Research Article

Measuring Total Factor Productivity of China Provincial Non-Life Insurance Market: A DEA-Malmquist Index Method

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The unbalanced economic development results in the difference in operating efficiency of the non-life insurance industry in China’s provinces; based on the DEA-Malmquist index method, this paper investigates the provincial differences, dynamic change characteristics, and causes of non-life insurance productivity in 31 provinces of China from 2004 to 2017. The results show that in the sample period, there are significant differences between provinces and regions in China’s non-life insurance efficiency, which generally shows the echelon spatial characteristics of "strong in the west and weak in the east". Technological progress in the western region promotes the rapid growth of total factor productivity, while the low efficiency of technological progress in the eastern region restrains the improvement of total factor productivity. The overall total factor productivity of China’s provincial non-life insurance industry is on the rise, mainly due to the improvement of pure technical efficiency and scale efficiency, while technological progress has an inhibiting effect on the contrary. These conclusions are of reference value for relevant stakeholders in China’s provincial non-life insurance market to formulate development strategies and business strategies.

1. Introduction

With the rapid development of China’s economy, the deepening of financial reform and opening up in recent years has brought substantial changes to the insurance market. The development of the non-life insurance market is particularly rapid. From 2000 to 2019, the non-life insurance premium grows at an annual rate of 206.37%, reaching 287.967 billion US dollars. At present, it is the second-largest non-life insurance market in the world [1]. However, due to China’s huge land area, the imbalance of provincial economic development has resulted in differences in the development of the non-life insurance market. According to statistics, the non-life insurance depth (non-life insurance premium/GDP) of China’s eastern, central, and western regions in 2019 will be 1.81%, 2.40%, and 1.95%, respectively. Then, is there any obvious regional difference in the efficiency of China’s non-life insurance market? At the same time, what are the basic characteristics and dynamic trends? These problems need to be discussed in detail.

The evaluation of insurance market efficiency has always been a hot topic in the academic and industry. Whether it was the efficiency of life insurance, non-life insurance, or the whole insurance market, the vast majority of literature were based on the investigation of insurance companies [2–14]; Only a few researchers took an international perspective to compare the insurance markets of different countries or regions [15–18]. Few studies compared the efficiency of the regional insurance market in a country, especially the non-life insurance market, which was highly related to the development level of the real economy. There were good reasons for this. In addition to the significant imbalance of regional economic development as a prerequisite for the study, it was also very difficult to collect reliable data. Therefore, this paper attempts to use the DEA-Malmquist index method [19–23] to analyze the spatial differentiation characteristics, dynamic trends, and determinants of the efficiency of total factor productivity of non-life insurance market in 31 provinces of China during 2004–2017. It provides important support for China to solve the problem...
of high-quality and balanced development of the regional non-life insurance market.

This paper has two main contributions to the literature. First, as far as we know, this is the first study focusing on the efficiency of China’s provincial non-life insurance market. Therefore, our paper expands the insurance literature of efficiency comparison by comparing the total factor productivity and segmentation efficiency of the developing non-life insurance markets in China. Second, the provincial comparison not only provides the regional distribution characteristics of relative efficiency but also shows the dynamic trend of non-life insurance market efficiency, which increases our understanding of the reasons for the efficiency differences of the provincial non-life insurance market. Evaluating the evolution of provincial-level non-life insurance efficiency in China has important reference significance for relevant stakeholders to formulate development strategies and business strategies.

The remaining part of the paper is organized as follows. In Section 2, the existing relevant studies are summarized. In Section 3, we introduce the principle of measuring the total factor productivity and the DEA-Malmquist index method and describe the selected evaluation index. Section 4 is the result of efficiency analysis and discussion. The conclusion is presented in Section 5.

2. Literature Review

Since the 1990s, the research focus of efficiency evaluation of non-life insurance market has continued till now. Cummins and Weiss [24] analyzed the cost efficiency levels and differences of property-liability insurance companies of different sizes; the results showed that the average efficiency of the large, medium, and small insurance companies were about 90%, 80%, and 88%, respectively, and medium and small insurance companies had more potential to reduce costs. Worthington and Hurley [25] calculated the pure technical efficiency, scale efficiency, allocation efficiency, and cost efficiency of 46 non-life insurance companies in Australia and found that the main cause of inefficiency was allocation inefficiency rather than technical inefficiency. Cummins and Xie [20] investigated the productivity and efficiency effects of mergers and acquisitions in the property-liability insurance industry in the United States. Luhten [8] made a comprehensive analysis of the efficiency and productivity of the German property-liability insurance industry. It was found that the total factor productivity growth was moderate, the efficiency growth was low, and the market had the potential to improve the technical efficiency by about 20 percentage points and the cost efficiency by about 50 percentage points. Chen et al. [3] discussed whether the efficiency of American property-liability insurance companies has improved before and after the conversion. Sun et al. [26] evaluated the comprehensive technical efficiency, pure technical efficiency, and scale efficiency of 34 Chinese property insurance companies. Cummins and Xie [27] examined the efficiency, productivity, and economies of scale of the property-liability insurance industry in the United States. Yaisawarg et al. [28] examined whether there were economies of scale and technological changes in Thailand’s non-life insurance market. Alhassan and Biekpe [19] conducted a comprehensive analysis on the efficiency, productivity, and returns to scale of South Africa’s non-life insurance market; the results showed that the inefficiency of non-life insurance companies was about 50%, while about 20% of insurance companies operate at optimal size. Ferro and León [5] evaluated the technical efficiency of non-life insurance companies in Argentina. Venkateswarlu and Rao [23] measured and compared the efficiency change, technology change, and total factor productivity index of Indian public and private non-life insurance companies.

Some scholars have also investigated the different characteristics of the operating efficiency of non-life insurance markets in different countries. For example, Weiss [18] studied the productivity of property-liability insurance companies in the United States, West Germany, Switzerland, France, and Japan during the period 1975–1987. Huang and Eling [16] used the multistage DEA method to analyze the efficiency of non-life insurance companies in BRIC countries. They found that Brazil, Russia, China, and India declined in order and that the environment affected the operating efficiency of non-life insurers in the BRIC countries.

The methods used in the existing insurance efficiency evaluation literature are mainly divided into two categories: one is the parametric method based on stochastic frontier analysis [5, 18, 24, 27], and the other is nonparametric methods based on DEA [8, 16, 25, 26]. Currently, the newly popular DEA-Malmquist index method based on the traditional DEA method is improved [3, 19, 20, 23, 27, 29]. The nonparametric methods can better track the evolution of non-life insurance market efficiency and overcome the prominent problems that the parametric method relies too much on the parametric hypothesis, and the traditional DEA method is not enough to describe the dynamic characteristics.

From the above literature, we can see that although the existing research compares the operating efficiency of the non-life insurance market with the non-life insurance companies in one country or different countries, few studies intend to consider from the perspective of the regional market, especially for the special situation of the large regional difference of non-life insurance.

3. The Measuring Total Factor Productivity of Provincial Non-Life Insurance Market Framework

3.1. The Principle. We investigated the operating efficiency of non-life insurance in China’s provinces, mainly based on the following principle. First, an index system of input and output is constructed as a quantitative objective standard for evaluating the operating efficiency of the provincial non-life insurance market. Second, with the help of the DEA-Malmquist index method, the evaluation model of provincial non-life insurance efficiency is constructed. Finally, the data of non-life insurance operations in 31 provinces in
China from 2004 to 2017 were collected for empirical analysis to estimate the total factor productivity and its segmentation efficiency (see Figure 1 for details).

3.2. Input-Output Index. In this paper, the DEA-Malmquist technique is used to measure and analyze the changes and causes of the provincial non-life insurance market efficiency in China. First, the input index and output index should be determined. According to the operating characteristics of China’s provincial non-life insurance market, we have determined an evaluation index system, as shown in Table 1. In terms of input index, considering the four basic elements of non-life insurance industry operation, namely “resources, capital, institutions, and manpower”, we selected six indexes, including GDP, household consumption level, permanent resident population, total fixed assets of non-life insurance institutions, number of non-life insurance institutions, and non-life insurance practitioners. GDP, household consumption level, and permanent resident population are the input of external resources for the development of the provincial non-life insurance market. The total fixed assets of non-life insurance institutions reflect the investment of capital. The number of non-life insurance institutions refers to the total number of branches in each province, which reflects the density of non-life insurance institutions in the province and reflects the physical input. Non-life insurance practitioners refer to the number of all staff of non-life insurance of province area, including company management personnel, business personnel, and other personnel, reflecting the input of manpower. In terms of output index, we selected three indicators: the premium, insurance indemnity, and underwriting profit. If the index of premium reflects the density of non-life insurance institutions in the province, number of non-life insurance practitioners reflects the number of non-life insurance practitioners. GDP, household consumption level, and permanent resident population are the three main indicators of non-life insurance business in the province.

3.3. DEA-Malmquist Index Model. In this paper, the DEA-Malmquist index method [21] is applied to analyze the dynamic changes and causes of operational efficiency in China’s provincial non-life insurance market. There are two main reasons to choose the DEA-Malmquist index method. First, it is a nonparametric method, which can avoid the problem that stochastic frontier analysis and other methods rely too much on parameter hypothesis. Second, the overall efficiency can be further subdivided into different seed efficiencies to better understand the dynamic evolution of efficiency and the main reasons.

Since it is difficult to satisfy the constant return to scale in reality, we adopt the BCC-DEA model based on the assumption that the return to scale is variable. The expression is as follows:

\[
\begin{align*}
\min \left[ \theta - \varepsilon \left( \sum_{i=1}^{m} si^- + \sum_{r=1}^{n} sr^+ \right) \right], \\
\sum_{j=1}^{m} x_{ij} \lambda_j + si^- = \theta x_i \kappa,
\end{align*}
\]

The above model measures the efficiency of each DMU from the perspective of input, and the objective function represents the comprehensive efficiency from the perspective of minimizing input, where \(x_i\) is the \(i\)-th input of a decision unit \(j\), \(x_i \geq 0\), \(y_j\) is the \(r\)-th output of a decision unit \(j\), \(y_j \geq 0\), \(y_i\) is the \(r\)-th output, \(\theta \geq 0\), \(\varepsilon\) is the target programming value, \(\varepsilon\) is non-Archimedean infinitesimal, and \(si^-\) and \(sr^+\) are slack variables. If \(\theta = 1\), \(s^- = 0\), and \(s^+ = 0\), then the DEA of the decision-making unit is valid; if \(\theta < 1\), DMU is DEA invalid; and if \(\theta = 1\) and \(s^- \neq 0\) or \(s^+ \neq 0\), DMU is weakly efficient.

BCC-DEA model can only compare the efficiency values of different decision-making units in the same period and cannot measure the changes of efficiency values in different periods. For this purpose, we also need to use the Malmquist index [33], whose expression is as follows:

\[
T_{fp} = M\left(x_i^{t+1}, y_j^{t+1}, x_i^t, y_j^t\right) = \left[ \frac{D'(x_i^{t+1}, y_j^{t+1})}{D'(x_i^t, y_j^t)} \right]^{1/2} \left[ \frac{D''(x_i^{t+1}, y_j^{t+1})}{D''(x_i^t, y_j^t)} \right]^{1/2},
\]

where \((x_i^t, y_j^t)\) represents the input and output of the period \(t\), respectively; \((x_i^{t+1}, y_j^{t+1})\) represents the input and output of the period \(t + 1\), respectively; \(D'(x_i^t, y_j^t)\) and \(D'(x_i^{t+1}, y_j^{t+1})\), respectively, refer to the distance function of decision unit in period \(t\) and period \(t + 1\) with data in period \(t\) as the reference set; and \(D''(x_i^t, y_j^t)\) and \(D''(x_i^{t+1}, y_j^{t+1})\), respectively, refer to the distance function of decision units in the period \(t\) and period \(t + 1\) with the data in the period \(t + 1\) as the reference set. When the Malmquist index of >1 indicates efficiency improvement, the Malmquist index = 1 indicates that the efficiency remains unchanged, and the Malmquist index <1 indicates reduced efficiency.

In this paper, the efficiency of total factor productivity is replaced by Tfp for short. Tfp can be further decomposed into the technical efficiency change index (Effch) and technical progress index (Tech) as follows:
In addition, by introducing variable returns into the scale distance function, the technical efficiency change index \((\text{Effch})\) in equation (4) can be subdivided into pure technical efficiency index \((\text{Pech})\) and scale efficiency index \((\text{Sech})\), which can be expressed as follows:

\[
\text{Effch} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})} \times \left[ \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})} \times \frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})} \right]^{1/2},
\]

\[
\text{Pech} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} \quad \text{and} \quad \text{Sech} = \left[ \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})} \times \frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})} \right]^{1/2}.
\]

where the subscripts \(V\) and \(C\) refer to variable returns to scale technology and constant return to scale technology, respectively.

\[
\text{Pech} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})},
\]

\[
\text{Sech} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} \times \frac{D^{t}(x^{t}, y^{t})}{D^{t+1}(x^{t}, y^{t})}.
\]

Therefore, the calculation formula of \(T_{fpch}\) is as follows:

\[
T_{fpch} = \text{Effch} \times \text{Tech} = \text{Pech} \times \text{Sech} \times \text{Tech},
\]

where \(T_{fpch}\) represents total factor productivity, \(\text{Effch}\) represents technical efficiency index, \(\text{Tech}\) represents technological progress index, \(\text{Sech}\) represents scale efficiency index, and \(\text{Pech}\) represents pure technical efficiency index. \(\text{Effch}\) measures whether the input of each factor is wasted. \(\text{Tech}\) reflects the innovation and improvement of science, technology, and activities in the business operation process to adapt to the future market environment. \(\text{Sech}\) reflects the influence of scale factors on total factor productivity. \(\text{Pech}\) is the production efficiency of an enterprise affected by management and technology factors. DEA-Malmquist technology
can help obtain more dynamic and comprehensive connotation information in the process of evaluating the efficiency of China’s provincial non-life insurance market.

4. Experimental Results and Analysis

4.1. Data. In this paper, the efficiency of the non-life insurance industry in 31 provinces of mainland China (excluding Hong Kong, Macao, and Taiwan) during 2004–2017 was studied. The input-output index data used in the evaluation are from the China Insurance Statistical Yearbook and the website of the National Bureau of Statistics of China. Since the input and output indexes in the BCC-DEA model are required to be non-negative, this paper converts the original data of underwriting profit into the data falling within a positive range. It is mainly achieved by the following function [16]:

$$z_{ij} = 0.1 + 0.9 \times \frac{x_{ij} - m_j}{M_j - m_j}$$

(9)

where $m_j = \min(x_{ij}); M_j = \max(x_{ij}); i = 1, 2, 3, ..., n; z_{ij} = [0, 1]$. The basic statistics are shown in Table 2. According to the statistics of minimum, maximum, and mean, there is an obvious gap between the input-output indicators of 31 provinces in China during 2004–2017.

4.2. The Evaluation Outcomes. Figures 2–6 show the basic situation of non-life insurance Tfpch and decomposition efficiency in provinces of China. During the sample period, China’s non-life insurance market efficiency showed significant differences among provinces and regions. From the microscopic perspective of specific provinces, the characteristics of non-life insurance efficiency are different. The Tfpch is less than 1 in 15 provinces, including Beijing, Hebei, Shanxi, Inner Mongolia, Liaoning, Shanghai, Jiangsu, Zhejiang, Anhui, Shandong, Guangdong, Chongqing, Sichuan, Ningxia, and Xinjiang. However, Tfpch is greater than 1 in 16 other provinces, which are Tianjin, Jilin, Heilongjiang, Fujian, Jiangxi, Henan, Hubei, Hunan, Guangxi, Hainan, Guizhou, Yunnan, Xizang, Shanxi, Gansu, and Qinghai. In terms of motivation, the 15 provinces with Tfpch of <1 are mainly caused by the low Tech, which indicates that the innovation and improvement of science and technology and activities in the process of enterprise operation have not adapted to the future market environment. In the 16 provinces with Tfpch of >1, it is mainly caused by the improvement of Effch, which indicates that the input of each factor in these provinces has less waste and a high utilization rate. In Tianjin, Heilongjiang, Jiangxi, Henan, Hebei, Hunan, Guangxi, Guizhou, Xizang, Gansu, Qinghai, and other provinces, Effch and Tech play a synergistic role.

From the perspective of geographical space, the efficiency of provincial non-life insurance also presents different characteristics. Tfpch and Tech show the spatial echelon characteristics of “weak in the west and strong in the east”. In terms of Effch, Hebei, Shanxi, and other provinces in Central China are relatively high. The Pech shows the spatial echelon characteristic of "strong in the west and weak in the east", and the eastern provinces such as Shandong and Liaoning are relatively high. The Sech is balanced in the whole country, and there is no obvious difference between provinces and regions.

Furthermore, it can be seen from Table 3 that the average non-life insurance Tfpch of eastern, western, and central regions of China is 0.980, 1.027, and 1.013 respectively, and the comprehensive ranking is: western region > central region > eastern region. The non-life insurance total factor productivity in western China grew rapidly, mainly due to technological progress. On the contrary, the low tech inhibits the improvement of Tfpch in the eastern region.

5. Discussion

The dynamic change characteristics of the overall total factor productivity of China’s provincial non-life insurance market and its decomposition efficiency are shown in Figure 7. From 2004 to 2017, the average value of the Tfpch was 1.003, showing a general upward trend, but the fluctuation was
Table 3: Average non-life insurance efficiency of the three regions in China during the sample period.

| Area     | Tfpch | Tech | Effch | Pech | Sech |
|----------|-------|------|-------|------|------|
| Eastern  | 0.980 | 0.977| 1.004 | 1.003| 1.002|
| Western  | 1.027 | 1.015| 1.001 | 1.001| 1.000|
| Central  | 1.013 | 1.007| 1.005 | 1.006| 1.004|

Note. The provinces in the eastern region include Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The provinces in the central region include Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The provinces in the western region include Chongqing, Sichuan, Yunnan, Guizhou, Xizang, Ningxia, Xinjiang, Qinghai, Shanxi, Gansu, Guangxi, and Neimenggu.
To be specific, the average annual increase of the Effch was 0.4%, and the average annual decrease of the Tech was 0.1%. Among them, the Sech and Pech increased by 0.1% and 0.3% on average, respectively. This fully shows that the overall management and technical level of the provincial non-life insurance market play a major role in improving the overall efficiency, while the driving effect of technological progress presents a negative effect. In fact, from 2004 to 2017, the development of China’s non-life insurance market is mainly driven by costs, manpower, and management and is still in the extensive development stage. It is worth pointing out that during the period of 2013/2014 to 2016/2017, technical efficiency still showed the characteristics of the shock. But the pure technical efficiency index showed a significant upward trend, which promoted the improvement of the overall efficiency.
Figure 6: Sech.

Figure 7: Provincial efficiency during the sample period.
6. Conclusion

Based on the empirical analysis of the differences, evolutionary characteristics, and drivers of non-life insurance market efficiency in 31 provinces of China during 2004–2017, the following conclusions are drawn: (1) from the perspective of provincial efficiency change, total factor productivity of half of the provinces in China has increased. The improvement of total factor productivity in Beijing, Hebei, Shanxi, and other provinces is mainly due to the improvement of technical efficiency index. The improvement of total factor productivity in Neimenggu, Jilin, Hainan, and other provinces is mainly due to the improvement of technological progress. The improvement of total factor productivity in Tianjin, Heilongjiang, Jiangxi, and other provinces is mainly due to the synergistic driving effect of technological efficiency and technological progress. (2) From the perspective of spatial distribution, total factor productivity: western region > central region > eastern region. Total factor productivity in the western region grew rapidly, mainly due to technological progress and improvement of pure technological efficiency. Technological progress in the eastern region shows a downward trend, which indicates that technological progress is the main restriction factor for the improvement of total factor productivity. (3) From the analysis of overall efficiency change, it can be seen that China’s non-life insurance total factor productivity is on the rise on the whole, but it is still in an unstable stage. The change of technical efficiency plays a major role in the improvement of total factor productivity, while the driving effect of technological progress is not significant. It reflects that the scale of China’s non-life insurance market continues to expand, but the technical level still needs to be improved. There is still much room to improve non-life total factor productivity by improving the technical level. In conclusion, Chinese insurance policymakers and non-life insurance operators should take targeted measures to effectively improve operating efficiency according to the constraints.

Data Availability

Some of the data involved commercial secrets. Therefore, the data in this paper are only used for scientific research and should not be shared.

Additional Points

(i) We investigated originally the provincial differences, dynamic change characteristics, and causes of non-life insurance productivity in 31 provinces of China from 2004 to 2017 using the DEA-Malmquist index method. (ii) The results show that China’s non-life insurance efficiency has been on the rise, and there were significant differences between provinces and regions, and the echelon spatial characteristics of “strong in the west and weak in the east”.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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