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Original Article

Evaluation of Operational Efficiency of Urban Employees' Endowment Insurance

Mengke Ye[1], Mengjin Yu[2], Zhongqiang Liu[3]

[1,2,3] *School of Mathematics and Information Science, Henan Polytechnic University, Henan, China.*

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Abstract *- In order to overcome the influence of environmental factors and random errors in the traditional data envelopment analysis (DEA) method, this paper selected 9 indicators and used panel three-stage DEA method to study the operation efficiency of urban employee pension insurance fund in 30 provinces (autonomous regions and municipalities directly under the central Government, except Heilongjiang Province) from 2011 to 2020. The results show that environmental factors have an impact on the operation efficiency of urban employee endowment insurance. The innovation of this paper lies in the exclusion of environmental factors through stochastic frontier analysis (SFA), so as to evaluate operational efficiency more accurately.*

Keywords *- Conditional expectation, DEA model, Normal distribution, Stochastic frontier analysis, Technical efficiency.*

1. Introduction

With the rapid development of economy, people's living standards are constantly improving. We find that while life expectancy is increasing, fertility is decreasing. Followed by "population aging", it has become a serious problem facing more and more countries. As early as 1999, China entered the aging society. In recent years, as the aging degree of population is becoming more and more serious, the endowment insurance system in our country is facing great pressure. Countries are also making their own contributions to the old-age insurance industry, and introducing appropriate policies to deal with the aging population. China is no exception. In order to reduce the pension risks brought by the aging population, the Chinese government has made a series of efforts in formulating the pension insurance system: In 2009 and 2011, the new rural social endowment insurance and urban residents social endowment insurance were implemented on a pilot basis, and in 2014, they were merged into the unified basic endowment insurance for urban and rural residents (" urban and rural residents insurance "for short). The completion of this work marks the formation of the world's largest number of insured people and the most extensive beneficiaries of the pension insurance safety net. With the expansion of the fund income and expenditure scale and the number of people covered by the system, it becomes extremely important to analyze the operating efficiency of the system. We hope to evaluate the errors in policy design and actual operation of endowment insurance for urban and rural residents by summarizing previous experience. And we use these experience on the work in the future, so as to achieve the purpose of improving efficiency.

Since the beginning of its operation, the endowment insurance for urban residents has been paid close attention by the academic circle. It is worth noting that some scholars have studied the efficiency of urban residents. Data show that among various methods, most scholars choose DEA model to study the operational efficiency of pension insurance:

In the analysis of the operational efficiency of Chinese pension insurance based on DEA, Yuanyuan Peng found that the efficiency of basic pension insurance in Jiangsu Province was generally not high, and the lack of technical efficiency came from the inefficiency of scale efficiency.

Xiaoling Liu and Kuntai Tu [1] also used DEA model to study the operational efficiency of urban and rural residence insurance funds in Jiangsu Province. Finally, it is concluded that the overall operation efficiency of pension insurance in Jiangsu Province is not high, and there are large regional differences.

Zhiguang Li and Xu Si et al [7] used the three-stage DEA model to analyze the basic pension insurance system in 31 provinces of China from 2014 to 2019, and concluded that the operation efficiency of the basic pension insurance is in a high level. But there is still a great room for improvement.

Wenjie Yang et al used the DEA model and Malmquist model to analyze the basic old-age insurance of Chinese urban enterprise staff and staff through the construction of index evaluation system. The results show that the operational efficiency of basic old-age insurance for urban employees in the 31 provinces, municipalities and autonomous regions is increasing [26].

Xiuling Yang, Yan Wei et al. first selected input and output indicators according to weights. Then they used the PCA-DEA model to study the operational efficiency of our basic endowment insurance system. Finally, they found that the overall operational efficiency was at a good level. But there are obvious regional gaps [27].

Shaowei Ma, Jiuyang Zhao et al[3]. analyzed the operating efficiency of the basic medical insurance fund for urban and rural residents of Xinjiang Corps based on the DEA model and drew the following conclusions: First, if the medical insurance policy is changed, the comprehensive efficiency of the fund will change accordingly. However, it has little effect on pure technical efficiency and great effect on scale efficiency. Secondly, it is found that the allocation of medical insurance resources has not reached the optimal ratio. Finally, this paper puts forward some suggestions on rational allocation of medical insurance resources, improvement of medical insurance system construction and formulation of appropriate policies.

Based on the DEA method, Jingzhong Xu et al. comprehensively evaluated the operating efficiency of the basic endowment insurance for urban and rural residents in different provinces in 2014. It is worth mentioning that they found that only a few areas have realized the rational allocation of resources, and most areas have a waste of resources. The author also puts forward some reasonable suggestions for the problems of regional differences and unbalanced development[10].

2. Index selection, Environmental Variables and Data Sources

2.1. Input and output indicators

If you want to analyze the operational efficiency of urban staff pension insurance, the key problem to be solved first is to determine the input-output index. The selection of indicators should be appropriate. If too many indicators are selected, there will be information duplication and mutual interference among indicators. On the contrary, if the selected indicators are too few, it will not be comprehensive enough, resulting in incomplete information, which will have a certain impact on the authenticity of the results. Therefore, the construction of evaluation index system should follow the principles of systematicness, consistency, independence, feasibility and comparability. It is worth noting that, in the design of indicators, the overlap between indicators should be fully considered to prevent the results from being biased and misleading. In order to ensure the accuracy of the measurement of the operational efficiency of the urban staff pension insurance, the author has consulted a large number of literature, and considered the previous research results and the actual situation of the basic pension insurance. Finally, the number of insured employees at the end of the year (NIE) , the number of insured retirees at the end of the year (NIR) and the income of pension insurance fund (FI) are selected as the input index, the expenditure of pension insurance fund (FE) , the accumulated balance of endowment insurance (APB) is used as the output index [6].

2.2. Environmental Variables

In addition to input and output indicators, environmental variables do have an impact on efficiency. But they are not subject to the subjective control of samples and cannot be changed in a short time. This paper takes the level of economic development (LED), the level of urbanization (LU), the dependency ratio of elderly population (DREP) and the scale of government public expenditure (SGPE) as the environmental variables.

The gross regional product (GDP) is often used to represent the level of regional macroeconomic development, and the effective operation of the endowment insurance system cannot be separated from the financial subsidies and support of the local government, which will also have a certain correlation with regional macroeconomic development. [16].

The LU refers to the degree of urbanization of a region, which is usually expressed by the percentage of urban population and urban population in the total population. The higher the percentage, the higher LU. The scale effect formed by population agglomeration will promote the growth of local employment situation and economic development, promote the improvement of residents' income level, thus promote the growth of regional productive value, and then affect the operation of the endowment insurance system.

As an embodiment of the population structure, the old-age dependency ratio will have a certain impact on the operating efficiency of the pension insurance system, and the public's social security needs are closely related to various demographic factors. Therefore, the DREP can be used to measure the influence of aging on the operation efficiency of the basic endowment insurance funds.

The level of local public finance expenditure is measured by the ratio of local public finance expenditure to the gross regional product. The financial subsidy income has always been the main part of the pension fund income, to a certain extent, it will affect the scale and efficiency of the regional social security fiscal expenditure. Therefore, the SGPE can be regarded as an environmental indicator affecting the operation efficiency of the basic endowment insurance fund.

Table 1. Input and output indicators and environmental variables

Indicators classification	Indicators name	Indicators symbol	Indicators unit
Input indicators	Number of insured employees at the end of the year	NIE	Ten thousand people
	Number of insured retirees at the end of the year	NIR	Ten thousand people
	Pension insurance fund income	FI	Hundred million
Output indicators	Pension insurance fund expenditure	FE	Hundred million
	Accumulated pension balance	APB	Hundred million
Environmental variables	Level of economic development	LED	One trillion
	Level of urbanization	LU	%
	Dependency ratio of elderly population	DREP	%
	Scale of government public expenditure	SGPE	%

2.3. Data Sources

In this paper, the operational efficiency of urban employee pension insurance fund is studied in 30 provinces from 2011 to 2020. The data of input and output indicators are from China Statistical Yearbook, provincial Statistical Yearbook and National Data. In order to more accurately analyze the regional differences in efficiency, the 30 provinces were divided into three regions: eastern, central and western.

3. Materials and Methods

3.1. The introduction to DEA

A review of the literature reveals that there are many ways to measure efficiency. We can divide these methods into parametric and nonparametric methods: (1) Stochastic Frontier Analysis (SFA), Distribution Free Analysis (DFA), Thick boundary Function Analysis (TFA), and Thick Recursive Frontier Analysis (TRFA); (2) Data Envelopment analysis (DEA) and Free Disposal Hull (FDH) [2].

From the principle of each method, DEA method has a great advantage in dealing with multi-input and multi-output problems, and has been widely used in practice. In 1978, the DEA method and its model were proposed by A. C. harnes and W.W. C. Looper, famous American operational research scientists [8]. Since the method was proposed, it has been widely used in different industries.

DEA is a quantitative analysis method to evaluate the relative effectiveness of comparable units of the same type. SFA is a function of input, output and environmental factors, and is affected by random errors and inefficiencies. This method can effectively distinguish invalid items from error items. However, compared with the DEA method, its limitation is that it can only measure the performance of a single output. Then the advantage of DEA method appears.

3.2. Construction of three-stage data envelopment analysis method

With the development of society, the traditional DEA model has been unable to satisfy the practical application. In order to solve practical problems better, three-stage DEA model appears in people's vision. This method was proposed by Fried et al in 2002. They combined the nonparametric DEA model with the parametric method's SFA (Stochastic Frontier Analysis) model, thus making up for the defects of the traditional DEA model [9].

The three-stage DEA model believes that the relaxation variables of input (or output) are affected by external environmental factors, random disturbance (mainly from the measurement errors of input and output data) and management inefficiency. Only by eliminating external environmental factors and random interference can a more realistic efficiency value be obtained.

This paper adjusts the input (or output) variables by relaxing variables, and studies the operational efficiency of the basic pension fund by using the adjusted input (or output) variables. The adjusted input (or output) of each DMU eliminates the influence of external environment and random factors on the efficiency, making the efficiency of DMU more accurate and real.

Efficiency is the ratio of input to output. Taking the jth decision unit as an example, it is assumed that there are s inputs and t outputs. Then,

$$h_j = \frac{\sum_{r=1}^{t} v_r y_{rj}}{\sum_{i=1}^{s} u_i x_{ij}} \tag{1}$$

Where,h_j is the efficiency of the first DMU. $x_{ij}$and y_{ij}represents the input and output of the first decision making unit. $u_r$and $v_i$respectively represents the combined weight of input and output.

In the first stage of the model, the input-oriented BCC model is used to calculate the technical efficiency, pure technical efficiency and scale efficiency of each DMU. Technical efficiency is the resource allocation ability and resource utilization efficiency of the DMU. Pure technical efficiency is the combination state of production factors that reflects the optimal scale of DMU influenced by management and technical level. Scale efficiency reflects the size of DMU and the effect of resource allocation on it. And there is the following relationship between them. When technical efficiency is equal to 1, it means that DMU is technically efficient; When technical efficiency is less than 1, it means that the DMU has not reached production optimization. The BCC model based on the variable return to scale hypothesis can be expressed as:

$$\min \theta \tag{2}$$

$$s.t. \quad \begin{aligned} & \theta \geq \frac{\sum_{i=1}^{s} \lambda_i x_i}{x_0} \\ & \sum_{j=1}^{t} \lambda_j y_j \geq y_0 \\ & \sum_{i=1}^{s} \lambda_i = 1 \\ & \sum_{j=1}^{t} \lambda_j = 1 \\ & \lambda_i, \lambda_j \geq 0 \end{aligned}$$

Where θ is unconstrained. It represents the ratio of minimum input to actual input. This objective function pursues the minimum value of i so as to obtain the maximum output with the minimum input.$x_i$andy_j respectively represent the ith input and jth output of DMU.$\lambda_i$and$\lambda_j$respectively represent the weight of input and output of DMU.$x_0$andy_0 represent the original input and output combination vectors, respectively [5].

In the second stage, The SFA method is used to remove the influence of environmental factors and management efficiency on the efficiency value, so that all DMU are in the same external environment. The explained variable is the relaxation value of the input variable in the results of the first stage, and the explanatory variable is the environment variable. Therefore, the established SFA model is as follows:

$$S_{ni} = f(z_i; \beta_n) + v_{ni} + \mu_{ni}; i = 1,2, \cdots, N \tag{3}$$

Where S_{ni} represents the slack value of the nth input of the ith DMU. $v_{ni} + \mu_{ni}$is the comprehensive interference term. Where v_{ni} represents a random interference and is assumed to follow normal distribution, i.e $v_{ni} \sim N(0, \sigma_{v_n}^2)$; μ_{ni} represents the management factor and assume that it follows the truncated normal distribution, i.e $\mu_{ni} \sim N(0, \sigma_{\mu_n}^2)$; $f(z_i; \beta_n)$ represents the impact of environmental variables on the input slack variable S_{ni} [11].

Next, adjust the input variables [20].
Suppose there are I DMUs and N input variables,

$$X = (x_1, x_{2,} \cdots, x_I) = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1I} \\ x_{21} & x_{22} & \cdots & x_{2I} \\ \vdots & \vdots & & \vdots \\ x_{N1} & x_{N2} & \cdots & x_{NI} \end{pmatrix}$$

Where X representing $N * I$ dimension input matrix, X_n represents the nth row of the input matrix.

$$\lambda = (\lambda_1, \lambda_2, \cdots, \lambda_I)^T = \begin{pmatrix} \lambda_{11} & \lambda_{12} & \cdots & \lambda_{1I} \\ \lambda_{21} & \lambda_{22} & \cdots & \lambda_{2I} \\ \vdots & \vdots & & \vdots \\ \lambda_{I1} & \lambda_{I2} & \cdots & \lambda_{II} \end{pmatrix}^T$$

Where λ is the combination coefficient of each unit, and the input of the ith DMU in the nth input is x_{ni}. $X_n\lambda_i$ is the optimal mapping of the nth input of the ith DMU on the efficiency frontier. The relaxation of the nth input variable of the ith DMU is S_{ni}, namely:

$$S_{ni} = x_{ni} - X_n\lambda_i, n = 1,2, \cdots N; i = 1,2, \cdots, I \quad (4)$$

In order to separate the comprehensive disturbance term, the expected value formula of management inefficiency under the stochastic frontier cost function model is as follows [15]:

$$E(\mu_{ni}|\varepsilon_{ni}) = \frac{\eta\sigma}{1+\eta^2}\left[\frac{\varphi(\frac{\varepsilon_{ni}}{\sigma})}{\phi(\frac{\varepsilon_{ni}}{\sigma})} + \frac{\varepsilon_{ni}\eta}{\sigma}\right] \quad (5)$$

Where $\varepsilon_{ni} = \mu_{ni} + v_{ni}$ represents the comprehensive interference of SFA model.

$$\sigma^2 = \sigma_\mu{}^2 + \sigma_v{}^2,$$
$$\eta = \frac{\sigma_\mu}{\sigma_v}$$

$\varphi(\cdot)$ represents the probability density function of standard normal distribution, and $\phi(\cdot)$ represents the distribution function of standard normal distribution.

According to Formula (5), we can obtain the expected value of the random interference term, namely:

$$E(v_{ni}|\varepsilon_{ni}) = S_{ni} - f(z_i; \beta_n) - E(\mu_{ni}|\varepsilon_{ni}) \quad (6)$$

Finally, we use the regression results of the SFA model to adjust the input variables of each DMU in the following manner:

$$x_{ni}{}^* = x_{ni} + [max_i\{f(z_i; \beta_n)\} - f(z_i; \beta_n)] + [max_i\{v_{ni}\} - v_{ni}] \quad (7)$$

Where $x_{ni}{}^*$ is the adjusted input variable, x_{ni} is the original input variable in the first stage, z_i is the observed value of environmental variable, β_n is the estimated parameter of environmental variable, v_{ni} is the random error obtained by the nth input of the ith DMU, $[max_i\{f(z_i; \beta_n)\} - f(z_i; \beta_n)]$ means to adjust all DMUs to the same environment, $[max_i\{v_{ni}\} - v_{ni}]$ means to adjust all DMUs to the same conditions [12].

In the third stage, we use the traditional DEA-BCC model. Change the input variable in the first stage to the adjusted input variable in the second stage. And the technical efficiency, pure technical efficiency and scale efficiency are recalculated. At this time, the efficiency has eliminated the influence of environmental factors and random interference, and the result is more true and accurate than that in the first stage [21].

4. Results

4.1. Correlation Result Analysis

Due to the negative accumulated balance of pension insurance in Heilongjiang and incomplete data, considering the authenticity of the calculation results, the author studied the efficiency operation of pension insurance funds for urban employees in other 30 provinces from 2011 to 2020. First, the correlation test of the 10 indicators that may have an impact on the efficiency is carried out. And the influencing factors with a large correlation are selected, while the factors with a small correlation with other factors are eliminated. By observing the results of the correlation coefficients of 10 indicators in the 10 years from 2011 to 2020, the consumer price index will be eliminated, so there are only 9 effective indicators [13].

4.2. Result Analysis of the First Stage

By consulting literature and studying the actual situation of our urban employee endowment insurance, it is suitable to make an investment index, the NIE, the NIR, the FI. The suitable indicators for output include the FE and the APB. Figure1 1-30 correspond to Beijing municipal, Tianjin municipal, Hebei province, Shanxi province, Inner Mongolia Autonomous Region, Liaoning province, Jilin province, Shanghai municipal, Jiangsu province, Zhejiang province, Anhui province, Fujian province, Jiangxi province, Shandong province, Henan province, Hubei province, Hunan province, Guangdong province, Guangxi province, Hainan province, Chongqing municipal, Sichuan province, Guizhou province, Yunnan province, Tibet Autonomous Region, Shaanxi province, Gansu province, Qinghai province, Ningxia Hui Autonomous Region and Xinjiang province respectively [23].

Assuming variable returns to scale, R software is used to analyze the original input and output. And input-oriented BCC model is used to calculate the technical efficiency, pure technical efficiency, scale efficiency and return to scale of the operation of urban employee pension insurance fund in 30 provinces of China from 2011 to 2020. First, as the table2 shows, on the whole, the efficiency of urban employees' endowment insurance operates better within the sample year. Guangdong province and Tibet Autonomous Region maintained a technical efficiency of 1 for 10 consecutive years. Shanxi Province, Shanghai municipal, Qinghai Province and Ningxia Hui Autonomous Region maintained a technical efficiency of 1 for 9, 7, 7 and 6 consecutive years respectively in the annual sample. And the average technical efficiency of Fujian province, Anhui province, Jiangxi province and Henan province was below 0.9, showing a large room for improvement. Second, from the regional perspective, the average technical efficiency of eastern, central and western regions is 0.949, 0.903 and 0.931, respectively. It shows a trend of eastern > western > central. The national average level of technical efficiency is 0.931, and the level of technical efficiency in the central region has not reached the national level. Third, technical efficiency can be decomposed into pure technical efficiency and scale efficiency, namely: technical efficiency = pure technical efficiency* *scale efficiency [24]. Low scale efficiency and pure technical efficiency are the main reasons restricting the improvement of technical efficiency in central and western regions respectively. Fourth, from the perspective of the scale presents the results of the remuneration of 2020, Beijing municipal, Shanghai municipal, Zhejiang province, Guangdong province, the scale of five provinces in the state of constant return. Most provinces are under increasing scale. Liaoning province, Jiangsu province, Shandong province, Shanxi province, Xinjiang province is in a state of diminishing returns of scale. It shows where the diminishing returns of scale, increasing input will improve the operation efficiency of endowment insurance [4].

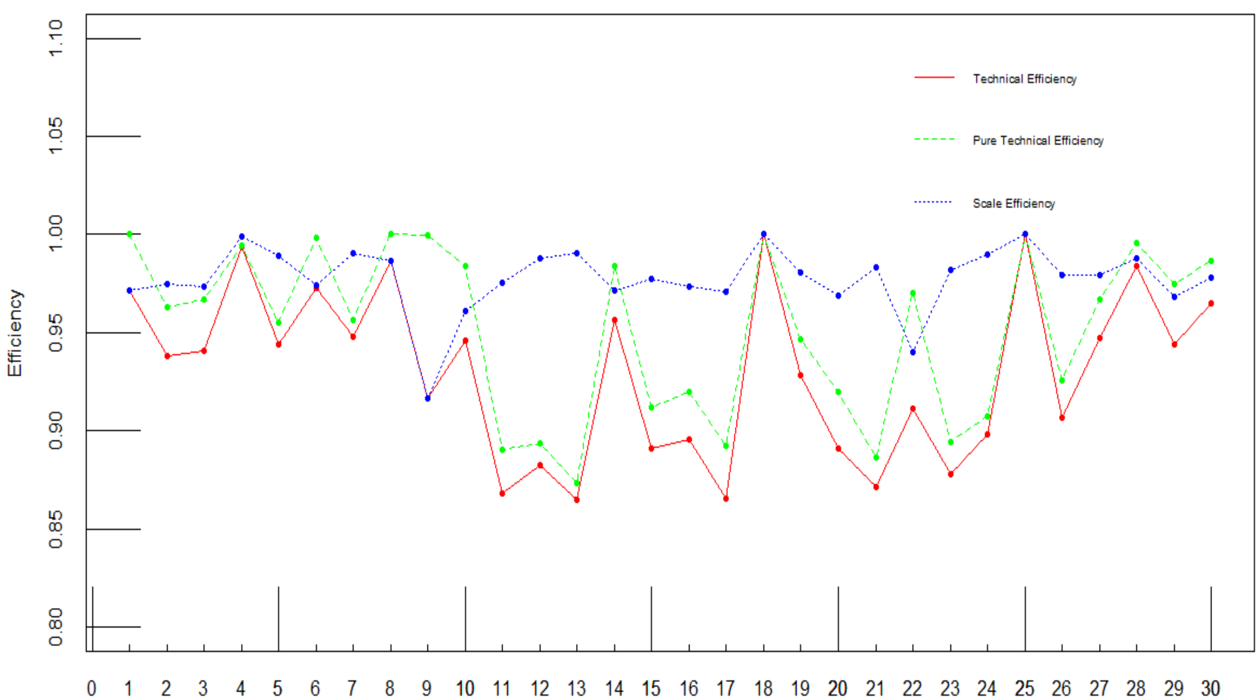

Fig. 1 Comparison of average efficiency in the first stage of the 10 years from 2011 to 2020 among 30 provinces

Table 2. Technical efficiency of old-age insurance for urban employees in China from 2011 to 2020

Region	Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
Eastern China	Beijing	0.984	0.936	0.929	0.952	0.916	1	1	1	1	1	0.972
	Tianjin	1	0.995	0.973	0.946	0.895	0.929	0.922	0.955	0.920	0.848	0.938
	Hebei	0.960	0.989	0.966	0.989	0.984	0.949	0.905	0.932	0.932	0.804	0.941
	Shanxi	1	1	1	1	1	1	1	1	1	0.935	0.994
	Shanghai	1	1	1	1	1	0.924	1	0.963	0.978	1	0.987
	Jiangsu	0.918	0.845	0.912	0.897	0.880	0.931	0.977	0.932	0.949	0.924	0.917
	Zhejiang	0.958	0.897	0.951	0.898	0.851	0.941	0.964	1	1	1	0.946
	Fujian	0.928	0.922	0.896	0.889	0.839	0.873	0.908	0.871	0.880	0.826	0.883
	Shandong	0.991	0.973	0.977	0.993	0.900	0.928	1	0.959	0.970	0.871	0.956
	Guangdong	1	1	1	1	1	1	1	1	1	1	1
	Hainan	0.921	0.987	0.957	0.975	0.874	0.831	0.843	0.932	0.864	0.830	0.901
	Mean	0.966	0.954	0.956	0.954	0.914	0.937	0.956	0.958	0.954	0.913	0.949
Central China	Liaoning	0.931	0.937	0.911	0.977	0.993	1	1	1	1	0.976	0.973
	Jilin	0.977	1	0.995	1	0.995	0.933	0.882	0.831	0.965	0.901	0.948
	Anhui	0.865	0.852	0.822	0.842	0.813	0.873	0.929	0.907	0.924	0.855	0.868
	Jiangxi	0.924	0.812	0.878	0.899	0.845	0.878	0.835	0.836	0.950	0.792	0.865
	Henan	0.931	0.895	0.883	0.895	0.901	0.896	0.908	0.922	0.880	0.799	0.891
	Hubei	0.806	0.888	0.942	0.969	0.913	0.918	0.962	0.943	0.849	0.765	0.910
	Hunan	0.862	0.865	0.867	0.892	0.905	0.890	0.917	0.782	0.904	0.775	0.866
	Mean	0.899	0.893	0.900	0.925	0.909	0.913	0.919	0.889	0.925	0.850	0.903
Wester China	Inner Mongolia	0.920	0.978	1	1	0.954	0.929	0.832	0.954	1	0.875	0.944
	Guangxi	1	0.952	1	0.988	0.940	0.925	0.884	0.896	0.904	0.796	0.929
	Chongqing	0.881	0.838	0.867	0.855	0.852	0.871	0.963	0.903	0.903	0.782	0.872
	Sichuan	0.873	0.876	0.903	0.901	0.908	0.998	0.795	0.954	1	0.902	0.911
	Guizhou	0.916	0.829	0.877	0.896	0.817	0.925	0.925	0.854	0.912	0.827	0.878
	Yunnan	0.858	0.867	0.934	0.921	0.874	0.814	1	0.905	0.943	0.870	0.899
	Tibet	1	1	1	1	1	1	1	1	1	1	1
	Shannxi	0.975	0.920	0.901	0.947	0.947	0.915	0.896	0.877	0.914	0.775	0.907
	Gansu	0.905	0.974	1	0.976	1	0.988	0.939	0.911	0.936	0.845	0.948
	Qinghai	0.920	1	1	1	1	0.920	1	1	1	0.919	0.976
	Ningxia	1	1	1	1	0.937	0.870	0.937	0.913	0.971	0.813	0.944
	Xinjiang	1	0.955	0.974	0.971	0.948	1	1	0.948	0.990	0.862	0.965
	Mean	0.937	0.932	0.955	0.955	0.932	0.930	0.931	0.926	0.956	0.856	0.931
Mean of all provinces		0.940	0.933	0.944	0.949	0.923	0.928	0.937	0.929	0.948	0.876	0.931

Due to the different economic conditions and other environments of different regions, the above table is the technical efficiency calculated without considering environmental factors and random errors, which does not really reflect the actual situation. Therefore, it is necessary to evaluate the operating efficiency of urban workers' pension fund after eliminating the influence of environmental factors and random error factors[28].

4.3. Result Analysis of the Second Stage

Due to the different geographical locations and development policies of different regions, there are inevitable objective differences in their economic and social development levels, which is also an important reason for the great differences in the external environment faced by the urban employee system of different regions. The efficiency value obtained in the first stage includes the influence of external environment variables and random errors on the efficiency value. In order to obtain a more realistic efficiency value, it is necessary to avoid the influence of these irrelevant factors as much as possible. If these factors are not taken into account, the actual efficiency may be overestimated or underestimated. Therefore, it is necessary to estimate the impact of environmental variables and random errors on the efficiency value. The author uses the Stochastic Frontier Analysis (SFA) to calculate the above factors and remove their influences. Stochastic frontier analysis (SFA) adjusts the input variables, and gets new input variables that are not affected by external environment or random errors[29].

In the second stage, the explained variable is the relaxation value of the input variable in the results of the first stage, and the explained variable is the four environment variables.σ_μ is the management efficiency error, σ_v is random factor error.

$$\Gamma = \frac{\sigma_\mu^2}{\sigma_\mu^2 + \sigma_v^2}$$

If Γ is closer to 1, the greater the impact of environmental factors on efficiency, so it is necessary to adjust the original input variables. Since the environmental variable is a regression of the relaxation value of the input variable, when the correlation coefficient (parameter) is positive, it means that the increase of the environmental variable is conducive to the increase of the relaxation value of the input variable. In other words, if the coefficient is positive, it means that the increase of the environmental variable, then the relaxation value of the input variable will also increase, which will lead to the waste of the input factors and is not conducive to the improvement of efficiency; if it is negative, it is the opposite.

Table 3. The second stage panel SFA regression results important parameters

	NIE	NIR	FI
Parameter	Γ	Γ	Γ
	β_0,β_1,β_2,β_3,β_4	β_0,β_1,β_2,β_3,β_4	β_0,β_1,β_2,β_3,β_4
	σ_μ,σ_v	σ_μ,σ_v	σ_μ,σ_v
2011	1.86E-08	1.00E+00	0
	120.6337,-0.45935,-7.65551,-0.35585, -3.90361	-0.0002753,-3.70252E-05,1.68439E-05, -8.583E-07,9.4849E-06	0,0,0,0,0
	9.33E-05,5025.214	187.6106,3.50E-09	0,0
2012	7.78E-07	1.00E+00	0
	-130.171,70.96808,0.73171,2.955957, 4.330806	-0.000275282,-3.70252E-05,1.68439E-05, -8.583E-07,9.4849E-06	0,0,0,0,0
	0.011838,15223.84	130.0931,9.64E-08	0,0
2013	9.82E-09	1.00E+00	0
	63.14222,29.25089,0.493252, -2.8806,-5.83699	-15.9152,-0.64022,0.0468,0.27056,0.96268	0,0,0,0,0
	0.000109,11110.5	398.2765,1.26E-05	0，0
2014	1.00E+00	4.46E-08	0
	1.75898,0.01039,-0.01436, -0.74777,0.01939	-25.6351,-1.4825,-0.36896,-0.08758,4.449075	0,0,0,0,0
	46572.37,3.33E-08	9.30E-06,208.3823	0，0
2015	9.17E-01	5.45E-06	0
	347.8066,80.34793,-2.96556,-7.47141, -8.41441	-102.316,-3.2111,-0.73527,0.667549,13.60645	0,0,0,0,0

	25501.14,2316.732	0.007296,1339.269	0，0
2016	1.57673E-06	1	0
	113.012036,51.615377,-3.986795, -3.460664,7.49771	0.0090477,-0.0014998,-0.0003994, -0.0120497,0.0024833	0,0,0,0,0
	0.15247203,121.425821	22.66445896,2.0025E-05	0,0
2017	6.27E-08	1.57475E-06	0
	115.6521,3.2985734,-1.0490914, -4.6787744,-1.9393187	-47.701905,3.892771, -0.69851,1.31996,6.208482	0,0,0,0,0
	0.012718097,50.77615582	0.036496575,29.08349876	0,0
2018	1	2.91217E-07	0
	13.7139,-0.01542,-0.12267,-2.42596, -0.08031	-46.5884568,-1.9690084, -0.1403015,0.931197,4.4121319	0,0,0,0,0
	205.6779,0.000936	0.01574,29.1673	0,0
2019	0.000248	6.27122E-09	0
	236.135,14.64558893,-3.86061023, -9.90851148,2.89630162	1.92695,-0.9621874,-0.0136037, -0.313334,0.3648588	0,0,0,0,0
	1.9504,123.7764	0.000762,9.6223	0,0
2020	1	2.45E-09	0
	-0.001181,0.000002956,-0.000003279, -0.000051817,0.000003763	-143.8834441,-0.6363932, -0.4504191,4.9736856,10.7568139	0,0,0,0,0
	187.2813392,0.00008842	0.002488,50.2605	0,0

Take the data of 2020 as an example for analysis.

Level of economic development (LED). The regression coefficient of this variable is positive for the NIE, and the regression coefficient for the NIR is negative. It indicates that the improvement of regional macroeconomic development level is conducive to promoting the operation efficiency of urban employees' basic endowment insurance. The higher the level of regional economic development, the more abundant the financial resources of local governments. Then there will increase the intensity of urban employees pension insurance subsidies [17].

Level of urbanization (LU). The regression coefficient of the LU on the NIE and the NIR is negative. It indicates that the convergence of production factors caused by the increase of the LU promotes the rapid development of regional economy, alleviates the pressure of local financial subsidies for urban and rural residential insurance, and is conducive to the improvement of the operation efficiency of urban workers' pension insurance.

Scale of government public expenditure (SGPE). The regression coefficient of the SGPE on the NIE is negative, and the regression coefficient of the SGPE on the NIR is positive. It shows that the increase of the SGPE has a great promoting effect on the improvement of the efficiency of urban employees' pension insurance.

Dependency ratio of elderly population (DREP). The regression coefficients of this variable on the NIE and the NIR are both positive. It can be concluded that the DREP is not conducive to the improvement of the operational efficiency of the old-age insurance for urban employees[30].

4.4. Result analysis of the third stage

The input variable adjusted in the second stage is used to replace the original input variable. And the BCC model with R software is used to re measure the technical efficiency, pure technical efficiency and scale efficiency of 30 provinces in China from 2011 to 2020. Figure1 1-30 correspond to Beijing municipal, Tianjin municipal, Hebei province, Shanxi province, Inner Mongolia Autonomous Region, Liaoning province, Jilin province, Shanghai municipal, Jiangsu province, Zhejiang province, Anhui province, Fujian province, Jiangxi province, Shandong province, Henan province, Hubei province, Hunan province, Guangdong province, Guangxi province, Hainan province, Chongqing municipal, Sichuan province, Guizhou province, Yunnan province, Tibet Autonomous Region, Shaanxi province, Gansu province, Qinghai province, Ningxia Hui Autonomous Region and Xinjiang province respectively.

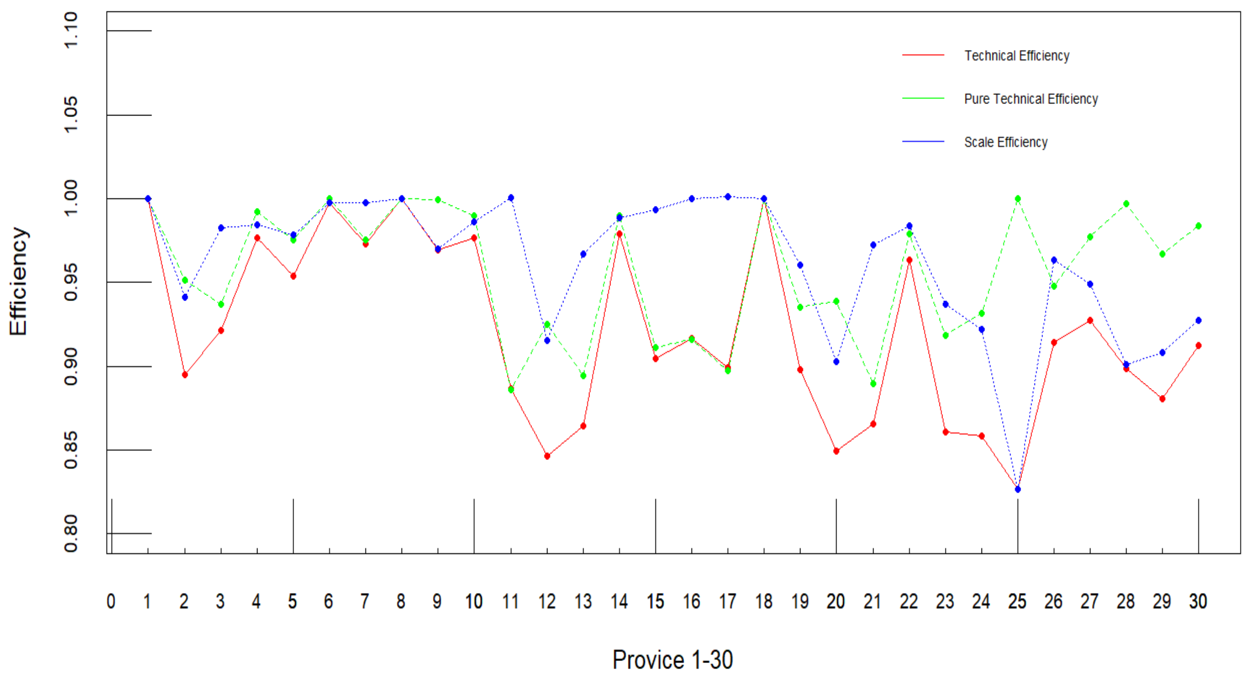

Fig. 2 Comparison of average efficiency of 30 provinces in the third stage from 2011 to 2020

The efficiency of the two stages has a certain deviation after removing the impact of environmental impact and random interference, which shows that the work done in the second stage is meaningful[31].

It can be seen from the table 4 that the average technical efficiency of the eastern region, the central region and the western region in the sample year is 0.949, 0.917 and 0.897 respectively. It shows a trend of eastern>central>western, which is different from the results of the first stage. However, after excluding the impact of environmental impact and random interference items, the average technical efficiency of 30 provinces in the sample year decreased from 0.930 to 0.921. The overall effectiveness decreased. Especially in the western provinces, the technical efficiency basically decreased by different extents. Especially in Tibet Autonomous Region, decreased to 0.826 from phase I technology effective, the lowest among the 30 provinces. The average technical efficiency of the western region was 0.897, which changed from the average of more than 30 provinces before the adjustment to below the average. While in the eastern region, except Tianjin province, Hebei province, Fujian province and Hainan province, the technical efficiency has decreased, other regions have seen a small increase. While Guangdong province is still technically effective, which shows that the basic operating efficiency of old-age care is relatively stable. In the central region, except for the decrease in Shanxi province and the stability in Jiangxi province, there has been a small increase. But the overall average technical efficiency has not exceeded the average value of 30 provinces. From this point of view, there are great differences in the operating efficiency of UEPI in different regions [18].

Next, a deeper analysis is made from the perspective of pure technical efficiency and scale efficiency.

Table. 4 Results of Stage 1 and Stage 3

Region		Results of Stage 1			Results of Stage 3			Lifting range		
		TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
Eastern China	Beijing	0.972	1.000	0.972	1.000	1.000	1.000	0.029	0	0.029
	Tianjin	0.938	0.963	0.975	0.895	0.952	0.941	-0.046	-0.012	-0.034
	Hebei	0.941	0.967	0.973	0.922	0.937	0.983	-0.020	-0.031	0.010
	Liaoning	0.973	0.998	0.974	0.998	1.000	0.998	0.026	0.002	0.024
	Shanghai	0.986	1.000	0.986	1.000	1.000	1.000	0.014	0	0.014
	Jiangsu	0.917	1.000	0.917	0.970	1.000	0.970	0.058	0	0.058
	Zhejiang	0.946	0.984	0.961	0.977	0.990	0.986	0.032	0.006	0.026
	Fujian	0.883	0.894	0.988	0.847	0.925	0.916	-0.041	0.035	-0.073
	Shandong	0.956	0.984	0.972	0.979	0.990	0.989	0.024	0.006	0.018
	Guangdong	1.000	1.000	1.000	1.000	1.000	1.000	0	0	0
	Hainan	0.891	0.920	0.969	0.850	0.939	0.903	-0.047	0.020	-0.068
	Mean	0.946	0.974	0.972	0.949	0.976	0.971	0.003	0.002	0
Central China	Shanxi	0.994	0.995	0.999	0.977	0.992	0.985	-0.017	-0.002	-0.014
	Jilin	0.948	0.957	0.990	0.973	0.975	0.998	0.027	0.019	0.007
	Anhui	0.868	0.891	0.975	0.887	0.886	1.001	0.021	-0.005	0.026
	Jiangxi	0.865	0.873	0.990	0.865	0.894	0.967	0	0.024	-0.023
	Henan	0.891	0.920	0.977	0.905	0.911	0.994	0.015	-0.001	0.017
	Hubei	0.896	0.920	0.974	0.917	0.916	1.000	0.024	-0.004	0.027
	Hunan	0.866	0.893	0.971	0.899	0.898	1.001	0.038	0.006	0.031
	Mean	0.904	0.920	0.982	0.917	0.925	0.992	0.015	0.005	0.010
Western China	Inner Monglia	0.944	0.955	0.989	0.954	0.975	0.978	0.010	0.021	-0.011
	Guangxi	0.929	0.947	0.981	0.898	0.935	0.960	-0.032	-0.012	-0.021
	Chongqing	0.872	0.886	0.983	0.865	0.890	0.973	-0.007	0.004	-0.011
	Sichuan	0.911	0.970	0.940	0.964	0.979	0.984	0.058	0.010	0.047
	Guizhou	0.878	0.894	0.982	0.861	0.918	0.937	-0.019	0.027	-0.045
	Yunnan	0.899	0.908	0.990	0.859	0.932	0.922	-0.044	0.027	-0.069
	Tibet	1.000	1.000	1.000	0.826	1.000	0.826	-0.174	0	-0.174
	Shannxi	0.907	0.926	0.979	0.914	0.948	0.964	0.008	0.024	-0.016
	Gansu	0.947	0.967	0.979	0.927	0.978	0.949	-0.021	0.011	-0.031
	Qinghai	0.984	0.996	0.988	0.899	0.997	0.901	-0.087	0.002	-0.088
	Ningxia	0.944	0.975	0.968	0.881	0.967	0.909	-0.067	-0.007	-0.061
	Xinjiang	0.965	0.987	0.978	0.913	0.984	0.927	-0.054	-0.003	-0.051
	Mean	0.932	0.951	0.980	0.897	0.959	0.936	-0.036	0.009	-0.044
Mean of all Provinces		0.930	0.952	0.977	0.921	0.957	0.962	-0.010	0.006	-0.015

Abbreviations: TE, technical efficiency; PTE, pure technical efficiency; SE, scale efficiency

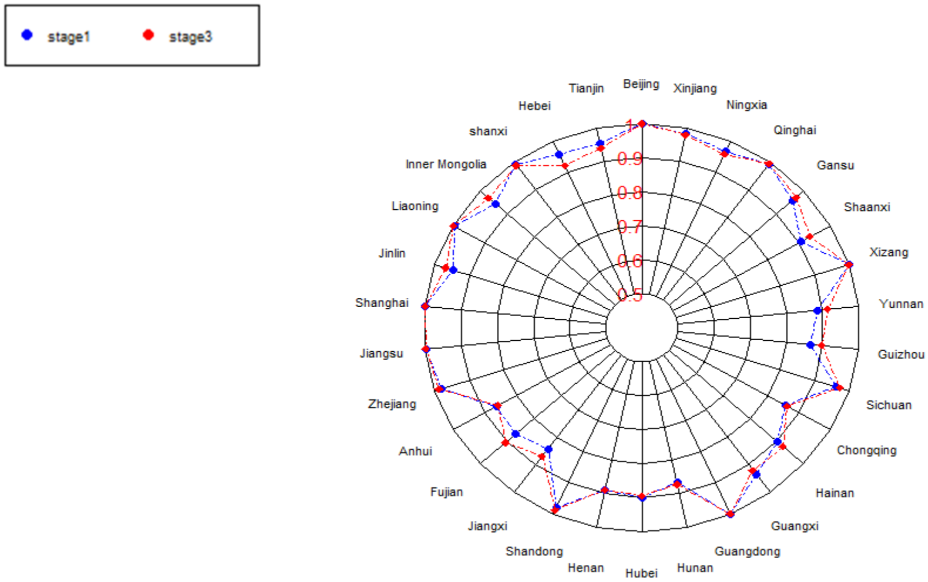

Fig. 3 Pure technical efficiency radar chart

It can be seen from the figure 3 that, compared with the technical efficiency, the change range of pure technical efficiency is not large after removing the influence of environmental factors and random interference items. In Beijing municipal, Liaoning province, Shanghai municipal, Jiangsu province, Guangdong province and Tibet Autonomous Region, the pure technical efficiency has reached 1 after adjustment, indicating that their input resources have been fully and effectively utilized. While other regions are in technical inefficiency. Among them, Anhui province has the lowest value of pure technical efficiency, indicating that there are problems in the allocation of resources. However, on the whole, the average pure technical efficiency of the 30 provinces has reached 0.957, and the resource utilization rate is considerable. However, in some regions with relatively low efficiency values, such as Anhui province, Jiangxi province, Hunan province and Chongqing municipal. There is still much room for improvement in resource allocation.

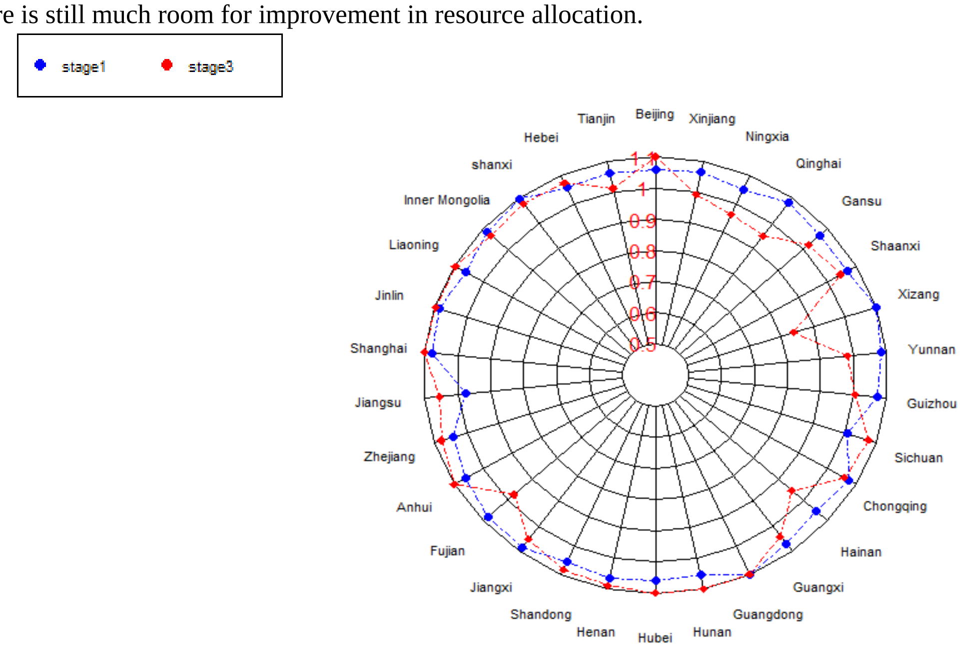

Fig. 4 Scale efficiency radar chart.

After excluding the impact of environmental factors and random interference items, the average scale efficiency of pension insurance for urban employees in 30 provinces decreased from 0.977 to 0.962. It can be seen from the figure that before the adjustment, Tibet was effective in scale. But after the adjustment, it became ineffective in scale and was the lowest scale efficiency value. It can be seen that its effectiveness in pure technical efficiency cannot make up for the defects in scale efficiency. Guangdong province has achieved scale effectiveness before and after the adjustment. In addition, Beijing municipal, Shanghai municipal, Anhui province, Hubei province, and Hunan province have not achieved scale effectiveness before the adjustment, but have achieved it after the adjustment. It indicates that their capital scale is relatively reasonable, and the difference in the optimal business scale is not large [25].

4.5. Research Conclusions and Policy Recommendations

According to China's economic development level and geographical location, combined with other realistic factors, the 30 provinces in China are divided into three major regions. Namely, the eastern region, the central region and the western region. From the regional perspective, the average technical efficiency of the east, central and west in the third stage is 0.949, 0.917 and 0.897 respectively, showing a trend of east> central >west, which is different from the results of the first stage. The average technical efficiency of the western region decreased most obviously. From the overall higher than the central part of the first stage to lower than the central part, it can be seen that it is greatly influenced by environmental factors and random disturbances. The higher pure technical efficiency and scale efficiency of the eastern region ensure the leading technical efficiency, matching its better economic strength and regional level. The overall operating efficiency of the central region is higher than that of the western region, which may also be because it has received more financial support and preferential policies in terms of social security and people's livelihood in recent years [14].

5. Conclusion

The three-stage DEA model is used to analyze the operation efficiency of UEPI in 30 provinces of China. The NIE, the NIR and the FI as input indicators. The FE and the APB as output indicators. The LED, the LU, the DREP, and the SGPE as environmental variables. The technical efficiency, pure technical efficiency and scale efficiency of 30 provinces were measured in China from 2011 to 2020. On the whole, the operation efficiency of UEPI is good, but there is still much room for improvement [19].

By comparing the efficiency before and after removing the impact of environmental factors and random interference items, it can be seen that they have a greater impact on the operating efficiency. After removal, the technical efficiency, pure technical efficiency and scale efficiency of each region have different gaps [22]. They have obvious regional characteristics, and are closely related to the policies of each region.

In order to further optimize the allocation of resources and improve efficiency, the following suggestions are put forward: First, the government should strengthen the supervision of the operation process of pension insurance funds in various regions, implement each step in place, avoid "cutting corners", "unfair distribution" and other situations. Resources can be properly tilted to the western region on the basis of reasonable allocation, and full consideration should be given to the impact of environmental factors; Secondly, the government should further improve the pension insurance system, realize rapid and clear information sharing, ensure that every worker is registered, and avoid repeated registration, repeated work and other waste of resources, so as to maximize the use of resources; Finally, due to the different characteristics of the operating efficiency of pension insurance in different regions, the government is required to "adjust measures to local conditions", make targeted plans according to the situation of each region, strengthen implementation, strengthen the responsibility of the management, and avoid "false big empty".

It is worth noting that due to the incomplete and unstable data of Heilongjiang Province, the data were excluded in this paper. Thus, the authenticity of the results is increased, but the comprehensiveness of the conclusion may be affected to some extent. In addition, when adjusting the input data of the provinces, the author adjusted the environmental factors and random interference factors to make the results more credible. However, considering the amount of calculation and the actual situation, the situation of management inefficiency was retained and all factors other than input were not eliminated, which should be explored in future studies.

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