An analysis on service efficiency in nursing homes and spatio-temporal variation in China

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Abstract

Background: Pension services market in China is still at the early stage, problems like low service efficiency and low quality of nursing care already exist. So it is inevitable to analyze the efficiency and productivity and spatio-temporal variation, as well as its influencing factors in nursing homes all over the country.

Methods: Data Envelopment Analysis (DEA) and Tobit model were applied to integrate several quality measures into a comprehensive benchmarking model. We present nationwide results and analyze the spatio-temporal distribution of the (technical efficiency) TE and productivity of nursing homes among Eastern, Central and Western of China. Furthermore, Tobit model was performed to explore factors associated with TE.

Results The average TE, pure technical efficiency (PTE) and scale efficiency (SE) of nursing homes for the 5-year period were 0.909. 0.928 and 0.979, respectively. The TE and SE decreased from 2012 to 2014, but improved after 2014. TE is 0.98 in the Eastern region, 0.93 of that in the Central region and 0.91 of that in the Western region, with a decrease range of 2%, 7% and 9%, respectively. The average improvement range of the five input indexes of the non-DEA effective nursing homes was 27.26%, 20.62%, 19.77%, 22.04%, and 38.84%, respectively. The influencing factors of efficiency value of nursing homes indicated that if there are more social workers, more patients in the nursing homes, and more employees who are aged 56 and above, the TE and productivity of nursing homes will be higher.

Conclusions There was considerable space for TE improvement in nursing homes due to the low proportion of effective TE. The TE and SE presented a decreasing trend from 2012 to 2014, which implicated that the large SE in nursing homes with less previous standardized management should be emphasized. (total factor productivity changes)TFPC experienced a decrease in productivity due to the adverse alteration in technological changes and pure technical efficiency. The service efficiency in nursing homes is facing with the problem of imbalance of regional development. The efficiency value of nursing homes was influenced by age of employees, the number of social workers and the number of older people. The measures and suggestions on improving efficiency of care in nursing homes were put forward.

Background

Population aging brings unpredicted global challenges. For one, the number of older people increased to 650 million in 2019 and expected to reach nearly 2.0 billion by 2050, with most of this growth taking place in the low- and middle-income countries. The number of elderly people living in cities in developing countries is expected to reach 908 million by 2051. On the other hand, the total number of people aged 65 and above stood at 166.58 million, which is 11.9% of the entire population in China for the year 20182. The proportion of older people is projected to reach 26% by 2050, exceeding that of most EU countries3. A report in 2017 showed that there were about 40.63 million disabled elderly people in the country4 and it is projected that 68 million of the older people in China will experience some degrees of disabilities in China by 2030, and approximately 18.6% of these people may require assistance for daily living activities5. In addition, a large number of empty-nest families have emerged, and the "empty-nest elderly" who are living alone and lonely are also growing at a rapid rate. The "China Family Development Report (2015)", shows that empty-nest elderly in China account for half of the total number of elderly people, of which the elderly living alone account for nearly 10% of the total number of elderly people, which broke the traditional Chinese way of supporting the family6. The traditional family-oriented care function for the elderly is constantly weakening. Therefore, the demand for equitable and efficient Long-term Care Facilities (LTCFs) will continue to increase as years go by, which can provide professional living care, rehabilitation care and emergency rescue services for the elderly.

In order to solve the problems brought about by the aging of the population, Chinese government has promulgated relevant laws, regulations and policies to encourage social forces to set up nursing homes for the older people. It has arranged a total investment of 9.17 billion yuan in the central budget, focused on supporting the construction of nursing homes for the elderly and facilities for elderly care with integrated medical care. By the end of January 2019, there were 163,800 nursing homes and various types of facilities in the country, of which 29,700 were nursing homes, 46,600 were community service facilities for elderly, and 87,300 were mutual care facilities. A total of 7.46 million beds were provided for the various types of elderly care services, and among them, there are 3.928 million beds in nursing homes7. Total beds account for 3% of the country's older population. Generally, developed countries can reach 5% -7%. From the calculation, the number of beds required should be at least 12.45 million to accommodate China's elderly, who are in the need of LTC8. It means that the overall shortage of beds for the elderly, there is also a large space to adjust, showing a very obvious contradiction between supply and demand. Moreover, substantive matters in residential care as they evolved in today's long-term health care environment due to the late implementation of residential care in China, which is still in the early stages of development, LTCFs are currently facing problems and difficulties like large investment, slow returns, low profits, and high risks. Also, service levels and quality need to be improved urgently. In the "Research Report on the Development of China's Pension Institutions," it was pointed out that about 257 residential cares in 12 interviewed cities, including Tianjin, Harbin, Jinan, and Wuhan, etc., among those, about 48.1% of the operating conditions were basically the same, 32.5% were in deficit, and only 19.4% had a surplus9.A survey showed that there were more than 30 private residential cares in the city of Chengdu, with a total of more than 8,000 beds with only 4,500 older people10. Even though the number of people who chose to take care of the elderly will vary due to the changing seasons, the overall occupancy is still not that high. The occupancy rate of most private institutions is far lower than that of the state-owned pension institutions11.

Various contradictions between supply and demand still inevitably occur in China, such as the serious shortage of beds, the corresponding number of nursing staff, the low level of professionalism, small-infrastructure scale of residential care, and the lack of risk management system and the service evaluation system for elderly care12. In addition, the survey showed that compared with Eastern and other regions, the beds utilization rate is significantly higher than that in the Western region; the available beds in the central urban area are difficult for the older people to get, while the bed utilization rate in the private pension institutions in the suburbs is very low13. Therefore, how to effectively improve the service quality, service efficiency, and also the output efficiency of nursing homes in various provinces in the process of increasing investment and rationally allocating service resources have become a focus of attention by the government and academia.

With the deepening of the research on the service quality of nursing homes, foreign scholars began to pay more attention to the problem of inputs and outputs of the nursing homes at the same time. A sample survey was conducted in nursing homes in certain areas of Finland, Italy, Japan and Norway respectively. Also, the relative efficiency and influencing factors were studied, based on explorations on application of Data Envelopment Analysis (DEA) method and regression model14-17. Efficiency can be simply used as a tool to explain the relationship between the inputs and outputs. And even TE can be applied to find out whether any waste can be eliminated without worsening any input or output18. DEA was defined as an advantageous non-parametric technique for evaluating performance in terms of relative efficiency in the presence of multiple inputs and outputs19.

Although most of researches in developed countries on the service efficiency of pension service institutions are relatively complete, their research approaches and results may not be applicable to China due to different levels of development. There exist amounts of shortcomings in the researches related to the efficiency of China's nursing homes. For example, many studies in China still focused on the theoretical researches for the institutional planning of LTCFs, including the exploration of institution building and service standards, service contents, and service personnel.

Moreover, many researches mainly focused on individual nursing home in a certain province or city. Also, some of the research methods are investigation and research methods, with less statistical data are used to quantitatively study the overall efficiency of pension service institutions in different regions of China, which cannot provide scientific basis for promoting the overall healthy development of the nursing homes in China from a macro perspective. In addition, most of the previous researches use the cross-sectional data to apply the single stage and DEA Tobit two-stage models in conducting a regional static research.

Therefore, a panel data was used to analyze the service efficiency of nursing homes of China's 31 provinces and municipalities and its spatio-temporal variation, based on the input-oriented DEA. DEA method was applied to make comprehensive evaluation of service efficiency for regional nursing homes and its spatio-temporal variation in China, combined with Tobit model to analyze the influencing factors of service efficiency. The purpose of this study is to provide an evidence for decision-making by integrating and optimizing resource allocation, as well as to promote countermeasures for the transition of LTCFs, and then getting sustainable development of increasing service quality to comprehensively improve the service efficiency of LTCFs.

Methods

Data

The original data set comprises all of the nursing homes in 31 provinces of China. These LTCFs were observed from 2012 to 2016. Data were collected from the China Civil Affairs statistical yearbook20, which is related to the social services in each year among all of China's provinces.

Data Envelopment Analysis

DEA is an advantageous non-parametric technique for measuring the relative efficiency of homogeneous decision making units (DMUs) because of its advantages in dealing with multi-input and multi-output indicators, such as the efficiency evaluation of medical services19. DEA can handle multiple input and chromatography at the same time, for example, a number of output efficiency does not need to presuppose function and parameters. On the other hand, the input and output variables of weight coefficient is produced by the mathematical programming according to the data. Also, the DEA doesn't need to set artificial weight coefficient, without being influenced by subjective factors efficiency value21. Furthermore, it has nothing to do with the dimension in selecting the suitable input and output items. Also, it avoids calculating the standard cost of each service because it can convert multiple inputs and outputs into numerators and denominators of the efficiency ratio without converting them into the same monetary units22. Therefore, the DEA model can be regarded as the better choice for the purpose and current situation of the research on the comprehensive efficiency of nursing homes.

Selection of the model

1. **Charnes-Cooper-Rhodes (CCR)and Banker-Charnes Cooper (BCC)model**

DEA is a mathematical programming approach for the empirical evaluation of the relative efficiency of a DMU based on observed inputs and outputs for a group of similar DMUs. It calculates a maximal performance measure for each DMU relative to all other DMUs in the observed population with the sole requirement that each DMU lie on or below the frontier23. The traditional DEA model mainly included CCR model based on constant returns to scale and BCC model with variable returns to scale[21]. Both models were radial models that rely on the basic assumption that inputs must be reduced as much as possible, while outputs must be maximized also as much as possible to serve as an advantage in the absence of the actual production process. However, the redial CCR model24and BCC model25 suffers from one

shortcoming; they neglect the slacks in the evaluation of efficiencies. To overcome this shortcoming efficiency scores can be computed using the “slack based” non-radial and non-oriented DEA model26. This paper measures the overall technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of 31 provinces of China. The TE refers to the extent to which a DMU can produce the maximum output from its chosen combination of inputs and scale efficiency refers to sub optimal activity level.

2.SBM model

It is known as the Additive Model (AM) or a slack-based model (SBM) and this is based on input and output slacks27. This model allows managers to work on both inputs and outputs to achieve efficiency. In this study, a non-oriented and non-radial model known as SBM-DEA model has been used27. BCC model and SBM model all choose input-oriented. The reason was that the output of LTCFs was the care of the elderly, not controlled by the LTCFs themselves. LTCFs can only improve service efficiency by adjusting input. Therefore, we used the input-oriented model in this demonstration. An input-oriented DEA model was used to compute TE scores of nursing care can be expressed by the following formula.

$$\begin{cases} \max\left[\theta-\varepsilon\left(e^T s^- + \hat{e}^T s^+\right)\right] \\ \sum_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j - s^+ = y_0 \\ \lambda_j \geq 0, j=1,\ldots,n, s^+ \geq 0; s^- \geq 0 \end{cases}$$

In the case of $\theta = 1$, $S^- = 0$, $S^+ = 0$, the nursing home is fully efficient, whereas θ < 1 means that a nursing home is inefficient. BCC model adds constraint conditions on the basis of CCR model:

$$\sum_{j=1}^{n} \lambda_j = 1$$

At this time, it means that the return on scale of DMU remains unchanged and reaches the maximum output scale. In addition, when $\sum_{j=1}^{n} \lambda_j = 1 < 1$, this means that returns to scale are increasing. If the input of DMU is appropriately increased on the basis of the original input, the output will be increased by a higher proportion. Whereas $\sum_{j=1}^{n} \lambda_j = 1 > 1$, it means diminishing returns to scale, and increasing input does not lead to a higher proportion of output. In addition, for the formula of SBM-DEA, please refer to the paper written by Mogha SK for details28. Due to TE values have truncated characteristics and efficiency values are relative, using general multiple regression models results in bias and parameter estimation instability29.

3. Malmquist model

Productivity measures changes in a production unit’s efficiency in transforming inputs into outputs from time t to time t+130. It was generally used in panel data. MPI was named after Malmquist31 and was introduced by Caves, Christensen and Diewert to evaluate productivity changes among different production units32. MPI (also called total factor productivity changes (TFPC)) can be decomposed into technical efficiency changes (TEC) and technological changes (TC). TEC can also be decomposed into pure technical efficiency changes (PTEC) and scale efficiency

changes (SEC)[33].
TFPC = TEC × TC= (PTEC × SEC) × TC

4. **DEA classification**

This method aims to find changes in the inputs of a DMU so that it can be classified into a different and desirable class. In this paper, we adhere to all the assumptions made by the Troutt et al.[34] and the Seiford and Zhu[35] studies to classify the DMUs into Eastern, Central and Western regions. Assuming non-negative inputs and an output of unity for all the acceptable cases and using the DEA model proposed by Banker et al.[36].

Variable selection

Input-output indicators

There is no consensus conclusion on the choice of input-output variables for the operation efficiency of old-age institutions[37,38]. Based on the theory of production factors in economics, the principles of representativeness, independence, and operability of the evaluation index selection, input factors can be divided into capital, labor, and material inputs, and output factors can be divided into economic benefits and social benefits[39]. As LTCFs were labor-intensive industries. Scholars usually used fixed assets as capital input index and various types of institutional staff as human input index[40,41]. The general rule of thumb is that the number of DMUs should be at least twice the sum of the input-output indicators. As In terms of material inputs, the actual number of beds was a resource that was easily controlled by managers in material resources. A number of studies considered the number of beds, the number of institutions and the original price of fixed assets as indicators of material resources[42,18,43]. In addition, the older care industry is a labor-intensive industry, the capital of the labor substitution is very small. Comprehensively, choosing human capital as input index is an appropriate index for efficiency comparison, like the main care resources including the number of social workers and the number of employees[44]. Therefore, the input indicators established in this article are the number of institutions, the number of employees at the end of the year, the original price of fixed assets, the number of social workers, the number of beds at the end of the year (please refer to table 1).

Output indicators are considered to be the most important factors in evaluating the quality and quantity of long-term care services[45]. In the selection of service efficiency evaluation indexes of nursing homes, most researches only consider the input of human capital or financial capital, like operating income, but fail to consider the service quality of pension service institutions comprehensively as the outcome index of input-output efficiency in the process of building institutions[46,47]. In addition, the quality of service directly affects the final effect of elderly care and the development prospects of the residential care. The health condition of the older people is very important for the improvement and development of LTCFs, and have a direct impact on the final performance evaluation results of the service, like the number of rehabilitation and medical outpatients. Furthermore, the service quality can be reflected by the number of disabled, the number of partially disabled the number of complete independents and in residential cares at the end of the year. Those older people were measured by Barthel index. Therefore, the output indexes should include operating income, the number of disabled, the number of partially disabled and the number of independents in residential cares at the end of the year, and also the number of rehabilitation and medical outpatients (refer to table 1). Table 2 presented summary statistics of input-output variables.

Results

Comparison of the efficiency of residential care between provinces and municipalities in China from 2012 to 2016.

Table 3 summarized the annual mean TE, PTE and SE of the sample LTCFs from 2012 to 2016. The average TE, PTE and SE for the 5-year period were 0.909. 0.928 and 0.979, respectively, and TE, PTE, SE of nursing homes are significantly different among different years, as shown by the mean rank and Kruskal-Wallis test. The TE and PTE of nursing homes improved from 2012 to 2014, but declined since 2014. This result implied that in 2014, if LTCFs were running efficiently, then facilities should have increased their outputs by 15.70% with the same volume of inputs. (table 3).

Table 4 showed that the traditional CCR model, BCC model, and SE model were used to count the number of nursing homes with effective TE, PTE and SE in various provinces and municipalities. As shown in figure 3, the number of nursing homes with effective TE, PTE and SE in all provinces decreased from 2012 to 2014. Then, the number gradually rose since 2014. The number of nursing homes with DEA-effective provinces and municipalities were at the lowest in 2014, while a trend showed an initial decrease and then an increase in the process.

SBM model was used to calculate the changes in the DEA efficiency value of the LTCF in various provinces and municipalities across the country

Figure 2 presented the distribution of SBM efficiency values in China's LTCFs. The results showed that the efficiency of LTCFs in the western region changes rapidly.

Several western provinces and municipalities have developed rapidly, with their LTCFs having an effective TE from 2015 to 2016. The changes in the efficiency of LTCFs in provinces and municipalities in the Eastern region are second to the changes of LTCFs in the West. Among them, the LTCFs in Beijing, Tianjin and Guangdong have been technically efficient from 2012 to 2016. The increase in the efficiency of LTCFs in the Western provinces and municipalities is greater than the Eastern region, while in the Central region is the worst. On the other hand, the LTCFs in Heilongjiang, Jilin, Shandong, Hunan, and Henan provinces have all shown to be non-efficient by 2016.

In addition, LTCFs in the western provinces have improved in TE, while the efficiency of LTCFs in the Central and Eastern provinces has declined in 2014 and in 2016. It was notable that from 2012 to 2016, LTCFs in Hebei, Inner Mongolia, Shanxi, Anhui and Yunnan provinces have never reached an effective TE.

Malmquist productivity index

It can be seen that under the overall evaluation model, the TFPC of LTCFs in 10 provinces and municipalities increased from 2012 to 2016. The average growth of LTCFs in Tibet was the highest, reaching 81.6%. In 21 provinces and municipalities, the TFPC of the LTCFs decreased, with the largest decline in Guizhou. As for the TEC, TEC of LTCFs in 10 provinces (Guizhou, Anhui, etc.) has declined, TEC of LTCFs in 7 provinces (Liaoning, Xinjiang, Fujian, etc.) improved. Among them, Fujian has the largest increase in efficiency. The TC of LTCFs in 8 provinces and municipalities has improved, but the extent of the improvement is small, only Tibet has the largest progress, reaching 79.2%. PTEC of LTCFs in 6 provinces (Hainan, Guizhou, Anhui, Yunnan, etc.) have declined, and PTEC of LTCFs in 8 provinces and municipalities (Liaoning, Fujian, Xinjiang, Chongqing, Gansu, etc.) improved, Fujian Province had the largest increase. The sech of LTCFs in 7 provinces (Tibet, Xinjiang, etc.) increased, with the largest increase in sech in Tibet. Etc.), but Hunan Province had the largest decline in sech of LTCFs (refer to table 5).

Table 6 showed that, from 2012 to 2016, the average TEC was 1.001, and the index increased or decreased by 1.1% to 26.4% in each year, with a large change range, among which the increase in 2015 was up to 26.4%. The average value of TC is 0.983, with an increase or decrease rate of less than 4% per year. After 2015, the trend of steady rise remains stable. The average PTEC was 1.003, with a sharp increase of 19.8% in 2015.The average value of SEC is 0.988, which is in a stable development state. The average value of TFPC was 0.984, and the maximum increase of TFPC in 2015

was 31.8%. As shown in figure 3, the five efficiency values of LTCFs in combined total of 31 provinces and municipalities reached the lowest in 2014 and the highest in 2015. During this period, the results showed a trend that initially went upward and then eventually downward.

DEA Classification was used to cpmpare the DEA efficiency value of the LTCFs in Eastern, Central and Western regions

The regions were divided into three major classifications, namely Eastern (developed), Central (generally developed), and Western (underdeveloped) regions, which refers to the regional division in the China Health Statistics Yearbook.

Table 7 presents the means of TE of nursing homes in East, Central and West were 0.98, 0.93, 0.91 respectively, with a decrease range of 2%, 7% and 9%, respectively; the means of PTE of nursing homes in Eastern, Central and Western regions were 0.98, 0.95, 0.94 respectively, with a decrease range of 2%, 5% and6%, respectively; the means of SE of nursing homes in Eastern, Central and Western were 0.99, 0.99, 0.96 respectively, with a decrease range of 1%, 1% and 4%, respectively

Table 8 presented PTE is significantly difference (P=0.043, <0.05), while TE and SE do not differ significantly among the nursing homes of Eastern, Central and Western regions from 2012 to 2016, as shown by the mean rank and Kruskal-Wallis test. The Mean rank of PTE and SE is the highest in the nursing homes of Eastern region, while the highest rank of TE is in Western region.

As shown in the figure 4, the efficiency values of the three regions all showed a trend of an initial decline, and then an increase, as the agency efficiency value reached the lowest point in 2014. The Eastern region, in 2014, also showed a slight decline at first, and then gradually increase. On the other hand, as the Central region showed a decreasing trend throughout 2014, the Western region showed an initial decrease which eventually increased on that same year.

Projected value of non-DEA effective nursing homes based on input-oriented in 2016

Based on input-oriented (assuming that the output is unchanged), the CCR model was used to calculate the projected value of non-effective LTCFs in all provinces and municipalities in terms of inputs, the number of adjustments (actual value-projected value) , and adjustment ratio[(adjusted number / actual value) ×100%]of 15 non-effective LTCFs in provinces and municipalities in terms of investment are calculated.(Table 9)

The results indicated that in 2016, the non-efficient LTCFs in all provinces and municipalities, the number of institutions, the number of employees by end of the year, the total value of assets, the number of social workers, and the number of beds at the end of the year have been redundant in varying degrees. If the original output of 31 provinces and municipalities of China is maintained, and the input structure and DEA is effectively optimized, it will result in the following: the number of beds in China's LTCFs can be reduced by 360038.9, the number of institutions can be reduced by 3464.9, and the number of social work can be reduced by 497, the total value of assets can be reduced by 87,0381.7 yuan, and the number of employees can be reduced by 3,5465.9.

The efficiency values calculated by SBM and BCC models were used as the Tobit influencing factors in regression analysis

The LTCFs with a greater number of women, social workers, and annual older people have a greater efficiency value. Also, age gets to have an effect on the efficiency value. The results showed that more people within the age range of 35 and below, and 46 to 55 in the LTCFs of nursing homes, a lower efficiency value is. However, if the LTCFs with the greater number of people over the age of 56, the efficiency value will be higher. (refer to table 10)

Discussion

The study looked into the two aspects of the efficiency level and the development and change rate of efficiency and productivity, based on the panel data of China Civil Affairs statistical yearbook from 2012 to 2016. Our results are based on a nationwide data with all of the nursing homes of 31 provinces and municipalities in China during a 5-year period.

1. **Comprehensive efficiency evaluation**

The change of efficiency is the result of the interaction of PTE and SE. In this paper, the results of horizontal annual analysis and longitudinal intertemporal analysis under three efficiency evaluation modes for LTCFs in 31 provinces and municipalities show that the PTE of most nursing homes is basically stable, and 63.23% of LTCFs in 31 provinces achieves the effective PTE. The average comprehensive efficiency of China's nursing homes is 0.909, and the national average PTE is 0.928, lower than the average SE of 0.979, which is consistent with previous research results of various provinces and cities in China[48,49]. but lower than the average TE, PTE and SE of LTCFs in Xiamen[50], suggesting that the nursing homes of the whole country may have problems of insufficient utilization of scale resources, lower TE and service quality than Xiamen city. From the perspective of scale efficiency, 52.26% of nursing homes in 31 provinces and municipalities were in effective SE, while the effective PTE accounted for 63.23%, suggesting that the smaller proportion of TE of LTCFs (52.26%) may be related to the unreasonable utilization of some LTCFs scale resources. Among them, TE and PTE in nursing homes in 2014 were relatively low (ie, 0.799 and 0.843, respectively) and lower than the average level in 5 years (ie, 0.909 and 0.928), while SE was relatively high (ie,0.948). Therefore, the low PTE in 2014 might be the main reason for the overall technical inefficiency. SE reflects the efficiency of production scale utilization, that is, SE reflects if the operations of nursing homes are under the most appropriate investment scale. During 2012 to 2014, the amount of nursing homes which are in effective TE of Chinese provinces and municipalities presented a decreasing trend, while the number of the nursing homes with effective TE presented an increasing trend on the whole after 2014. The possible reasons behind for the decrease of the efficiency might be the blindly expanded the construction of nursing homes with less standardized management previously. However, China's Ministry of Civil Affairs effectively strengthen the policy support to build up *pension service three years action plan (2014-2016)*. With regard to the facilities construction, since pension service facilities were included in 20 public project each yea, 385 construction pension agency, 1191 community elderly day care centers, and 392 community canteens and catering center were established during the period. As for the standardized management, it has compiled local standards such as *service standards for pension institutions,classification and evaluation of pension institutions*, and formulated implementation *rules for the establishment of pension institutions* and *measures for administration pension institutions* to standardize the management system of pension institutions. Moreover, service reform was carried out by the national pension service comprehensive reform since 2014[51]. A series of national policies laid a great foundation to promote economy and development motivation of pension institution by improving the service specification standards and national investment to expand the scale of the institution.

2. **Spatial, temporal and regional distribution analysis of the operational effectiveness of nursing homes in China**

Nursing homes in Beijing, Guangdong, Tianjin and other economically developed provinces and municipalities have always been technically efficient from 2012 to 2016. Based on enacted policies of Tianjin, it has removed and closed nearly 30 seriously substandard pension institutions by encouraging renovation of firefighting for nursing homes. Referring to the guidelines for the quality inspection of nursing homes nationwide, the policy of "one district one case" and "one hospital one policy" have been adopted to make up for some existing shortcomings[53,54]. The results showed that nursing homes in Shandong province changed from being technical inefficiency in 2014 to an effective TE in 2015. The existing reasons behind might be that in 2014, the "China's 12th five-year plan for the development of

undertakings for the elderly", and "Suggestions on accelerating the development of the elderly care service industry" were comprehensively implemented. Furthermore, the government has allocated services development special funds of 2.4 billion yuan to support the development of pension services industry of market-oriented polit area in Jilin, Shandong and other eight provinces55. All of these were done to effectively promote the nursing homes in Shandong in one year by means of a rapid rise from being technical inefficient into technical efficient.

TFPC of the sample nursing homes from 31 provinces declined by 2.14% during the 5-year period. Although TEC has improved with an average of 0.1%, the average1.7% decrease of TC leads to the decrease of TFPC. Therefore, improving TC to boost TFPC is essential. The results obtained in the nursing homes of 31 provinces are not distinct. Torabipour et al56 studied the productivity changes of hospitals in Ahvaz county from 2007 to 2010 and found that TC played a major role in productivity changes. Li explored the changes in efficiency and productivity of 45 THs in Anhui Province and determined that the efficiency of these hospitals exhibited a downward trend from 2009 to 2011; TEC and TC also decreased by 3.8% and 14.1%, respectively57.According to the average of the efficiency change from 2012 to 2016, almost of the productivity index values of nursing homes improved from 2013 to 2015, while the fluctuation of SE was not as strong as that of TE and PTE, with the relatively smaller SEC. This showed that the improvement of the productivity and TE of nursing homes has not kept pace with the development of the scale of institutions. The SEC of pension institutions in provinces like Hebei and Anhui was increasing, while the PTE and TC have declined to a certain extent. This was an indication that the SEC was too large that it weakened the functions of TE and TC in promoting economic growth. The SEC of nursing homes, on the other hand, in Jiangsu, Henan, Liaoning and other 10 provinces declined, which showed that the technology and resource utilization of nursing homes in less economically developed provinces have not kept pace with the scale development of institutions. The SEC of institutions in Liaoning province decreased, while the PTE and TC both increased. The nursing homes in Liaoning province need to reduce the scale of construction of nursing homes, and also improve the TC and PTE to promote the comprehensive efficiency of institutions.

3. **Comparison of TE of nursing homes in Eastern, Central and Western regions in China**

The TE, PTE, SE of nursing homes in Eastern regions were all the highest, followed by Central region and Western region from 2012 to 2014. The nursing homes in Eastern China have a developed economy, with abundant health resources and a large number of excellent management talents, which can raise the level of efficiency of nursing homes.

PTE of nursing homes is 0.98 in the Eastern region, 0.95 of that in the Central region, and 0.94 of that in the Western region. SE of nursing homes is 0.99 in the Eastern region, 0.99 of that in the Central region, and 0.96 of that in the Western region. However, TE of nursing homes is 0.98 in the Eastern region, 0.93 of that in the Central region, and 0.91 of that in the Western region, with a decrease range of 2%, 7%, and 9%, respectively. This result presented that among these three efficiency values, TE of nursing homes is lowest due to the higher SE of nursing homes in China. The possible reason behind might be due to the expansion of institution scale, which fails to compensate the adverse effects of having insufficient technology during operations of the institution, and then accompanied with inefficient utilization and wasting of input resources. It indicated that there is a need to downsize the scale of nursing homes appropriately to fit the levels of technology among the different regions of China. In addition, the efficiency value of the three regions showed an upward trend after 2014. In the Central and Western regions, the service efficiency of institutions has decreased greatly, which is similar to the research results of Qian Haiyan. It was concluded that there existed significant differences in the efficiency of nursing homes among Eastern, Central and Western regions and also between urban and rural areas according to DEA model analysis58. There are also regional differences in the service efficiency of medical institutions, which are related to the results of the imbalance allocation of medical resources and

multiple levels of economic development among Eastern, Central, and Western regions of China[59]. The level of economic development in the Central region is only followed to that of the Eastern region, however, the service efficiency of the nursing homes in the Central region remains much low. The service efficiency of the old-age care service institutions in the central area urgently needs to be improved overall. It is to optimize organization management and break the development bottleneck caused by low TE. Regarding the Western region, health resources are fewer than other regions with lower service efficiency than that in Central region. Attentions should be paid to the balanced development of the Eastern, Central and western regions. In the future, this should be the main concern.

4. **The adjustment of projected value for non-DEA effective nursing homes in 31 provinces and municipalities of China in 2016**

The average improvement range of the five input indexes of the non-DEA effective nursing homes of 31 provinces was 27.26%, 20.62%, 19.77%, 22.04%, and 38.84%, respectively. Five input indexes included the number of institutions, the number of employees at the end of the year, the original price of fixed assets, the number of social workers, the number of beds at the end of the year. It was noticeable that the number of beds at the end of the year in in non-DEA effective nursing homes needs to be improved the most, which indicated that the construction scale of nursing homes in some provinces were blindly expanded, while the beds occupancy rate of private nursing homes was lower, with amount of idle beds. All of these caused wasting amount of expenditure and capital. In addition, compared with Eastern and other regions, the beds utilization rate was significantly higher than that in the Western region. The available beds in the central urban area are difficult for the older people to get, while the bed utilization rate in the private nursing homes in the suburbs was very low[13]. A survey showed that there were more than 30 private residential cares in Chengdu, with a total of more than 8,000 beds with only 4,500 older people[10]. It was presented that only about half of the beds in the elderly care institutions in Chengdu urban area were applied, and 32.5% of the urban institutions in Tianjin, Harbin, Jinan, Wuhan and other cities are in deficit for a whole year, with an overall low bed occupancy rate[9]. The number of social workers also needs to be improved by 22%, which is consistent with the current situation that China's integrated medical and nursing system is still far from perfect, the corresponding number of nursing staff is still small, and also the professional level is very low. As the service quality of the older adults care depends on the mainstay resources, the competence of social workers is an important reflection of the overall quality of nursing homes. The development of social workers needs the support of the government because of its relevant policies it can introduce. Also, it needs to attach importance to the prospects being trained in social work-related majors in colleges, universities and society, so as to ensure that highly qualified social workers can play an important role in manpower for the elderly care service[60].

5. **The analysis of factors affecting the efficiency of nursing homes, based on Tobit model**

The efficiency value of nursing homes in 31 provinces was influenced respectively by gender and age of employees, the number of social workers, the number of older people in a year. If there are more women in nursing homes, more social workers, and more patients at the end of the year, the TE and productivity of nursing homes will be higher. The age of the employees also has an influence on the efficiency value, if there are more employees in the age of 35 and below, and the more within the age of 46 to 55, the efficiency value in nursing homes will be lower. On the other hand, the more employees who are aged 56 and above, the efficiency value gets to be higher. Mueller et al. (2006) and Castle (2008) consider that the level of professional ability of nursing staff can make a great effect on the service quality and the life quality of the elderly in nursing homes[61]. The research also showed that relatively the young nursing staff, who are mainly women around 40 years old, do not have any sense of longevity with their jobs due to their lack of sufficient skills. However, after long years of working experiences, their level of skills could eventually improve. Also, the nursing staff’s level of professionalism can be improved with more practical experiences, especially for female nurses. Furthermore, they are expected to have more patience and dedication to elderly care, so that the elderly can

obtain better service quality for them to be able to practice self-care ability; thus, improving the outputs and efficiency of nursing homes in the process[62]. A study showed that social workers play an important role in resource integration, emotional supplement, communication and coordination, spiritual support, social function and also in managing of nursing homes. This situation reflects the inadequacy of competent personnel, which resulted in the decline of the efficiency in the social work services[63]. The development of social workers needs to be strengthened the supported by the government by setting up policies, standards and norms to ensure that highly competent social workers can fill in the manpower needed by elderly service institutions. Rosko et al. (1995) conducted a research to evaluate the service efficiency and influencing factors in nursing homes in Pennsylvania, which presented that the occupancy rate of institutions affected the service efficiency[64]. The bed occupancy rate significantly affects the service efficiency, that is, for every 1% increase in occupancy rate, the comprehensive efficiency of pension institutions will increase by 0.871%[65]. As the pension industry development information asymmetry, it is easy to find the phenomenon of vacant beds and a bed at in different regions. However, the number of patients at the end of the year to some extent, can reflect the bed occupancy levels in nursing homes, the recognition of acceptance and the levels of service quality of the elderly.

Strengths And Limitations

This study introduced the DEA method to comprehensively evaluate the performance of nursing homes in China, based on panel data, by analyzing the efficiency and productivity of nursing homes and spatio-temporal variation, as well as its influencing factors in nursing homes all over the country. Furthermore, this data is representative of the status quo in China. Therefore, this study is representative of the overall country and can improve the understanding of the complex efficiency issues in the different regions of China.

However, we believe that this study can still be improved and extended in a number of directions. The first limitation is the limited variables related to the outputs and inputs because of data limitations. Even though we compensate the limitations of previous studies to include outcome quality, further research should be conducted and include more variables of the quality of care to comprehensively analyze the efficiency of the nursing homes. As another limitation of this study, since DEA is a data-oriented method, the efficiency values obtained are directly affected by the combination of inputs and outputs applied. In this study, we calculated efficiency scores using five finance and manpower variables as inputs and five quality-of-care and finance variables as outputs, and we defined the scores as TE of nursing care, according to the study setting, data availability, and researcher decision making. However, further research should explore the standardized criteria and mechanism to appropriately selected to measure the efficiency of decision-making units, for example, qualitative studies could be applied to explore the reasons for the changes in TE and productivity.

Conclusions

This study provides an empirical representation of the efficiency and productivity changes of nursing homes in the process of advancing the marketization of pension services in China. The TFPC of nursing homes in 21 provinces and municipalities experienced a decrease in productivity from 2012 to 2016, while the fluctuation of SEC was not as strong as that of TC and PTEC, with the relatively smaller SEC. The improvement of the productivity and TE of nursing homes has not kept pace with the development of the scale of institutions. So the adverse alteration in TC and PTEC should be emphasized. Compared with Western and Central regions, the TE, PTE, SE of nursing homes in Eastern regions were all the highest, followed by Western region and Central region. Among these three efficiency values, TE of nursing homes is lowest due to the higher SE of nursing homes in China. The results showed that the influencing factors of in nursing homes might include gender and age of employees, the number of social workers, the number of

older people in a year. It was suggested that the country have to attach great importance to the cultivation and improvement of the professional level, educational background and experiences of the professionals for elderly care, so as to meet the diversified needs of different types of elderly groups.

Abbreviations

TE: Technical Efficiency; DEA:Data Envelopment Analysis; BCC model:Banker-Charnes-Cooper model; SBM model:Slacks-Based Measure model; PTE:Pure Technical Efficiency; SE:scale efficiency; TFPC:Total Factor Productivity Changes; LTCFs:Long-term care facilities; TC:Technological Changes; PTEC:Pure Technical Efficiency Changes.

Declarations

Availability of data and materials

Data are available through the China Civil Affairs statistical yearbook.

Ethics approval and consent to participate

The study did not involve human subjects and care was taken to ensure anonymity so that there were no identifiable information of individual nursing home, patient or staff being reported.

Consent for publication

Not applicable.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions:

LW Zhang, Y Han and Y Fang worked together. LW Zhang and Y Han were in charge of the study design. Y Han analyzed and interpreted the data, and drafted the manuscript. Y Fang and LW Zhang participated in the statistical analysis and manuscript drafting. Y Fang supervised and revised the manuscript. All authors have revised, read and approved the final manuscript.

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Tables

Table 1 Description of inputs and outputs

· Primary index	Secondary index	Tertiary index
Inputs	Financial capital	The number of institutions
		The original price of fixed assets
		The number of beds at the end of the year
	Human capital	The number of employees
		The number of social workers
Outputs	Financial capital	Operating income
	Quality of the older people care	The number of disabled
		The number of partially disabled
		The number of independents
		The number of rehabilitation and medical outpatients

Table 2 Summary statistics of input-output variables (from 2012 to 2016)

	Outputs					Inputs				
	O1	O2	O3	O4	O5	I1	I2	I3	I4	I5
2012										
Mean	152148	65453	14604	7221	218607	1429	10671	239816	63	127989
Min	12908	2049	418	5	15	79	513	10158	1	7199
Max	961553	225829	44380	30246	1074797	3386	29491	1041701	209	365270
2013										
Mean	169846	67221	15904	7865	241950	1370	11481	274530	75	138552
Min	3774	3389	392	258	105	78	601	26545	4	7935
Max	497703	232059	48926	28246	1720412	3336	30914	858955	223	399449
2014										
Mean	142765	55502	14800	7606	208109	2978	15359	290807	96	180558
Min	3696	2574	440	105	350	86	627	20523	3	6943
Max	470109	240348	52511	29134	955228	22305	54869	1193418	290	554479
2015										
Mean	138312	44347	12948	7600	269197	895	10266	234295	100	115528
Min	2176	1181	217	16	3605	35	381	8897	3	5022
Max	492278	180009	46398	29471	1436994	2547	30717	851817	353	388561
2016										
Mean	157470	44035	14124	8463	244204	922	10929	260846	132	122186
Min	11630	815	22	29	3535	7	91	22070	4	1124
Max	524550	174632	48365	32577	1187467	2573	33463	1008513	664	410441

Note: O1,operating income; O2, the number of independents; O3, the number of partially disabled; O4, the number of disabled;O5, the number of rehabilitation and medical outpatients; I1the number of institutions; I2, the number of employees at the end of the year; I3, the original price of fixed assets; I4, the number of social workers;I5 the number of beds at the end of the year.

Table 3 The TE evaluation among nursing homes in 31 provinces and municipalities

	TE	PTE	SE
2012	0.932	0.939	0.992
2013	0.922	0.944	0.977
2014	0.799	0.843	0.948
2015	0.959	0.965	0.994
2016	0.933	0.947	0.985
Mean	0.909	0.928	0.979
Mean rank	4.60	6.80	12.60
c^2	8.54		
P	0.014		

Table 4 the number of nursing homes with effective TE, PTE and SE in various provinces and municipalities.

Year	Effective TE	Effective PTE	Effective SE
2012	18	19	18
2013	15	18	15
2014	12	17	12
2015	20	22	20
2016	16	22	16
mean	16.2	19.6	16.2
Proportion	0.522581	0.632258	0.522581

Note: A score =1 indicates Effective TE, PTE and SE

Table 5 evaluation of the Malmquist productivity index

No.	DMUs	TEC	TC	PTEC	SEC	TFPC
1	Beijing	1	1.019	1	1	1.019
2	Tianjin	1	1.055	1	1	1.055
3	Hebei	0.988	0.919	0.987	1.001	0.908
4	Shanxi	0.998	0.973	1.004	0.995	0.971
5	Inner Mongolia	0.976	0.995	0.977	0.999	0.971
6	Liaoning	1.055	0.943	1.063	0.992	0.995
7	Jilin	1	1.015	1	1	1.015
8	Heilongjiang	1	0.932	1	1	0.932
9	Shanghai	1	0.979	1	1	0.979
10	Jiangsu	0.984	0.997	1	0.984	0.981
11	Zhejiang	1	1.02	1	1	1.02
12	Anhui	0.946	0.96	0.945	1.001	0.908
13	Fujian	1.122	0.99	1.118	1.003	1.11
14	Jiangxi	1	0.976	1	1	0.976
15	Shandong	0.999	0.914	1	0.999	0.913
16	Henan	0.983	0.884	0.993	0.99	0.868
17	Hubei	1	0.849	1	1	0.849
18	Hunan	0.977	0.989	1.005	0.973	0.967
19	Guangdong	1	1.04	1	1	1.04
20	Guangxi	1.008	1.058	1.016	0.993	1.067
21	Hainan	1	0.972	1	1	0.972
22	Chongqing	1.018	0.994	1.017	1.001	1.012
23	Sichuan	1	0.935	1	1	0.935
24	Guizhou	0.925	0.856	0.932	0.993	0.792
25	Yunnan	0.981	0.975	0.978	1.003	0.957
26	Tibet	1.013	1.792	1	1.013	1.816
27	Shaanxi	1	0.996	1	1	0.996
28	Gansu	1.02	1.024	1.024	0.996	1.045
29	Qinghai	1	0.882	1	1	0.882
30	Ningxia	1	0.89	1	1	0.89
31	Xinjiang	1.049	0.935	1.041	1.007	0.981
Mean		1.001	0.983	1.003	0.998	0.984

Note: TFPC, total factor productivity changes; PTEC, pure technical efficiency changes; SEC, scale efficiency changes; TC, technological changes; TEC, technical efficiency changes

Table 6 Changes in the average of Malmquist indexes of LTCFs in provinces and municipalities of China from 2012 to 2016.

	TEC	TC	PTEC	SEC	TFPC
2013	0.989	0.952	1.006	0.983	0.942
2014	0.828	0.911	0.856	0.967	0.755
2015	1.264	1.042	1.198	1.055	1.318
2016	0.969	1.034	0.979	0.990	1.002
Mean	1.001	0.983	1.003	0.998	0.984
Mean rank	10.00	10.25	11.00	11.50	9.75
c^2	0.24				
P	0.993				

Note: TFPC, total factor productivity changes; PTEC, pure technical efficiency changes; SEC, scale efficiency changes; TC, technological changes; TEC, technical efficiency changes.

Table 7 Summary of TE, PTE, SE scores according to the different region (2012-2016)

	East	Central	West
TE			
2012	0.9527979	0.9764228	0.9267942
2013	0.971567	0.9488472	0.9274889
2014	0.9529572	0.8219322	0.7887823
2015	1	0.9635217	0.9577605
2016	1	0.9498861	0.9253417
Mean	0.975464	0.932122	0.905234
PTE			
2012	0.9634443	0.9847335	0.9375137
2013	0.9817871	0.962965	0.9450924
2014	0.9583564	0.8465335	0.9211046
2015	1	0.9699101	0.9618286
2016	1	0.964072	0.9339631
Mean	0.98071756	0.945643	0.9399
SE			
2012	0.98894965	0.99156	0.988566
2013	0.98959031	0.985339	0.981374
2014	0.99436619	0.970939	0.856344
2015	1	0.993413	0.99577
2016	1	0.985285	0.990769
Mean	0.99464315	0.985702	0.963117

Table 8 Comparison of efficiency values of nursing homes among Eastern, Central and Western regions from 2012 to 2016

		Mean Rank	c^2	*P*
TE	Eastern region	8.60	1.12	0.572
	Central region	6.30		
	Western region	9.10		
PTE	Eastern region	11.20	6.27	0.043
	Central region	8.60		
	Western region	4.20		
SE	Eastern region	11.20	3.85	0.146
	Central region	6.40		
	Western region	6.40		

Table 9 Adjusted volume and proportion of input indicators in 2016

DMU	The number of institutions		The number of employees		The original price of fixed assets		The number of social workers		The number of beds at the end of the year	
	*NA	%	*NA	%	*NA	%	*NA	%	*NA	%
Hebei	205.6	19.5	6400.8	34.1	190282.4	35.3	25.4	19.5	3145.2	19.5
Shanxi	293.4	50.8	2681.6	42.1	41806.9	30.1	23.6	26.5	13533.9	26.5
Inner Mongolia	236.9	33.2	2374.9	33.2	63201.8	36.7	27.5	33.2	28617.2	33.2
Liaoning	421.8	29.15	1319.5	7.9	21801.2	7.9	58.1	27.0	18039.6	10.7
Heilongjiang	0.8	0.1	9.2	0.1	28513.9	10.9	0.1	0.1	793.7	0.7
Jiangsu	145.9	6.2	2083.3	6.2	172907.5	17.1	23.1	6.2	87739.5	21.4
Anhui	271.1	23.3	3072.6	28.3	56644.1	23.3	27.0	23.3	50081.0	334
Fujian	132.3	38.2	686.6	16.4	20236.4	17.4	24.3	27.0	14236.6	29.7
Shandong	8.1	0.4	8019.6	29.0	2980.9	0.4	117.1	17.6	86740.7	27.0
Henan	217.8	19.0	3948.0	31.1	12386.6	6.8	27.8	22.6	8022.1	6.8
Hunan	753.7	42.2	1858.9	13.4	148558.3	35.3	22.2	12.2	17156.9	12.2
Guangxi	240.0	50.0	1114.6	16.2	3903.8	5.1	90.4	64.1	2119.7	5.1
Guizhou	392.5	45.1	1201.5	26.7	82944.7	45.6	18.1	26.7	19734.4	26.7
Yunnan	40.0	9.7	357.6	9.4	11998.6	9.5	3.9	9.4	4859.8	9.4
Gansu	105.0	42.1	337.2	15.2	12214.6	15.2	8.2	15.2	5218.6	19.7
Total	3464.9	27.26	35465.9	20.62	870381.7	19.77	496.8	22.04	360038.9	38.84

*NA: the number of adjustments

Table 10 Tobit regression analysis of the influential factors on TE of nursing homes

SBM model					BCC model			
	Std.Err	**p**	**95%CI**		**Std.Err.**	**P**	**95%CI**	
cons.	0.0433	0.00	0.7985	0.9697	0.0410	0.00	0.8631	1.0250
Support factors								
Entitled group	0.0000	0.41	(0.0000)	0.0000	0.0000	0.11	(0.0000)	0.0001
Strand group	0.0000	0.11	(0.0000)	0.0000	0.0000	0.24	(0.0000)	0.0000
Self-paid personnel	0.0000	0.11	(0.0000)	0.0000	0.0000	0.10	(0.0000)	0.0000
annual older people	0.0000	**0.01**	0.0000	0.0000	0.0000	0.07	(0.0000)	0.0000
Management factors								
Female	0.0000	**0.00**	0.0000	0.0002	0.0000	**0.00**	0.0001	0.0002
Technical school	0.0001	0.23	(0.0002)	0.0000	0.0001	0.35	(0.0002)	0.0001
College graduate and above	0.0001	0.15	(0.0002)	0.0000	0.0001	0.06	(0.0003)	0.0000
Age 35 and below	0.0000	**0.02**	(0.0002)	(0.0000)	0.0000	0.09	(0.0002)	0.0000
Between 35 to 45	0.0000	0.50	(0.0001)	0.0001	0.0000	0.37	(0.0001)	0.0000
Between 46 to 55	0.0000	**0.00**	(0.0003)	(0.0001)	0.0001	**0.00**	(0.0003)	(0.0001)
Age 56 and above	0.0000	0.06	(0.0000)	0.0001	0.0000	**0.02**	0.0000	0.0002
Social workers	0.0003	0.43	(0.0004)	0.0009	0.0005	**0.04**	0.0001	0.0019
Number of volunteers	0.0000	0.50	(0.0000)	0.0000	0.0000	0.50	(0.0000)	0.0000
Volunteer service hours	0.0000	0.43	(0.0000)	0.0000	0.0000	0.59	(0.0000)	0.0000
Environmental factor								
Construction space	0.0000	0.07	(0.0000)	0.0000	0.0000	0.28	(0.0000)	0.0000
LR	61.1000				63.8800			
R^2	0.3848				0.4900			

Figures

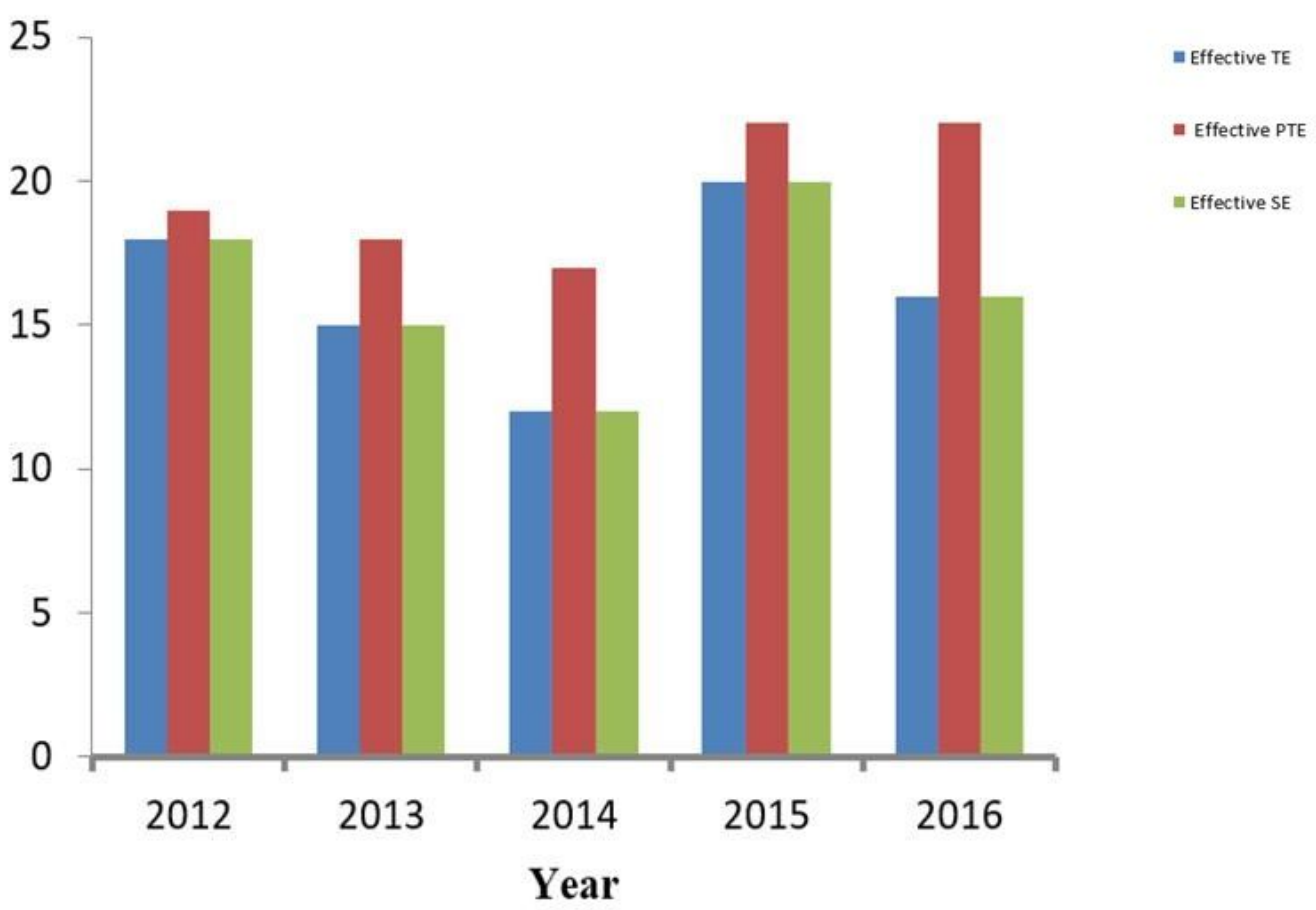

Figure 1

The number of provinces and municipalities with effective TE, PTE and SE from 2012 to 2014

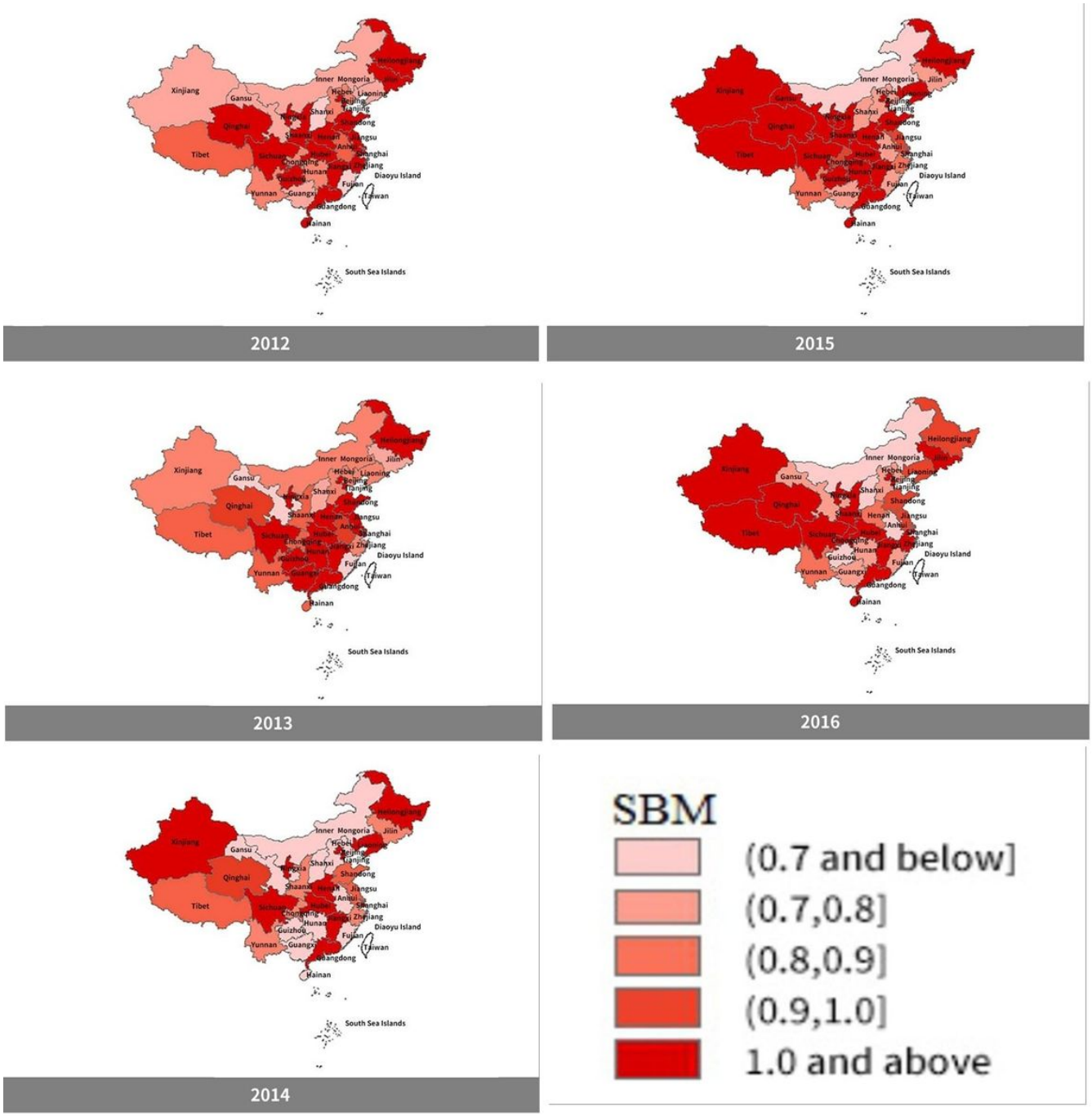

Figure 2

The distribution of TE of SBM in the LTCFs in 31 provinces and municipalities of China from 2012 to 2016

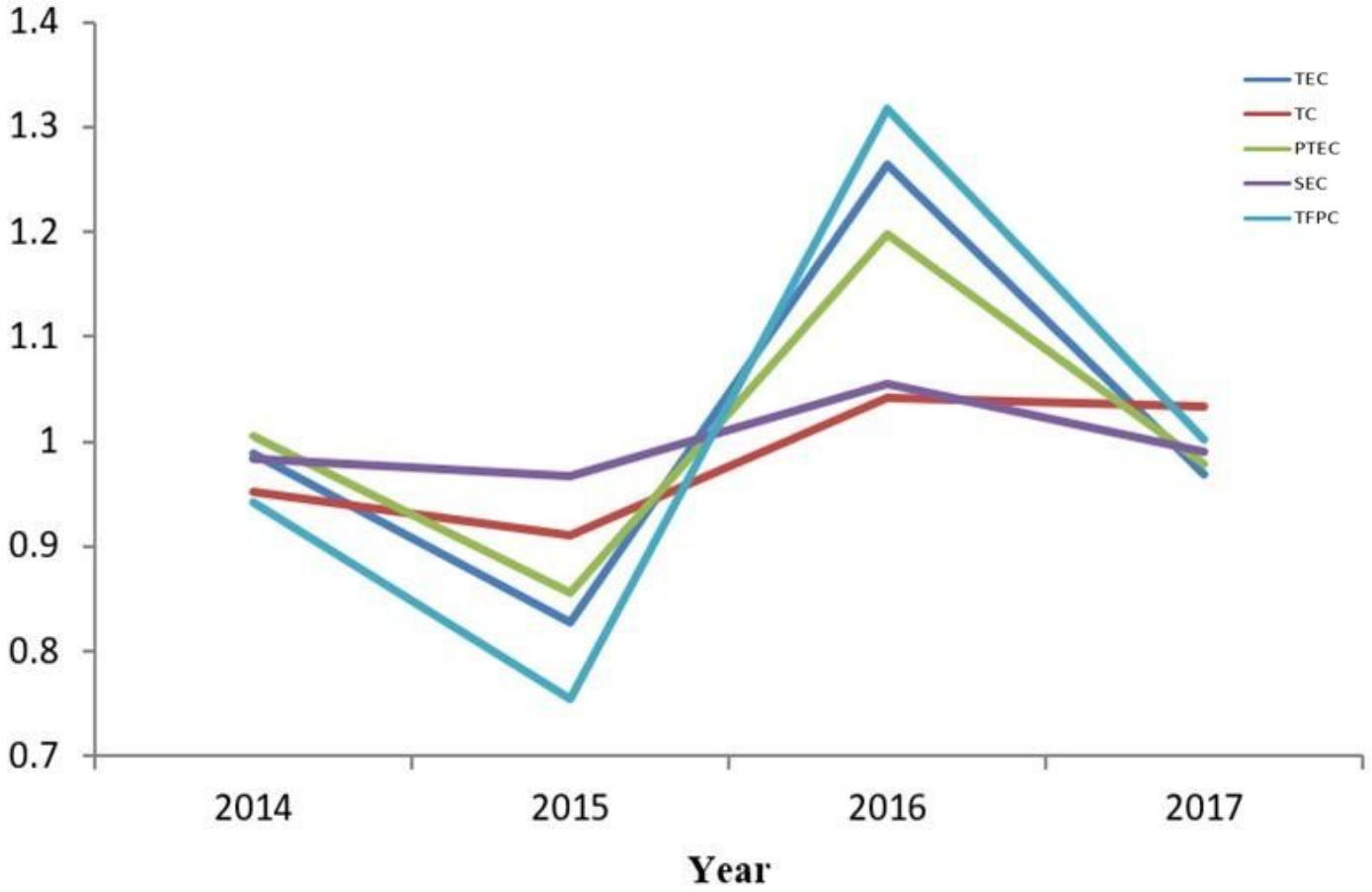

Figure 3

The Malmquist productivity of nursing homes in China and its general evolution trend from 2012 to 2016

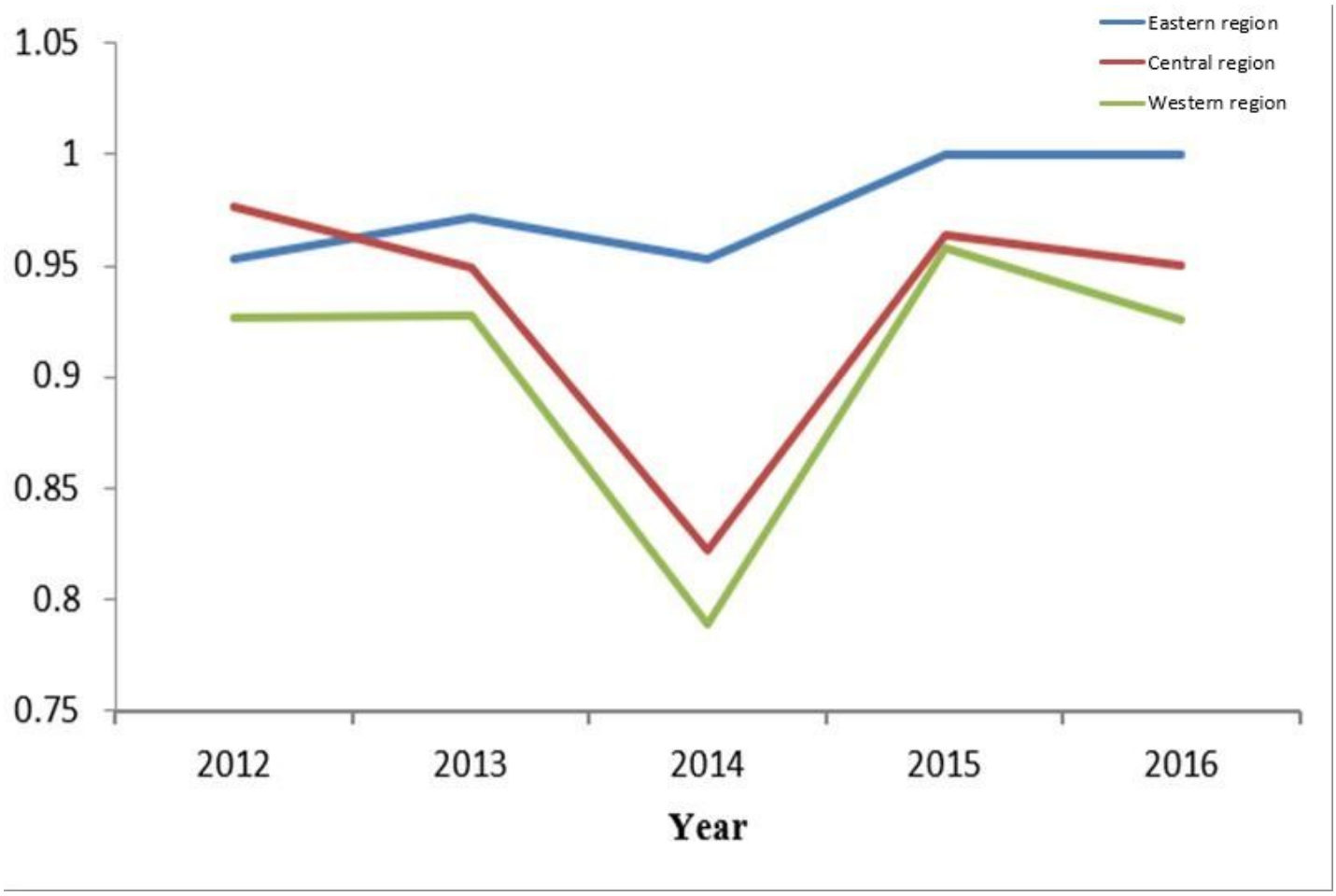

Figure 4

An evolution trend of TE among nursing homes in different regions in China

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