Management Science Letters 3 (2013) 303–308

Contents lists available at GrowingScience

Management Science Letters

homepage: www.GrowingScience.com/msl

Performance measurement of insurance firms using a two-stage DEA method

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ARTICLEINFO

Article history:
Received April 25, 2012
Received in revised format
20 October 2012
Accepted 22 October 2012
Available online
October 24 2012

Keywords:
Insurance
Performance measurement
DEA
Two-stage DEA

ABSTRACT

Measuring the relative performance of insurance firms plays an important role in this industry. In this paper, we present a two-stage data envelopment analysis to measure the performance of insurance firms, which were active over the period of 2006-2010. The proposed study of this paper performs DEA method in two stages where the first stage considers five inputs and three outputs while the second stage considers the outputs of the first stage as the inputs of the second stage and uses three different outputs for this stage. The results of our survey have indicated that while there were 4 efficient insurance firms most other insurances were noticeably inefficient. This means market was monopolized mostly by a limited number of insurance firms and competition was not fare enough to let other firms participate in economy, more efficiently.

1. Introduction

Performance measurement is one of the most important issues among insurance firms and there are many studies focusing on measuring the relative efficiencies of insurance firms in this sector (Barros et al., 2010; Cummins & Xie, 2008). China, for instance, joined world trade organization in 2001 and had to fully open up its insurance market to foreign rivals by 2006. However, the domestic insurance market was overwhelmingly dominated by limited number of either state-owned or state-controlled companies. As the market was still underdeveloped and the demand for insurance was rising significantly, there was a huge potential, opportunities as well as challenges for non-state, foreign and joint-venture insurance companies. In such circumstances, efficiency was a key concern of policy makers to encourage further development of the insurance industry. Yao et al. (2007) implemented a panel data set of 22 companies over the period 1999–2004 to assess their efficiency scores by using a data envelopment analysis (DEA) technique and decomposed the productivity growth into technical efficiency improvement and technological progress by building a Malmquist Index. They also used

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doi: 10.5267/j.msl.2012.10.029

an econometric technique to determine the key determinants of efficiency. The empirical results recommended the direction of how to improve firm efficiency. They also reported that firm size, ownership structure, mode of business and human capital play essential role in firm performance. Cummins et al. (2010) investigated economies of scope in the US insurance industry over the period 1993–2006. They examined the conglomeration hypothesis, which holds that insurance companies could optimize by diversifying across market, versus the strategic focus hypothesis, which holds that companies optimize by focusing on core markets. They investigated whether it is benefitial for insurers to give both life-health and property-liability insurance or to specialize in one major industry segment. They estimated cost, revenue, and profit efficiency utilizing DEA and examined for scope economies by regressing efficiency scores on control variables and an indicator for strategic focus.

Yang (2006) used a two-stage DEA model to provide valuable managerial insights when evaluating the dual effects of operating and business strategies for the Canadian insurance industry. The proposed model permitted integration of the production performance and investment performance for the insurance firms and provided management overall performance evaluation and how to access efficiency systematically for the insurers involved. The results indicated that the Canadian insurance industry operated efficiently during the investigation period.

2. Problem Statement

We first present the problem statement of the proposed DEA method implemented in this paper. In a DEA method, there are normally some inputs and outputs related to all decision-making units. Let x_{ij} be the inputs for one of decision-making unit with $i=1,\ldots,m$ and y_{rj} be the outputs of the same units with $r=1,\ldots,s$ and $j=1,\ldots,n$ and suppose u_i and v_j are the dual variables associated with x_i and y_j, respectively. The constant return to scale DEA modeling formulation is as follows,

$$\begin{aligned} \max \quad & z = \frac{\sum_{r=1}^{s} u_r y_{r.}}{\sum_{i=1}^{m} v_i x_{i.}} \\ \text{subject to} \quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \\ & x_{ij}, y_{ij \ge 0} \end{aligned} \tag{1}$$

Model (1) is the basic DEA, which can be solved j times to determine the efficiencies of various units. However, since model (1) is nonlinear in structure, Charles et al. (1978) proposed a simple modification of the objective function to convert model (1) into a simple linear programming problem as follows,

$$\begin{aligned} \max \quad & z = \sum_{r=1}^{s} u_r y_{r.} \\ \text{subject to} \quad & \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1. \\ & \sum_{i=1}^{m} v_i x_{i.} = 1 \end{aligned} \tag{2}$$

$$u_r, v_i \geq 0, \qquad j = 1,...,n$$

3. Two-stage DEA

As we explained, the input oriented DEA is formulated as follows,

$$\max \quad E = \sum_{r=1}^{s} u_r y_{rp}$$

subject to

$$\begin{aligned}
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \qquad j = 1, \cdots, n \\
&\sum_{i=1}^{m} v_i x_{ip} = 1, \\
&v_i \geq \varepsilon, \qquad i = 1, \cdots, n \\
&u_r \geq \varepsilon. \qquad r = 1, \cdots, s
\end{aligned} \tag{2}$$

Now an intermediate unit $z_{pj}, p = 1, \cdots, q$ according to Fig. 1 can be depicted as follows,

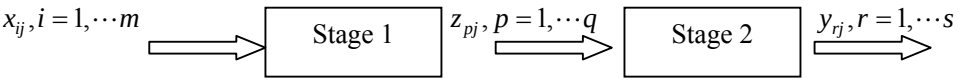

Fig. 1. A two-stage DEA

Let E_k^1 and E_k^2 be the efficiencies of stage 1 and 2, respectively, which yields $E_k = E_k^1 \times E_k^2$ and the new DEA model can be written as follows (Charles et al., 1996; Banker, 1984),

$$E_k^1 = \max \quad \sum_{p=1}^{q} w_p Z_{pk}$$

subject to

$$\begin{aligned}
&\sum_{i=1}^{m} v_i X_{ik} = 1, \\
&\sum_{r=1}^{s} u_r Y_{rk} - E_s \sum_{i=1}^{m} v_i X_{ik} = 0, \\
&\sum_{r=1}^{s} u_r Y_{rj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, \qquad j = 1,...., n, \\
&\sum_{p=1}^{q} w_p Z_{pj} - \sum_{i=1}^{m} v_i X_{ij} \leq 0, \qquad j = 1,....., n, \\
&\sum_{r=1}^{s} u_r Y_{rj} - \sum_{p=1}^{q} w_p Z_{pj} \leq 0, \qquad j = 1,...., n, \\
&u_r, v_i, w_p \geq \varepsilon, \quad r = 1, \cdots, s; \ i = 1, \cdots, m; \ p = 1, \cdots, q.
\end{aligned} \tag{2}$$

The dual of model (2) can be written as follows,

$$E_k = \min \quad a - \left(\sum_{i=1}^{m} s_l^n + \sum_{p=1}^{q} s_p^w + \sum_{w=1}^{s} s_i^n \right)$$

subject to

$$ax_a - \sum_{l=1}^{s} a_j X_q - \sum_{p=1}^{s} \beta_t x_y - s = 0, \quad i = 1,...., m,$$

$$\sum_{j=1}^{n} \beta_l Z_{pl} - \sum_{j=1}^{a} \gamma_l Z_{pl} - s_p^w = 0, \qquad p = 1,....,q, \tag{3}$$

$$\sum_{j=1}^{m} \alpha_l Y_{rj} + \sum_{j=1}^{s} \gamma_l Y_{rj} - s_p^w = Y_{rk}, \qquad r = 1,....,s,$$

$$\alpha_j, \beta_l, s_l^w, s_p^w, s_r^w \geq 0, \qquad j = 1,....,n;\ r = 1,....,s;\ i = 1,....,m;\ p = 1,....,q.$$

DEA model (2) and (3) can be implemented to measure the efficiency of various units. However, we require to be cautious on using the models for two reasons. First, the model is formulated for constant return to scale and second, the relative importance for the output of the first stage is the same as the input of the second stage. There are alternative procedure, which could be implemented whenever the return to scale would not be constant. Interested reader could see Kao and Hwang (1994) for more details.

4. Case study

In this section, we present the implementation of DEA methods for an application of insurance firms in Iran. The proposed study of this paper uses DEA model (2) and (3) to measure the relative efficiencies of the insurance firms. The proposed study of this paper performs DEA method in two stages where the first stage considers five inputs and three outputs while the second stage considers the outputs of the first stage as the inputs of the second stage and uses three different outputs for this stage. Fig.2 one shows details of our proposed model.

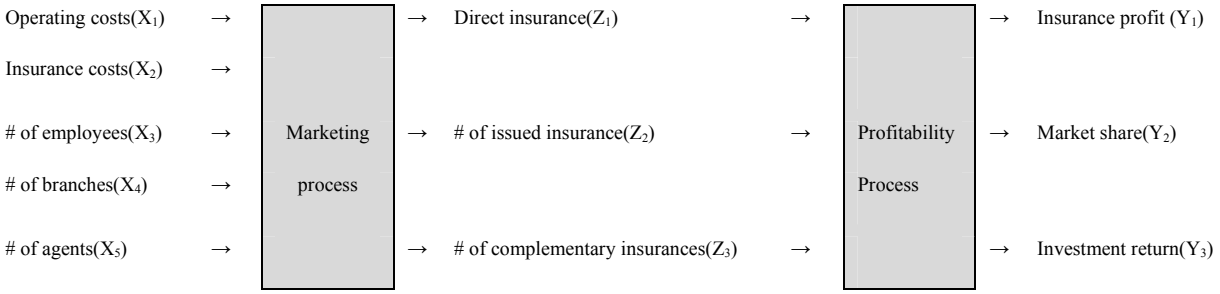

Fig. 2. The proposed two stages DEA model

Operating cost (X_1) is the first input, which includes employee wages and other operating expenditures. Insurance cost (X_2) is the second input of the first stage, which is associated with the cost of insurance marketing, the expenses paid to different agents and consultants. The number of employees who work for any insurance unit (X_3) is the third inputs of the first stage. The other input is the number of branches and central offices (X_4) and finally, the number of agents who are responsible to sell insurance (X_5) is the last input of the first stage. There are three outputs associated with first stage of the proposed model, which are also the inputs of the second stage. Direct insurance (Z_1), which is the fees received directly from the customers is the first output, total number of insurance certificates (Z_2) and Complementary insurance (Z_3) is the second output, which are received from companies. As we can see from Fig. 1, the outputs of the first stage are considered as the inputs of the second stage. For the outputs of the second stage, we consider the net income from sales of insurances (Y_1), short term and long term investment returns (Y_2) and market share (Y_3). The study measure the relative efficiencies over the period of 2006-2010. We first calculate the efficiencies of these insurance firms in two stages independently and then multiply these numbers together to calculate the overall efficiencies. We also use the proposed model presented in Eq. (3) to measure the relative efficiencies. Table 1 demonstrates the relative efficiencies of these units over the

period 2006-2008. Table 2 also shows the relative efficiencies of 20 insurance units over the period 2009-2010.

Table 1
The results of the relative efficiencies of 18 insurance firms over the period 2006-2008

	2006			2007			2008		
Insurance	E_1	E_2	E_k	E_1	E_2	E_k	E_1	E_2	E_k
1	1	1	1	0.672	0.310	0.672	0.677	0.179	0.677
2	0.234	0.149	0.349	1	1	1	1	0.137	1
3	1	0.316	0.316	0.556	0.516	0.556	1	1	1
4	0.347	1	0.347	0.338	1	0.338	1	1	1
5	0.556	0.002	0.001	0.313	0.223	0.313	0.234	0.316	0.234
6	0.338	0.039	0.013	0.347	0.236	0.347	0.358	0.483	0.358
7	0.391	0.087	0.034	0.304	0.406	0.304	0.022	0.228	0.022
8	0.482	0.348	0.168	0.483	0.215	0.483	0.135	0.360	0.135
9	0.174	0.089	0.015	0.316	0.179	0.316	0.189	0.002	0.189
10	0.330	0.022	0.007	0.228	0.303	0.228	0.022	0.328	0.022
11	0.673	0.533	0.359	0.358	0.495	0.358	0.317	0.087	0.317
12	0.447	0.081	0.036	0.022	0.364	0.022	0.221	0.255	0.221
13	0.516	0.174	0.090	0.170	0.281	0.170	0.180	0.039	0.180
14	0.661	0.074	0.049	0.647	0.221	0.647	0.179	0.251	0.179
15	0.463	0.211	0.098	0.158	0.159	0.158	0.137	0.228	0.137
16	0.538	0.179	0.096	0.315	0.009	0.315	0.316	0.333	0.316
17	0.655	0.419	0.274	0.251	0.581	0.251	0.228	0.419	0.228
18	0.492	0.022	0.011	0.228	0.112	0.228	0.002	0.022	0.002
Average			0.181			0.373			0.345

Table 2
The results of relative efficiencies of 20 insurance firms for the fiscal year of 2009 and 2010

	2009			2010		
Insurance	E_1	E_2	E_k	E_1	E_2	E_k
1	0.310	0.552	0.171	0.875	0.251	0.220
2	0.288	1	0.288	0.582	1	0.582
3	1	1	1	1	1	1
4	1	0.546	0.546	1	0.470	0.470
5	0.588	0.174	0.102	0.515	1	0.515
6	0.166	0.347	0.058	0.573	0.118	0.068
7	0.236	0.556	0.131	0.591	0.129	0.076
8	0.406	0.338	0.137	0.884	0.449	0.397
9	0.495	0.377	0.187	0.524	0.233	0.122
10	0.364	0.292	0.106	0.544	0.269	0.146
11	0.073	0.313	0.023	0.578	0.117	0.068
12	0.584	0.234	0.137	0.677	0.260	0.176
13	0.475	0.672	0.319	0.524	0.390	0.204
14	0.493	0.391	0.193	0.657	0.117	0.076
15	0.457	0.447	0.204	0.631	0.251	0.158
16	0.539	0.673	0.363	0.512	1	0.512
17	0.747	0.482	0.360	0.769	0.556	0.428
18	0.303	0.516	0.156	0.641	0.472	0.303
19	0.281	0.492	0.138	0.012	0.761	0.438
20	0.221	0.584	0.129	0.312	0.118	0.037
Average			0.238			0.289

As we can observe from the results of Table 1 and Table 2, the average efficiencies of insurance firms in all years were relatively low, which means a limited number units dominated the market compared with other insurance firms. Fig. 2 shows details of efficiencies and our judgment can be follows more precisely.

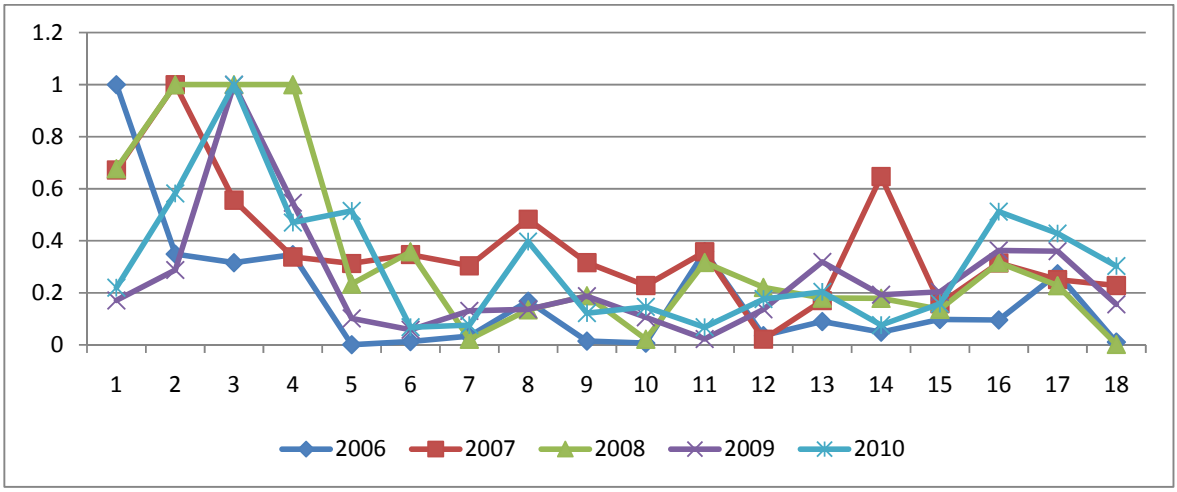

Fig. 2. The relative efficiencies of 18 units over the period 2006-2010

5. Conclusion

In this paper, we have presented an empirical investigation to measure the relative efficiencies of insurance firms in Iran. The proposed model of this paper has implemented two-stage DEA technique to measure the relative efficiencies of these units. The results of our survey have indicated that while there were 4 efficient insurance firms most other insurances were noticeably inefficient. This means market was monopolized mostly by a limited number of insurance firms and competition was not fare enough to let other firms participate in economy, more efficiently.

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