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Asymmetric Dependence between Efficiency and Market Power: Longitudinal Perspective of the Taiwan Life Insurance Industry

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ABSTRACT

Both market power and efficiency contribute to the viability of the insurer, making these attributes essential to the management of life insurance companies. This study measured efficiency using the stochastic frontier approach based on the translog cost function and then investigated the dependence between efficiency and market power using the interval censored value of the Clayton copula. The results show a strong nonlinear, asymmetric dependence between efficiency and the market power of Taiwan insurers. Restated, the companies with greater market power are not necessarily more efficient. This investigation provides reference for life insurance companies in the formulation of operational strategies.

Keywords: Market power, efficiency, Clayton copula, asymmetric dependence.

Mathematics Subject Classification: 62P20

Computing Classification System: G.4

1. INTRODUCTION

The life insurance industry in Taiwan is vital to the domestic financial system. Between 2002 and 2011, income from premiums increased from 8.54% to 16.99% of Gross Domestic Product (GDP), representing an extremely rapid growth rate of 99%. Taiwan ranked first in the world in insurance penetration (the ratio of insurance premiums to GDP) in2006, 2008, 2009 and 2011.

In 2011, the 23 domestic and 8 foreign life insurance companies in Taiwan collectively earned premium income of NT$1,570 million. The largest life insurance company in Taiwan in terms of assets has an approximately 26% market share, while the smallest life insurance company has a mere 0.08%. Many companies in the Taiwan life insurance industry endeavour to increase their market power, expand their economies of scale and increase their operational efficiency.

This study evaluates efficiency using the stochastic frontier approach (SFA). The SFA is a form of parameter analysis in which the setting of a translog function considers the cross-terms among the variables to reduce the number of resulting errors (Bergeret *al.*, 1997;Cummins and Zi, 1998). Numerous studies have found a causal relationship between efficiency and market power (Bajtelsmit and Bouxouita, 1998; Choi and Weiss, 2005). However, other studies have employed Tobin's regression analysis to determine the influence of market power on efficiency (Greene and Segal, 2004; Weiss and Choi, 2008). In accordance with Weiss and Choi (2008), this investigation uses market share as a proxy for market power. Life insurance companies tend to pursue efficiency and market power without exception; therefore, this investigation employed the Clayton copula to calculate the dependence relationship between efficiency and market power. The Clayton copula operates under the premise that no information distribution assumptions are required, and it operates without the constraints of normal distribution models. Therefore, Nelsen (2006) proposed that it contributes to relationship analysis on the distribution of interval-censored values in the sample to confirm joint distribution. This study estimates efficiency using the SFA and then employs the Clayton copula to identify the censored value relationship between efficiency and market power.

The main contribution of this studyis its novel merging of the SFA and the Clayton copula. Furthermore, our results provide reference for managers in the formulation of operational strategies: the pattern of asymmetric dependence between efficiency and market power in the Taiwan life insurance industrygives a new perspective on this topic. The remainder of this paper is organized as follows. Section 2 describes the data and methodology. The main empirical results are then presented in Section 3. Section 4 presents conclusions and suggestions.

2. DATA AND METHODOLOGY

2.1. Data

The study data were taken from the period 1976 to 2011 and included a total of 693 observations. The data were generated from the Annual Report on Life Insurance of the Taiwan Insurance Institute.

2.1.1. Measurement of efficiency

This study modified the value-added approach suggested by Yuengert (1993) and Greene and Segal (2004) to select input and output factors. These factors, along with the SFA, were used to measure efficiency. Output factors are defined in Table 1, while Table 2 presents the definitions of input factors and their costs.

Table 1: Definitions of output factors

Output	Definition	Reference
Incurred benefits (Y1)	Payments received by policyholders in the current year, including interest and dividend income	Yuengert (1993)
Incurred claims (Y2)	Incurred claims on services related to insured losses	Berger *et al.* (1997) an Greene and Segal (2004)
Life insurance premiums (Y3)	Adopted individual insurance premiums: including life insurance, annuity insurance and A&H insuran	Cummins and Zi (1998 Greene and Segal (2004)and Hu and Shi (2013)

Table 2: Definitions of input factors and their costs

Input	Definition and measure	Reference
Price of Financ capital (P1)	1. Capital that produces a net profit on investmer including invested assets 2. The ratio of total investment income to total invested assets	Cummins and Zi (1998 Greene and Segal (2004)and Hu and Shi (2013)
Price of Busine services (P2)	1. All operational expenses other than labor and capital expenses 2. Related expenses divided by total number of policies sold	Cummins and Zi (1998 and Greene and Segal (2004)
Price of Labor (P3)	1. A single input combining office and agent labo 2. Measured in New Taiwan Dollars (NTD) using data on average annual wages from Labor Department	Cummins and Zi (1998 Greene and Segal (2004)and Hu and Shi (2013)

Total operational cost for the insurer is defined as the sum of the costs of financial capital, business services and labor. This total cost varies according to input prices and production factors. Table 3 lists descriptive statistics for all variables.

*Table 3:*Descriptive statistics of input and output factors

Variable	Mean	S.E.	Min	Max
Cost (NTD million)	9824	22143	12	22143
Incurred benefits (Y1, NTD million)	5046	13122	0.11	98215
Incurred claims (Y2, NTD million)	10174	28737	0.01	317683
Insurance premiums (Y3, NTD million)	25683	56374	0.02	484524
Price of Financial capital (P1, %)	6.04	3.03	0.02	26.27
Price of Business services (P2, NTD million)	0.02	0.18	0.01	4.32
Price of Labor(P3, NTD million)	0.33	0.14	0.03	0.51

Note: S.E. denotes standard error.

2.1.2.Measurement of market power

The market power hypothesis primarily suggests that firm's market power determines firm market capacity (Shepherd, 1982;Julien, 2010). Shepherd (1982) proposed that life insurance companies with a large market share enjoy unique market power. Therefore, this study used market share as a proxy for market power. To calculate market power, this study defined it as the annual premium of an individual insurance company divided by total annual market premium.

2.2.Methodology

This study employed the SFA, originally proposed by Aigner*et al.* (1977),to evaluate individual company efficiency. The SFA also considers relative price as an input in determining individual company efficiency. To control random error, Greene and Segal (2004)proposedthat the cost function should be set to $\ln TC_{it} = \ln TC^*_{it}(y_i, p_i) + \varepsilon_{it}$, $\varepsilon_{it} = v_{it} + u_{it}$, where TC_{it} are observed total costs of firm i at time t, $TC^*_{it}(.)$ is the cost function of firm i at time t, y_i is a vector of outputs and p_i is a vector of input price.Furthermore, ε_{it} can be separated into two main components (Berger *et al.*, 1997;

Cummins and Zi, 1998).The first is the random error term (v_{it}), which accounts for measurement error and other factors unspecified in the cost function. This random error term is generally assumed to be an i.i.d. normal random variable with mean zero and constant variance σ_v^2. The second term is a nonnegative inefficiency term (u_{it}), which includes a description of the expansion of the translog function as follows (Kumbhakar, 1991; Choi and Weiss, 2005;Weiss and Choi, 2008):

$$\ln TC_{it} = \alpha_0 + \sum_{k=1}^{2} \beta_k \times \ln P_{kit} + \sum_{m=1}^{3} \gamma_m \times \ln Y_{mit} + 0.5 \sum_{k=1}^{2}\sum_{l=1}^{2} \beta_{kl} \times \ln P_{kit} \times \ln P_{lit}$$
$$+ 0.5 \sum_{m=1}^{3}\sum_{n=1}^{3} \gamma_{\mathrm{mn}} \times \ln Y_{mit} \times \ln Y_{nit} + \sum_{k=1}^{2}\sum_{m=1}^{3} \rho_{mk} \times \ln P_{kit} \times \ln Y_{mit} + \varphi_0 \times t$$
$$+ 0.5\varphi_1 \times t^2 + \sum_{k=1}^{2} \lambda_k \times t \times \ln P_{kit} + \sum_{m=1}^{3} \phi_m \times t \times \ln Y_{mit} + \varepsilon_{it},\ \varepsilon_{it} = v_{it} + u_{it},$$

$$k, l = 1,2,3 \ m, n = 1,2,3,$$

where Y_{mit} represents the output m for the ith firm at time t and P_{kit} is the price of input k for the ith firm at time t. Meanwhile, α_0 β_k , β_{kl} , γ_m , γ_{mn} , ρ_{mk} , φ_0 , φ_1 , λ_{kit} , ϕ_{mit} are unknown parameters that the cost function is constrained to be homogeneous of degree one in input prices and symmetry requires $\beta_{kl} = \beta_{lk}$ and $\gamma_{mn} = \gamma_{nm}$ (Greene and Segal, 2004). Based on a common frontier, the methods used to estimate efficiency include technical efficiency and allocative efficiency, which are obtained by comparing all sample firms under identical technological and environmental conditions.

Copulas provide flexible models for dependence between positively associated variables (Ghoudi*et al.*, 1998). Copulas are mathematical methods that can help derive the joint distributions among variables by utilizing the sample. Sun *et al.* (2006) suggested that the Clayton copula with nonparametric marginal distributions can be used to estimate the association for bivariate interval-censored failure data.Moreover, several authors have considered the analysis of interval-censored failure time data(Wang and Ding, 2000;Hu and Gui, 2014). Sun (2005) considered the estimation of Kendall's coefficient for bivariate interval-censored data, in the process providing a relatively complete review of the literature for interval-censored failure time data.Wang and Ding (2000) developed an inference procedure for the association of two related survival variables based on current status data. The study estimated two variables based on interval-censored data.

Let T_1 and T_2 have marginal survival functions $S_1(t)$ and $S_2(t)$, respectively, and joint survival function $S(t_1, t_2) = P(T_1 > t_1, T_2 > t_2)$. To estimate the association between T_1 and T_2 , we assume the following copula model:

$$S(t_1, t_2) = C_\alpha(S_1(t_1), S_2(t_2))$$

where C_α is a specific one-parameter copula and $\alpha \in R$ is a global association parameter. An attractive feature of copula model is its modeling flexibility; it includes many useful bivariate failure time models as special cases, such as the Archimedean copula family:

$$C_\alpha(u,v) = \phi_\alpha\{\phi_\alpha^{-1}(u) + \phi_u^{-1}(v)\},\ 0 \le u,\ v \le 1$$

where $0 \le \phi_\alpha \le 1$, $\phi_\alpha(0) = 1$, $\phi_\alpha^{'} < 0$, $\phi_\alpha^{''} > 0$. According to the standards set by previous studies, this study has $C_\alpha(u,v) = (u^{1-\alpha} + v^{1-\alpha} - 1)^{1/(1-\alpha)}$ and $\alpha > 1$; Kendall's tau is given by $\tau = \alpha/(\alpha + 2)$, and it exhibits dependency, which is commonly referred to as the Clayton (1978) and Sun(2005).

3. EMPIRICAL RESULTS

Efficiency is first assessed in this study by applying the SFA to the translogcost function. Table 4 lists the estimation results which reveal that most of the output factors correlate positively with cost, which is broadly consistent with the limitations of the cost function. Table 5 shows the descriptive statistics for efficiency and market power in the Taiwan life insurance industry. Based on these statistics, the mean and maximum efficiency of the local life insurance companies were determined to be 64% and 85%, respectively, with a mean market power of 8%, and foreign life insurance companies display mean and maximum efficiency values of 50% and 74%, respectively, with mean market power of 1%.

*Table 4:*Estimates of the translog cost function (n=36)

Parameter	Estimate	t-value	Parameter	Estimate	t-value
α_0	-1.22**	-4.37	ρ_{21}	1.07**	5.35
γ_1	-0.11**	-3.68	ρ_{22}	0.10*	2.27
γ_2	0.01*	2.40	ρ_{31}	-0.00*	-0.11
γ_3	0.06	1.56	ρ_{32}	-0.03*	-1.59
β_1	1.36**	4.61	β_{11}	0.89**	5.19
β_2	1.41**	5.06	β_{22}	0.17*	2.02
γ_{11}	0.00*	2.84	β_{12}	0.05	0.65
γ_{22}	0.01*	2.82	φ_0	0.01	0.01
γ_{33}	-0.00**	-3.39	φ_1	-0.00	-0.55
γ_{12}	-0.01*	-2.90	λ_1	0.01	0.01
γ_{13}	0.01**	5.74	λ_2	-0.03**	-3.38
γ_{23}	-0.00*	-2.93	ϕ_1	-0.01**	-11.88
ρ_{11}	-0.01	-0.26	ϕ_2	0.01**	3.65
ρ_{12}	0.05*	2.34	ϕ_3	0.02**	11.74

Notes: (1) The translogcost function is defined in Section 2.2.
(2) ** (*) indicates significance at 1% (5%) level.
(3) Maximum log likelihood value = 1552.941.

*Table 5:*Descriptive statistics of efficiency and market power

Variables	Mean	S.E.	Min	Max
Local (obs=429)				
Efficiency	0.64	0.12	0.09	0.85
Market power	0.08	0.13	2.7E-07	0.58
Foreign (obs=264)				
Efficiency	0.50	0.12	0.08	0.74
Market power	0.01	0.02	7.5E-08	0.10
Whole samples (obs=693)				
Efficiency	0.58	0.14	0.08	0.85
Market power	0.05	0.11	7.5E-08	0.58

Note:S.E. denotes standard error.

This paper applied maximum likelihood to estimate the correlation parameter of the Clayton copula for interval-censored data. Table 6 lists the maximum likelihood estimate for a 36-year time series of annual efficiency and market power. Significance at the 5% level, the results depicted in Figure 1 indicate a strong relationship between market power and efficiency with $\alpha = 0.31$. The lower tail dependence of this copula is clearly shown in the CDF and density. The level sets of the CDF are pushed much closer to the origin where the density is strong.

*Table 6:*Maximum likelihood of correlation in Clayton copula

Parameter	Eestimate	S.E.	t-value
α	0.31	0.08	20.68**
Log-like		42.12	

Note:(1) ** (*) indicates significance at 1% (5%) level.
(2) S.E. denotes standard error.
(3) Log-like denotes logarithms of likelihood value.

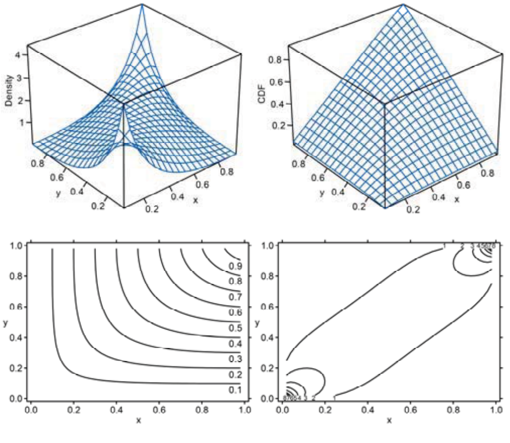

Figure 1. Surface and contour plots for $c(u,v)$ and $C(u,v)$ for the Clayton copula with $\alpha = 0.31$.

4. CONCLUSIONS AND SUGGESTIONS

This study employed SFA to evaluate insurance company efficiency and then employed the Clayton copula to examine the relationship between efficiency and market power. The results indicated a strong correlation between these variables, which was further characterized as asymmetric. The coefficients of the Clayton copula reveal a strong asymmetric correlation between the two variables. This finding indicates that highly efficient life insurance companies do not necessarily have strong market power. Therefore, strong market power does not guarantee high efficiency. Additionally, doubly censored regression analysis was also shown to be a robust test for variable relationships[1], consistent with the Clayton copula.

The empirical results of this paper elucidate the current status of the life insurance industry in Taiwan, demonstrating that companies with greater market power do not necessarily exhibit higher efficiency. Moreover, in pursuing greater market power, life insurance companies should consider the efficiency of input and output resources simultaneously and allocate controlled resources appropriately. Consequently, this study suggests that management at life insurance companies clarify their objectives and leverage company resources when cultivating market power and efficiency. As seen in the current situation of the life insurance industry in Taiwan, companies adopt numerous strategies to expand market power. Additionally, the operational strategies offering the greatest advantages to the company should be adopted. Therefore, life insurance companies can focus on efficiency as well as improving low penetration in the life insurance market, which is caused by low market power.

5. REFERENCES

Aigner, D. J., Lovell, C. A. K., andSchmidt, P., 1977, Formulation and estimation of stochastic frontier production function models.*J. Econometrics***6**, 21-37.

Bajtelsmit, V. L., and Bouzouita, R., 1998, Market power and performance in private passenger automobile insurance.*J. Risk Insur.***65**,503-514.

Berger,A.N., Cummins, J. D., and Weiss, M. A., 1997, The coexistence of multiple distribution systems for financial services: the case of property-liability insurance.*J. Bus.***70**, 515-546.

Choi, P. B., and Weiss, M. A., 2005, An empirical investigation of market power, efficiency, and performance in property-liability insurance.*J. Risk Insur.***72**, 635-673.

Clayton,D.G., 1978, A model for association in bivariate life tables and its application in epidemiological studies of familial tendency in chronic disease incidence.*Biometrika***65**,141-152.

Cummins, J.D., and Zi, H., 1998, Comparison of frontier efficiency methods: An application to the US life insurance industry.*J. Prod. Anal.***10**, 131-152.

Ghoudi, K., Khoudraji, A., and Rivest,L., 1998, Propriétés statistiques des copules de valeues extrêmes bidimensionnelles.*Can. J. Stat.***26**, 187-197.

[1]Due to limits of the length paper, the results are upon requested.

Greene, W. H., and Segal,D., 2004, Profitability and efficiency in the US life insurance industry.*J. Prod. Anal.***21**,229-247.

Hu M., and Gui, W., 2014, Time truncated double acceptance sampling plans for inverse Rayleigh distribution. *Int. J. Appl. Math. Stat.***52**, 128-136.

Hu R., and Shieh, C. M., 2013, High-tech industries overseas investment performance evaluation - application of data envelopment analysis. *S. Afr. J. Econ. Manag. Sci.***16***,* 67-73*.*

Julien C., 2010, Intertemporal emissions trading and allocation rules: Gainers, losers and the spectre of market power.*Int. J. Ecol. Econ. Stat.***18**, 1-19.

Kumbhakar, S. C., 1991, The measurement and decomposition of cost-inefficiency: The translog cost system.*Oxf. Econ. Paper***43**, 667-683.

Nelsen, R. B., 2006, *An introduction to Copulas*, 2nd Edition, New York, Springer.

Shepherd, W. G., 1982, *Economies of scale and monopoly profits*. in Craven, J. V. (Ed.),in Industrial Organization, Antitrust, and Public Policy, Boston, Kluwer Nijhoff Publishing.

Sun, J., 2005, *Interval censoring*. in Armitage, P. andColton T. (Eds.), in Encyclopedia of Biostatistics, New York: Wiley, 2603-2609.

Sun,L., Wang, L., and Sun, J., 2006, Estimation of the association for bivariate interval-censored failure time data.*Scand. J. Stat.***33**, 637-649.

Wang, W., and Ding,A. A., 2000, On assessing the association for bivariate current status data.*Biometrika***87**, 879-893.

Weiss M. A., and Choi, B. P., 2008, State regulation and structure, conduct, efficiency and performance of US auto insurers.*J. Bank. Finance***32**, 134-156.

Yuengert, A. M., 1993, The measurement of efficiency in life insurance: Estimates of a mixed normal-gamma error model.*J. Bank. Finance***17**, 483-496.