A total of 136 observation values are collected for domestic life insurance companies				
2. A total of 53 observation values are collected for foreign insurance companies				

This study uses the specified input and output variables to assess the performance of insurance institutions, and the findings are presented in Table 4. Panel A of Table 4 details the efficiency scores obtained using the two-stage DEA proposed by Simar and Wilson (2007). The average efficiency score is 0.8784. For a given level of output, the management in Taiwanese life insurance companies should aim to reduce their production inputs by 12.16% to obtain a production portfolio on the efficient frontier. Allianz has the lowest efficiency score (0.4482), whereas Yuanta Financial has the highest (0.9825). The average efficiency score of the life insurance subsidiaries of FHCs (0.8820) is slightly higher than that of the life insurance subsidiaries of non-FHCs (0.8766). The domestic life insurance companies have a higher average efficiency score (0.8857) than the foreign life insurance companies (0.8596). Accordingly, the operational performance of Taiwanese life insurance subsidiaries under FHCs is overall more favorable than that of subsidiaries of non-FHCs, and that of domestic life insurance companies is more favorable than that of foreign life insurance companies. For comparison, Panel B in Table 4 presents the

efficiency scores obtained using conventional DEA. The results indicate that not correcting the efficiency scores results in overestimation of performance, though the observations are consistent with those in previous studies. All of the uncorrected efficiency scores, obtained using conventional DEA are higher than the modified efficiency scores. The present study uses the Mann–Whitney U test to determine the difference between the efficiency scores obtained using the two models. The result indicates significant differences ($p < 0.0001$) when all samples are considered, and the differences for the various sample groups are also significant ($p < 0.05$). Accordingly, the two-stage DEA developed by Simar and Wilson (2007) is found to reduce the bias in efficiency estimations obtained using conventional DEA.

Table 4. DEA efficiency scores

	Mean	Standard error	Minimum	Maximum	* <i>p</i> value
Panel A Bias-corrected efficiency scores					
All sample	0.8784	0.0923	0.4482	0.9825	<0.0001
FHCs	0.8820	0.0687	0.7449	0.9825	0.0014
non-FHCs	0.8766	0.1018	0.4482	0.9817	0.0029
Domestic	0.8857	0.0627	0.7051	0.9825	0.0001
Foreign	0.8596	0.1417	0.4482	0.9817	0.0137
Panel B Conventional DEA efficiency scores					
All sample	0.9068	0.0973	0.4705	1.0000	
FHCs	0.9191	0.0769	0.7665	1.0000	
non-FHCs	0.9010	0.1054	0.4705	1.0000	
Domestic	0.9159	0.0709	0.7151	1.0000	
Foreign	0.8835	0.1428	0.4705	1.0000	
Note: * refers to <i>p</i> values comparing the two models according to the Mann–Whitney U test					

Figure 1 illustrates the average DEA efficiency score of the sample companies and reveals that the average efficiency score obtained using conventional DEA has the same trend but higher values than that obtained using two-stage DEA (Simar and Wilson 2007). This indicates that obtained uncorrected efficiency scores leads to overestimation of performance. The average bias-corrected efficiency scores slightly increase between 2009 and 2011, after which they begin to decrease, perhaps because of the European debt crisis in 2010–2012. The scores then increase from 2013 until 2016, after which they slightly decline. Figure 2 compares the average efficiency scores of the life insurance subsidiaries of FHCs and non-FHCs. The average efficiency score of the subsidiaries under non-FHCs decreases after 2011 but fluctuates little overall. By contrast, the average score of the life insurance subsidiaries under FHCs increases over the entire period, indicating that these companies were not directly affected by the European debt crisis. The data for

Fubon Insurance (a subsidiary of Fubon Financial) show that they had an investment of 0.27 million Euros (approximately NT\$10.8 million) in Spanish government debt in 2011, explaining why they were the first Taiwanese insurance company to be directly affected by the crisis. Other medium and large insurance companies, such as Cathay Life Insurance, Shin Kong Life, China Life, and Taiwan Life Insurance, did not invest in European government debt and were thus not directly affected by the crisis. The comparison between the average efficiency scores of the domestic and foreign life insurance companies, illustrated in Figure 3, shows that the efficiency of the domestic companies increases relatively stably, whereas that of the foreign companies decreases from 2010 until 2013, after which it is stable. This result suggests that the European debt crisis had a greater effect on foreign than domestic life insurance companies. Figures 2 and 3 show that subsidiaries under non-FHCs initially had higher performance than those under FHCs and that foreign life insurance companies initially performed better than domestic life insurance companies. After 2012, the subsidiaries under FHCs and domestic life insurance companies began to exhibit higher performance than their counterparts and have become more efficient since. Overall, the European debt crisis had stronger negative effects on foreign life insurance companies and subsidiaries under non-FHCs.

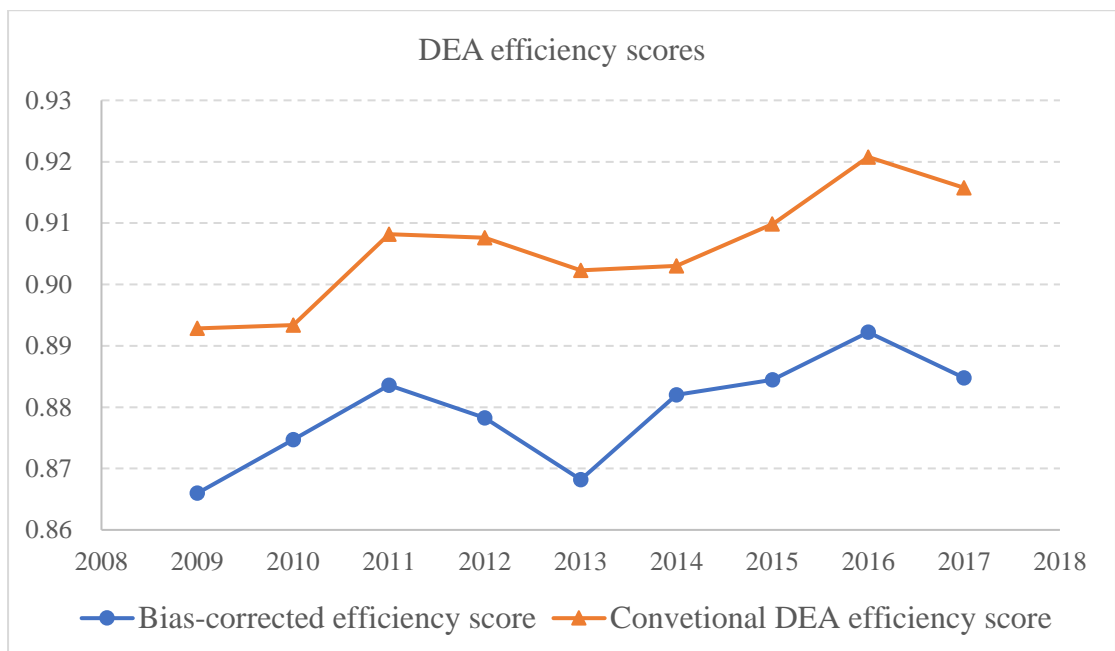


Figure 1. Trend in average DEA efficiency score of Taiwanese life insurance companies in 2009–2017.

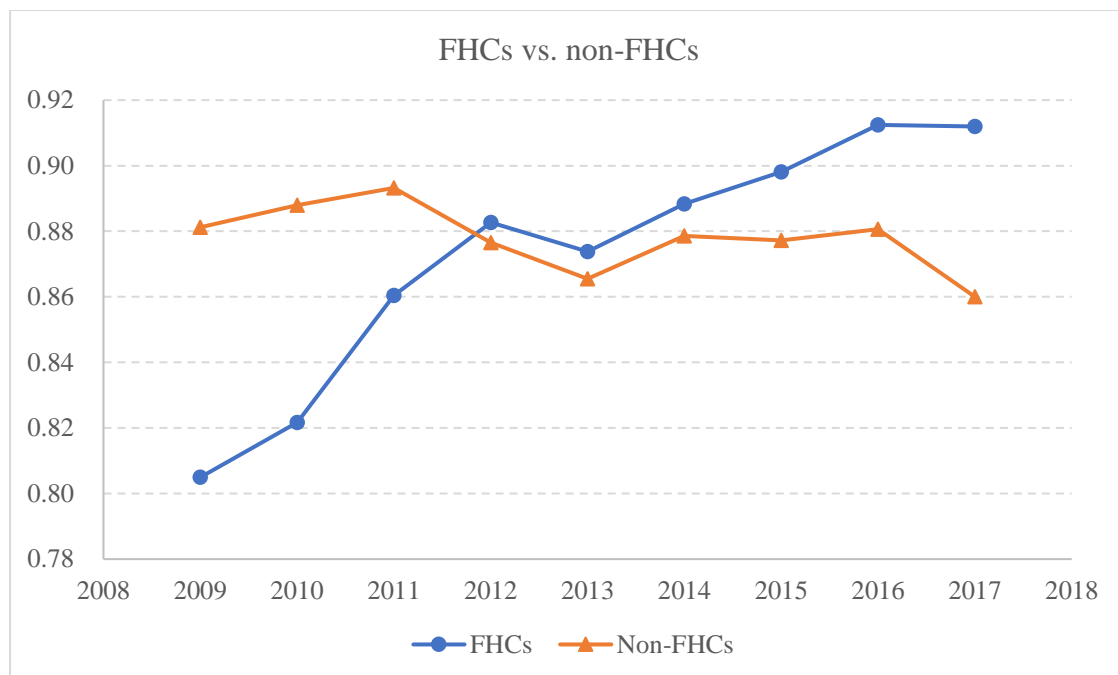


Figure 2. Trend in average DEA efficiency score of Taiwanese life insurance subsidiaries of FHCs and non-FHCs in 2009–2017.

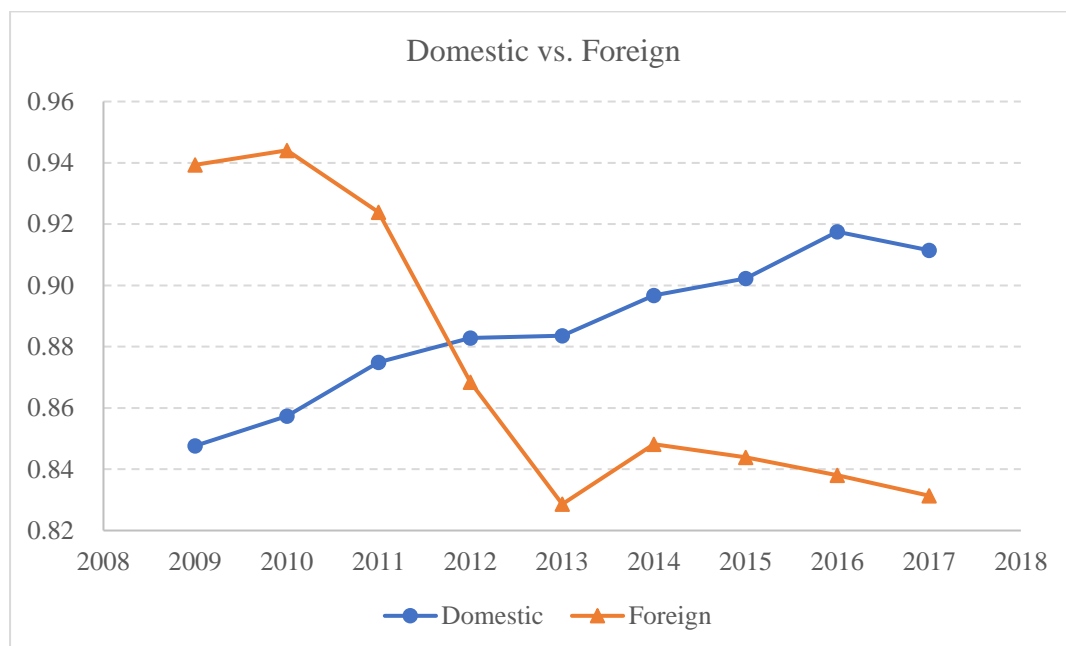


Figure 3. Trend in average DEA efficiency score of Taiwanese and foreign life insurance companies in 2009–2017.

This study further identifies the determinants of the efficiency of life insurance companies, with estimates of the bootstrap truncated regression model presented in Table 5. The results in Panel A are obtained under the consideration of only one variable, namely whether a company is a subsidiary of an FHC; the results in Panel B are obtained under the consideration of only whether a company is domestic; the results in Panel C are obtained under the consideration of both these variables in the regression model; and the results in Panel D included a time trend in the model. According to Table 5, the model considering subsidiary status has a positive regression coefficient but no significance (Panel A); that considering whether a company is domestic has a positive coefficient and significance (Panel B); and the model with both variables has a positive coefficient and significance (Panel C). These results imply that domestic life insurance companies have superior operational performance to their foreign counterparts. Total assets have a negative regression coefficient and significance, indicating that larger companies are less technically efficient. This might be explained by the more departments, employees, equipment, and resources in large life insurance companies (Table 2); inefficient resource utilization can easily occur under poor management. Market share has a positive regression coefficient and significance, meaning that a larger market share results in higher operational performance, which is in agreement with market power theory (Berger 1995). This theory proposes that a higher market share indicates greater control over market price, greater earnings power, and higher operational performance. In panel D results, a positive significant coefficient was found for the time trend variable suggesting an increase in efficiency over time. To sum up, the results for coefficient of FHC or Domestic firms do not change regardless of whether market share, total assets or time trend is considered.

Table 5. Estimates of the bootstrap truncated regression model (control variables: market share and total assets)

	Observational coefficient	Bootstrap corrected SD	95% confidence interval	
Panel A				
Intercept	2.1138***	0.3868	1.4839	3.0021
FHC or non-FHC	0.0363	0.0373	-0.0303	0.1150
Market share	0.3473**	0.1732	0.0416	0.7361
Total assets	-0.0616***	0.0196	-0.1055	-0.0288
Panel B				
Intercept	2.1367***	0.3534	1.5465	2.9368
Domestic or Foreign	0.1109***	0.0377	0.0383	0.1921
Market share	0.3097**	0.1544	0.0624	0.6586
Total assets	-0.0665***	0.0183	-0.1075	-0.0356
Panel C				
Intercept	2.1360***	0.3439	1.5304	2.8957
FHC or non-FHC	-0.0026	0.0376	-0.0734	0.0743
Domestic or Foreign	0.1123***	0.0385	0.0405	0.1927
Market share	0.3130*	0.1539	0.0415	0.6482
Total assets	-0.0665***	0.0180	-0.1065	-0.0345
Panel D				
Intercept	2.3113***	0.3551	1.6719	3.0756
FHC or non-FHC	-0.0324	0.0372	-0.1045	0.0457
Domestic or Foreign	0.1370***	0.0398	0.0575	0.2158
Market share	0.4959***	0.1657	0.1821	0.8398
Total assets	-0.0824***	0.0194	-0.1253	-0.0471
Time	0.0196***	0.0070	0.0061	0.0340

The results obtained using the SW two-stage bootstrap truncated regression model (Table 5) and conventionally employed Tobit regression model (Table 6) are compared. We discover that the two models have similar regression coefficients and significance, but the coefficients in the Tobit model are smaller than those in the bootstrap model. In summary, domestic life insurance companies have higher operational performance than foreign life insurance companies; larger life insurance companies are less efficient; high market share is correlated with higher operational performance in domestic life insurance companies; and life insurance subsidiaries of FHCs and non-FHCs do not exhibit significantly different performance.

Table 6. Estimates of the conventional Tobit regression model

	Observational coefficients	Bootstrap corrected SD	95% confidence interval	
Panel A				
Intercept	1.3049***	0.1239	1.0604	1.5494
FHC or non-FHC	0.0194	0.0162	-0.0126	0.0514
Market share	0.1714**	0.0685	0.0362	0.3066
Total assets	-0.0219***	0.0067	-0.0352	-0.0087
Panel B				
Intercept	1.3667***	0.1234	1.1233	1.6102
Domestic or foreign	0.0493***	0.0164	0.0168	0.0817
Market share	0.1854***	0.0649	0.0573	0.3136
Total assets	-0.0267***	0.0068	-0.0401	-0.0133
Panel C				
Intercept	1.3654***	0.1235	1.1217	1.6091
FHC or non-FHC	0.0039	0.0169	-0.0294	0.0373
Domestic or foreign	0.0479***	0.0174	0.0135	0.0824
Market share	0.1813***	0.0673	0.0485	0.3141
Total assets	-0.0267***	0.0068	-0.0401	-0.0132
Panel D				
Intercept	1.4694***	0.1255	1.2219	1.7170
FHC or non-FHC	-0.0098	0.0171	-0.0436	0.0239
Domestic or foreign	0.0623***	0.0177	0.0274	0.0972
Market share	0.2565***	0.0703	0.1178	0.3952
Total assets	-0.0353***	0.0072	-0.0496	-0.0210
Time	0.0092***	0.0030	0.0032	0.0152

6. Conclusion

Conventionally, DEA efficiency scores are used in the Tobit regression model to determine to what extent each determinant affects the efficiency score. However, Simar and Wilson (2007) maintain that the variables selected during the first stage are usually strongly correlated with the determinants of efficiency used in the second stage, often leading to invalid statistical inferences. Simar and Wilson (2007) propose the use of bootstrap estimation to obtain consistent and unbiased statistics. Therefore, the present study uses the two-stage bootstrap truncated regression model developed by Simar and Wilson (2007) to explore the performance of 29 Taiwanese life insurance companies according to data spanning 2009–2017. A total of 189 observation values are collected from the Taiwan Economic Journal database and Annual Report of Life Insurance of Taiwan. The empirical results reveal an average efficiency score of 0.8784 for all sample companies, indicating that the optimal efficiency can be achieved by reducing the inputs by 12.16%. The

conventional DEA approach yields an average efficiency of 0.9068, which is a clear overestimation. According to the Mann–Whitney U test, the efficiency scores obtained using the two approaches are significantly different.

DEA reveals that domestic life insurance companies have higher performance than their foreign counterparts; additionally, larger life insurance companies exhibit lower management efficiency, implying that large institutions should improve their management to reduce waste and improve efficiency. Moreover, Taiwanese life insurance companies with larger market share have higher operational efficiency, which is consistent with market power theory (Berger 1995). The Taiwanese life insurance companies improved their efficiency during the period investigated. The results also indicate a nonsignificant difference between Taiwanese life insurance subsidiaries of FHCs and those of non-FHCs regarding performance. The present study also reveals that the Tobit model obtains underestimated marginal effects of determinants on efficiency.

We employ the two-stage bootstrap truncated regression model proposed by Simar and Wilson (2007) to prevent biases in efficiency estimates and then discuss the determinants of operational performance in the insurance industry to fill the research in previous studies investigating the efficiency of Taiwanese life insurance companies. Our empirical results provide deeper insight into the insurance industry's production activities and contribute to the understanding of the determinants of operational efficiency in Taiwanese life insurance companies. This study may also serve as a reference for managers in the industry to improve their management and for authorities concerned to establish appropriate policies.

ACKNOWLEDGEMENTS.

Financial support from Ministry of Science and Technology (MOST) of Taiwan is gratefully acknowledged (MOST 106-2410-H-126-002).

References

- [1] Banker, R. D., A. Charnes, and W. W. Cooper, Some models for estimating technical and scale inefficiencies in data envelopment analysis, *Management Science*, **30**, (1984), 1078–1092.
- [2] Barros, C.P., M. Nektarios, and A. Assaf, Efficiency in the Greek insurance industry, *European Journal of Operational Research*, **205**, (2010), 431–436.
- [3] Berger, A. N., The profit-structure relationship in banking—tests of market-power and efficient-structure hypothesis, *Journal of Money, Credit, and Banking*. **27**, (1995), 404–431.
- [4] Berger, A. N., and D. B. Humphrey, Efficiency of financial institutions: International survey and directions for future research, *European Journal of Operational Research*, **98**, (1997), 175–212.
- [5] Chang, W. W., Assessment methods for the insurance industry's efficiency, *Insurance Monograph*, **56**, (1999), 75–102.

- [6] Charnes, A., W. W. Cooper, and E. Rhodes, Measuring the efficiency of decision making units, *Journal of Operational Research*, **2**, (1978), 429–444.
- [7] Chuang, C.C., and Y.C. Tang., Asymmetric dependence between efficiency and market power in the Taiwanese life insurance industry, *Panoeconomicus*, **62**, (2015), 511–525.
- [8] Cummins, J. D., and H. Zi, Comparison of frontier efficiency methods: An application to the U.S. life insurance industry, *Journal of Productivity Analysis*, **10**, (1998), 131–152.
- [9] Cummins, J. D., S. Tennyson, and M. A. Weiss, Consolidation and efficiency in the US life insurance industry, *Journal of Banking and Finance*, **23**, (1999), 325–357.
- [10] Cummins, J. D., and X. Xie, Mergers and acquisitions in the U.S. property-liability insurance industry: Productivity and efficiency effects, *Journal of Banking and Finance*, **32**, (2008), 30–55.
- [11] Cummins, J. D., and M. A. Weiss, Analyzing firm performance in the insurance industry using frontier efficiency methods, In *Handbook of Insurance*, ed. G. Dionne, Boston, MA: Springer. 2013.
- [12] Eling, M., and M. Luhnen, Frontier efficiency methodologies to measure performance in the insurance industry: Overview, systematization, and recent developments, *The Geneva Papers on Risk and Insurance-Issues and Practice*, **35**, (2010), 217–265.
- [13] Farrell, M. J, The measurement of productive efficiency, *Journal of the Royal Statistical Society Series(Part 3)* , **120**(3), (1957), 253–281.
- [14] Fenn, P., D. Vencappa, S. Diacon, P. Klumpes, and C. O’Brien, Market structure and the efficiency of European insurance companies: A stochastic frontier analysis, *Journal of Banking and Finance*, **32**, (2008), 86–100.
- [15] Fukuyama, H, Investing productive efficiency and productivity changes of Japanese life insurance companies, *Pacific-Basin Finance Journal*, **15**, (1997), 481–509.
- [16] Gaganis, C., I. Hasan, and F. Pasiouras, Efficiency and stock returns: Evidence from the insurance industry, *Journal of Productivity Analysis*, **40**, (2013), 429–442.
- [17] Genetay, N., and P. Molyneux, *Bancassurance*, New York: St. Martin’s Press, 1998.
- [18] Greene, W. H., and D. Segal, Profitability and efficiency in the U.S. life insurance industry, *Journal of Productivity Analysis*, **21**, (2004), 229–247.
- [19] Hao, C. J., and L. Y. Chou, A factor analysis of the operating efficiency of life insurance companies in Taiwan, *Insurance Monograph*, **19**(1), (2003), 75–105.
- [20] Hao, J. C. J., and L. Y. Chou, The estimation of efficiency for life insurance industry: The case in Taiwan, *Journal of Asian Economics*, **16**, (2005), 847–860.
- [21] Hardwick, P, Measuring cost inefficiency in the UK life insurance industry, *Applied Financial Economics*, **7**, (1997), 37–44.

- [22] Hu, J. L., S. E. Yu, and F. L. Lin, Efficiency analysis of life insurance companies in Taiwan: A two-stage data envelopment analysis, *Insurance Issues and Practices*, **11**(1), (2012), 21–42.
- [23] Hu, J. L., and H. E. Yu, Risk, capital, and operating efficiency: Evidence from Taiwan’s life insurance market, *Emerging Markets Finance and Trade*, **51**, (2015), 121–132.
- [24] Huang, L. Y., T. Y. Hsiao, and G. C. Lai, Does corporate governance and ownership structure influence performance? Evidence from Taiwan life insurance companies., *Journal of Insurance Issues*, **30**(2), (2007), 123–151.
- [25] Huang, T. H., T. L. Kao, L. C. Chiang, and J. H. Liang, A study of technical efficiency and productivity change on Taiwan’s life insurance companies with quasi-fixed inputs, *Soochow Journal of Economics and Business*, **68**, (2010), 1–38.
- [26] Huang, W., and M. Eling, An efficiency comparison of the non-life insurance industry in the BRIC countries, *European Journal of Operational Research*, **226**, (2013), 577–591.
- [27] Hwang, S. N., and K. H. Wu, Measuring the operational performance of life insurance industry in Taiwan, *Journal of Management & Systems*, **4**, (2001), 401–419.
- [28] Hwang, S. N., and T. L. Kao, Measuring managerial efficiency in non-life insurance companies: An application of two-stage data envelopment analysis, *International Journal of Management*, **23**, (2006), 699–720.
- [29] Jeng, V., and G. C. Lai, The impact of deregulation on efficiency: An analysis of life insurance industry in Taiwan from 1981 to 2004, *Risk Management and Insurance Review*, **11**, (2008), 349–375.
- [30] Kaffash, S., R. Azizi, Y. Huang, and J. Zhu, A survey of data envelopment analysis applications in the insurance industry 1993-2018, *European Journal of Operational Research*, 2019.
- [31] Kao, C., and S. N. Hwang, Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan, *European Journal of Operational Research*, **185**, (2008), 418–429.
- [32] Lee, C. I., M. K. Shyu, and Y. H. Chiu, Evaluating the operational efficiency of life insurance companies in Taiwan-An application of the dynamic network SBM model, *Applied Economics and Finance*, **4**, (2017), 18–33.
- [33] Leverty, J. T., and M. F. Grace, The robustness of output measures in property-liability insurance efficiency studies, *Journal of Banking and Finance*, **34**, (2010), 1510–1524.
- [34] Lee, Y. C, Relationship between profitability, market structure, and efficiency in Taiwan life insurance industry, *Insurance Monograph*, **65**, (2001), 30–63.
- [35] Liu, C. C, Assessment on the operational efficiency of insurance companies: A comparative analysis between domestic and foreign companies, *Insurance Monograph*, **37**, (1994), 114–126.

- [36] Liu, C. C., and J. P. Lee, Economies of scale and the operational efficiency of life insurance companies: A discussion of data envelopment analysis, *Life Insurance Quarterly*, **95**, (1995), 19–28.
- [37] Lu, Y. H., C. Wang, and C. H. Lee, The difference in the technology efficiency of Taiwan's life insurance companies: The application of the metafrontier DEA model, *Journal of Economics and Management*, **7**(1), (2011), 73–100.
- [38] Lu, W. M., W. K. Wang, and W. L. Kweh, Intellectual capital and performance in the Chinese life insurance industry, *Omega*, **42**, (2014), 65–74.
- [39] Peng, J. L., L. R. Chen, and W. P. Liu, The bancassurance cooperation strategy and efficiency of life insurance companies, *Academia Economic Papers*, **42**(2), (2014), 235–269.
- [40] Shyu, J., and C. C. Hsu, Operational efficiency of Taiwanese life insurance industry: Application of data envelopment analysis, *Bank of Taiwan Quarterly*, **62**(4), (2011), 42–67.
- [41] Simar, L., and P. W. Wilson, Estimation and inference in two-stage, semi-parametric models of production processes, *Journal of Econometrics*, **136**, (2007), 31–64.
- [42] Wang, J. L., J. L. Peng, and Y. H. Chang, The impact of bancassurance on the efficiency performance of life insurance companies in Taiwan, *NTU Management Review*, **17**(1), (2006), 59–90.
- [43] Wang, J. L., V. Jeng, and J. L. Peng, The impact of corporate governance structure on the efficiency performance of insurance companies in Taiwan, *The Geneva Papers on Risk and Insurance-Issues and Practice*, **32**, (2007), 264–282.
- [44] Wise, W., A survey of life insurance efficiency papers: Methods, pros & cons, trends, *Accounting*, **3**, (2017), 137–170.
- [45] Yeh, T. L., and T. Y. Chen, Measuring life insurance industry's efficiency of utilization, *Bank of Taiwan Quarterly*, **51**, (2000), 322–341.