



Efficiency Measurement of Financial Subsidies for Agricultural Insurance and Analysis of Provincial differences—A Study Based on Super-SBM Model and Malmquist Index

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Abstract. The efficiency evaluation of financial subsidies for agricultural insurance is of great significance to promote the high-quality development of regional agriculture. Taking the 31 provinces, autonomous regions and municipalities directly under the central government as decision-making units, this paper uses the Super SBM model and Malmquist total factor productivity index to make an empirical quantitative analysis of the efficiency of financial subsidies for agricultural insurance in China from 2017 to 2020. The results show that the overall growth of financial subsidies for agricultural insurance in China has remained stable, while at the provincial level, it has changed to varying degrees in space during the observation period. However, some provinces are still in a state of inefficiency, indicating that there is still much room for improvement in domestic agricultural development. The efficiency of agricultural insurance subsidies shows a spatial pattern of “the East is higher than the middle, and the middle is higher than the west”.

Keywords: Efficiency of financial subsidies for agricultural insurance · Super SBM model · Malmquist index

Since 2007, the central government has implemented a financial subsidy policy for agricultural insurance, that is, mainly through the central government and governments at all levels to bear part of the net premium of agricultural insurance for insured farmers, so as to reduce the insurance cost of farmers and mobilize the enthusiasm of farmers to participate in insurance. However, at present, the premium subsidy for agricultural insurance has far exceeded the self-paid premium of farmers. Does such a high proportion of subsidies achieve the expected effect of the policy? How to evaluate the efficiency of agricultural insurance subsidies in China and then seeking a practical way to improve the efficiency of the use of fiscal funds has become a standing problem in the field of agricultural insurance, which will also be discussed in this paper.

At present, the relevant literature on the efficiency of agricultural insurance financial subsidies mainly uses DEA method and its derivative model to study the efficiency of

agricultural insurance financial subsidies in China. Zhao Junyan et al. (2015) and Feng Wenli et al. (2015) respectively used BCC and CCR models to measure and analyze the efficiency of agricultural insurance financial subsidies in China. Wang Ren et al. (2016) used the Three-stage DEA model to calculate the efficiency of financial subsidies for agricultural insurance in China, believing that the overall efficiency is at a high level. Huang Yuanji et al. (2018) used DEA Tobit model to identify inefficient decision-making units, their efficiency values, and analyzed the factors affecting their efficiency. According to the empirical results of the three stages of DEA, Ning Wei et al. (2021) divided provinces and cities into two categories: insufficient efficiency of agricultural insurance subsidies and redundant efficiency of subsidies, and then discussed the improvement direction of agricultural insurance subsidy efficiency according to economic conditions.

Although the above literature uses different methods to calculate the efficiency of financial subsidies for agricultural insurance in China, the traditional DEA models may overestimate the efficiency of decision-making units, and lead to the efficiency value of multiple decision-making units being 1 at the same time. Based on this, to improve the reliability and accuracy of efficiency evaluation, this paper uses Super SBM model and Malmquist total factor productivity index to quantitatively analyze the agricultural insurance subsidy efficiency of 31 provinces, autonomous regions and municipalities directly under the central government (excluding Hong Kong, Macao and Taiwan, the same below).

1 Research Method and Index Selection

1.1 Research Method

To achieve the aim of evaluating the efficiency of agricultural insurance financial subsidy in China more comprehensively, Malmquist index will be used to further analyze the changes in agricultural insurance financial subsidy efficiency in different time periods.

Super SBM Model. Andersen & Petersen (1993) proposed Super Efficiency Model (Super-DEA). Tone (2001) proposed a Slack Based Measure (SBM-DEA) based on relaxation variables. In the SBM model, the proportional improvement of invalidity and the improvement of relaxation variables are considered. Tone (2002) proposed Super SBM model based on SBM model. The Super SBM model is actually a non-radial mode of the Super DEA model. The model considers the relaxation variables involved in the input and output indicators in practical problems, and can avoid the deviation of the results. Therefore, this paper chooses Super SBM model. The model assumes that there are n Decision-Making Units (DMU), which are recorded as \mathbf{DMU}_j ($j = 1, 2, \dots$). Each DMU has m inputs and s outputs, which are recorded as \mathbf{x}_j ($= 1, 2, \dots$) and \mathbf{y}_j ($r = 1, 2, \dots$) respectively. The Super SBM model under variable returns to scale can be expressed as:

$$\delta^* = \min \delta = \frac{\frac{1}{m} \sum_{i=1}^m \frac{\bar{x}_i}{x_{i0}}}{\frac{1}{s} \sum_{r=1}^s \frac{\bar{y}_r}{y_{r0}}} \quad (1)$$

$$\left\{ \begin{array}{l} \bar{x}_i \geq \sum_{j=1, j \neq 0}^n x_{ij} \lambda_j \\ \bar{y}_r \leq \sum_{j=1, j \neq 0}^n y_{rj} \lambda_j \\ \bar{x}_i \geq x_{i0} \\ \bar{y}_r \leq y_{r0} \\ \bar{y} \geq 0 \\ \lambda \geq 0 \text{ 且 } \sum_{j=1, j \neq 0}^n \lambda_j = 1 \end{array} \right.$$

Among them δ^* is the efficiency value of super efficiency SBM, λ is a weight vector.

Malmquist Index Model. In 1953, Sten Malmaquist first proposed the Malmquist index. färe et al.(1992) first used DEA method to calculate Malmquist index and split the index into two directions: one is efficiency change (EC), which mainly reflects the change of input-output ratio; The second is technological change (TC), which mainly reflects the changes in the production frontier of the whole industry.

The value of efficiency change and technology change can be greater than 1, less than 1 or equal to 1, indicating that the efficiency has improved, declined or remained unchanged compared with the previous year. Malmquist index can reflect the impact of time on the efficiency of production units by constructing time series functions.

Assuming that x^t 、 y^t and x^{t+1} 、 y^{t+1} represent the values of the evaluated DMU_k in periods t and t + 1, respectively, the Malmquist index from period t to t + 1 is expressed as:

$$MI(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{E^t(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^{t+1}(x^t, y^t)}} \tag{2}$$

$E^t(x^t, y^t)$ and $E^t(x^{t+1}, y^{t+1})$ are the efficiency values of DMU_k in two periods, then the efficiency change is shown in Eq. (3) and the technical change is shown in Eq. (4):

$$EC = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \tag{3}$$

$$TC = \sqrt{\frac{E^t(x^t, y^t)}{E^{t+1}(x^t, y^t)} \frac{E^t(x^{t+1}, y^{t+1})}{E^{t+1}(x^{t+1}, y^{t+1})}} \tag{4}$$

The Malmquist index can be broken down into two parts: efficiency change and technology change:

$$MI = \sqrt{\frac{E^t(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^{t+1}(x^t, y^t)}} = \frac{E^{t+1}(x^{t+1}, y^{t+1})}{E^t(x^t, y^t)} \times \sqrt{\frac{E^t(x^t, y^t)}{E^{t+1}(x^t, y^t)} \frac{E^t(x^{t+1}, y^{t+1})}{E^{t+1}(x^{t+1}, y^{t+1})}} \tag{5}$$

= EC × TC

1.2 Selection of Evaluation Indicators

In this paper, the central financial subsidy quota and the provincial and below-provincial financial (hereinafter referred to as local financial) subsidy quota are used as input indicators, and the premium income, depth and density of agricultural insurance are used as output indicators. The data are from the official website of the provincial finance department and the statistical yearbook of all the provinces. The indicators are shown in Table 1.

Table 1. Input output indicators of financial subsidies for agricultural insurance.

Index variable	Variable name	Index variable	Variable name
Input variable	Central subsidy quota (x1) Local subsidy quota (x2)	Output variable	Agricultural insurance premium income(y1) Agricultural insurance density(y2) Depth of agricultural insurance (y3)

2 Empirical Analysis of the Efficiency of Financial Subsidies for Agricultural Insurance

2.1 Efficiency Calculation of Agricultural Insurance Financial Subsidy Based on Super SBM Model

This study uses MaxDEA8.21 software, combined with the panel data of 31 provinces, autonomous regions and municipalities directly under the central government from 2017 to 2020, the efficiency of agricultural insurance financial subsidies is calculated based on Efficiency calculation of agricultural insurance financial subsidy based on Super SBM model. The efficiency value and ranking results are shown in Table 2.

Table 2. The calculation results of Super SBM model

DMU	2017		2018		2019		2020	
	value	ranking	value	ranking	value	ranking	value	ranking
BJ	1.3874	2	1.3703	2	1.3950	2	1.2719	2
TJ	1.0546	5	1.1914	3	1.2982	3	1.2172	3
LN	0.9492	15	0.9651	14	0.8826	19	0.8912	17
SH	2.8268	1	2.7306	1	2.9615	1	3.5735	1
JS	1.0432	6	1.0382	4	1.0664	4	1.0711	4
ZJ	0.7364	31	0.7329	31	0.7358	31	0.7335	31
FJ	0.8758	22	0.9312	15	0.9051	15	0.9135	14
SD	1.0259	8	1.0279	5	0.8882	18	0.8870	18
GD	0.8663	23	0.8719	23	0.8597	25	0.8675	23
Eastern mean	1.1962	—	1.2066	—	1.2214	—	1.2696	—
HE	0.9176	19	0.9259	16	0.8914	16	0.9031	15
SX	0.7465	30	0.7483	29	0.7572	29	0.7667	29
JL	0.9219	18	0.9212	18	0.9113	14	0.9216	13
HL	0.9844	13	0.9834	13	0.9739	9	0.9852	10
AH	0.9107	20	0.9114	19	0.8638	24	0.8665	25
JX	0.9586	14	1.0123	8	1.0207	6	1.0276	6
HA	0.9357	17	0.9865	12	0.9466	11	0.9331	11
HB	0.8638	24	0.8787	22	0.8886	17	0.8956	16
HN	0.9951	11	0.9977	10	1.0189	7	1.0101	8
HI	0.9468	16	0.8386	27	0.8679	23	0.8674	24
Central mean	0.9181	—	0.9204	—	0.9140	—	0.9177	—
IM	0.9933	12	0.9904	11	0.9879	8	1.0053	9
GX	0.8463	25	0.8684	25	0.8438	26	0.8473	26
CQ	1.0706	4	0.9259	17	0.9682	10	1.0365	5
SC	1.0384	7	1.0202	6	0.9244	13	0.9239	12
YN	0.7592	29	0.7463	30	0.7532	30	0.7438	30
GZ	0.8463	26	0.8788	21	0.8694	22	0.8691	22
XZ	1.1061	3	1.0014	9	0.9315	12	0.8716	21
SN	0.8275	27	0.8679	26	0.8737	20	0.8768	20
GS	0.7694	28	0.7768	28	0.7914	27	0.7873	27
QH	1.0179	9	0.8691	24	0.7775	28	0.7758	28

(continued)

Table 2. (continued)

DMU	2017		2018		2019		2020	
	value	ranking	value	ranking	value	ranking	value	ranking
NX	0.9021	21	0.8871	20	0.8728	21	0.8856	19
XJ	1.0130	10	1.0172	7	1.0339	5	1.0270	7
Western average	0.9325	—	0.9041	—	0.8856	—	0.8875	—
Annual average	1.0044	—	0.9972	—	0.9923	—	1.0082	—

As can be seen from Table 2: The efficiency of agricultural insurance financial subsidies in various provinces across the country is quite different. In these four years, the efficiency of subsidies has steadily increased in 13 provinces. 7 provinces remained a stable level with not much change in subsidy efficiency, while another 11 provinces had varying degrees of decline in subsidy efficiency. The overall fluctuation of the efficiency of agricultural insurance financial subsidies in China is relatively small, showing a trend of steady development with a slight improvement over the years. The efficiency of agricultural insurance subsidies in the three major regions of China shows obvious differences. On the contrary, the average efficiency in the western region continued to decline, while the average efficiency in the central region fluctuated and remained stable as a whole.

In order to more intuitively observe the spatial characteristics and differences of the efficiency of agricultural insurance financial subsidies in 31 provinces, autonomous regions and municipalities directly under the central government, This paper uses ArcGIS 10.2 software to analyze the spatial pattern of the efficiency of agricultural insurance financial subsidies in 2017 and 2020, respectively, in Fig. 1 and 2.

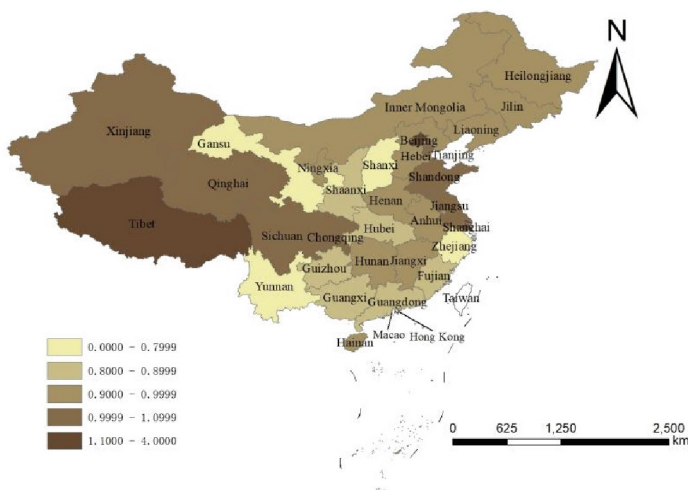


Fig. 1. 2017

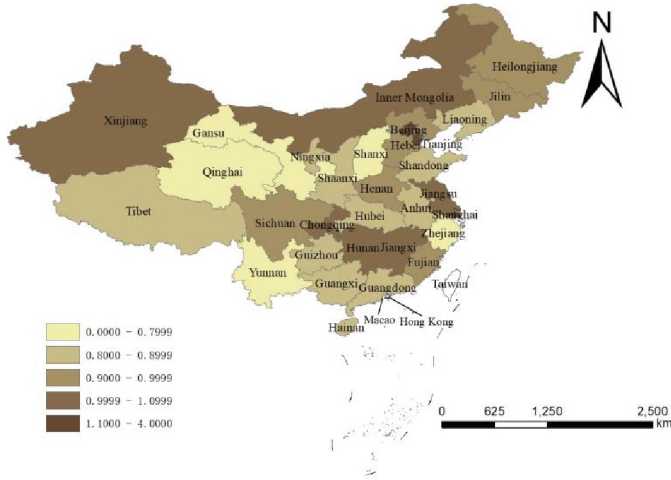


Fig. 2. 2020

2.2 Analysis of Total Factor Productivity Based on Malmquist Index

Using MaxDEA8.21, the Malmquist index of agricultural insurance financial subsidies in 31 provinces, autonomous regions and municipalities directly under the central government from 2017 to 2020 can not only get the efficiency changes in different periods, but also reflect the progress of technology, that is, the movement of production frontier, so as to realize the dynamic analysis of the efficiency of agricultural insurance financial subsidies in various provinces. The specific calculation results and analysis are as follows:

The calculation result of Malmquist total factor index shows the change of the efficiency level of fiscal subsidy policy in these years compared with the previous year. Table 3 clearly reflects the change of Malmquist index of agricultural insurance financial subsidy efficiency in 31 provinces, autonomous regions and municipalities directly under the central government from 2017 to 2020, from 0.982 to 1.040, indicating that the overall production frontier has increased, showing an upward trend.

Malmquist productivity index can be divided into economic efficiency change index (EC) and technological progress efficiency change index (TC). The economic efficiency change index represents the contribution of capital allocation and subsidy scale to the change of efficiency level. The efficiency change index of technological progress represents the contribution of technological and institutional improvement to the change of efficiency level.

According to Table 4, the average total factor productivity of the efficiency of agricultural insurance financial subsidies in various provinces in China from 2017 to 2020 is 1.0112, indicating that the overall premium efficiency level is improving. According to the change rate of economic efficiency of 0.9968 and the efficiency of technological progress of 1.0160, it can be seen that the improvement of the efficiency of financial

Table 3. Malmquist index and sub value of agricultural insurance financial subsidy efficiency

DMU	2017–2018			2018–2019			2019–2020		
	MI	EC	TC	MI	EC	TC	MI	EC	TC
BJ	0.911	0.988	0.922	1.008	1.018	0.990	1.367	0.912	1.499
TJ	0.909	1.130	0.804	1.005	1.090	0.922	0.981	0.938	1.046
LN	1.015	1.017	0.998	1.015	0.914	1.110	1.031	1.010	1.021
SH	1.034	0.966	1.070	0.994	1.085	0.917	1.106	1.207	0.917
JS	1.008	0.995	1.013	1.047	1.027	1.020	1.067	1.004	1.062
ZJ	1.000	0.995	1.005	1.000	1.004	0.996	1.025	0.997	1.028
FJ	0.942	1.063	0.886	0.963	0.972	0.991	0.979	1.009	0.970
SD	1.012	1.002	1.011	1.013	0.864	1.173	1.010	0.999	1.011
GD	1.022	1.006	1.016	1.019	0.986	1.034	1.026	1.009	1.017
HE	1.012	1.009	1.003	1.013	0.963	1.052	1.038	1.013	1.025
SX	1.000	1.002	0.998	1.027	1.012	1.015	1.044	1.013	1.031
JL	1.047	0.999	1.047	1.032	0.989	1.043	1.036	1.011	1.025
HL	1.019	0.999	1.020	1.017	0.990	1.027	1.024	1.012	1.012
AH	1.006	1.001	1.006	1.002	0.948	1.057	1.017	1.003	1.014
JX	1.067	1.056	1.010	1.020	1.008	1.011	1.096	1.007	1.089
HA	1.020	1.054	0.967	1.017	0.960	1.060	1.041	0.986	1.056
HB	1.038	1.017	1.020	1.052	1.011	1.040	1.032	1.008	1.024
HN	1.006	1.003	1.003	1.016	1.021	0.995	1.074	0.991	1.083
HI	0.847	0.886	0.956	1.006	1.035	0.972	1.076	0.999	1.077
IM	1.017	0.997	1.020	1.023	0.997	1.025	1.028	1.018	1.010
GX	1.042	1.026	1.016	1.014	0.972	1.044	1.024	1.004	1.019
CQ	0.754	0.865	0.872	0.998	1.046	0.955	0.986	1.071	0.921
SC	1.003	0.983	1.021	0.979	0.906	1.081	1.015	1.000	1.015
YN	1.002	0.983	1.019	1.042	1.009	1.033	1.007	0.988	1.020
GZ	1.038	1.038	1.000	1.024	0.989	1.035	1.029	1.000	1.029
XZ	0.831	0.905	0.918	0.966	0.930	1.039	0.989	0.936	1.057
SN	1.025	1.049	0.977	1.043	1.007	1.036	1.032	1.004	1.028
GS	1.028	1.010	1.018	1.052	1.019	1.032	1.018	0.995	1.024
QH	0.795	0.854	0.931	0.947	0.895	1.058	1.013	0.998	1.015
NX	0.964	0.983	0.981	0.998	0.984	1.014	1.008	1.015	0.994
XJ	1.018	1.004	1.014	1.022	1.016	1.005	1.016	0.993	1.023
mean value	0.982	0.996	0.985	1.012	0.989	1.025	1.040	1.005	1.037

subsidies for agricultural insurance in China is mainly due to the improvement of the efficiency of technological progress.

Table 4. The average annual Malmquist index and sub value of subsidy efficiency

DMU	EC	TC	MI	DMU	EC	TC	MI
BJ	0.9725	1.1372	1.1059	HB	1.0121	1.0283	1.0407
TJ	1.0523	0.9241	0.9725	HN	1.0051	1.0271	1.0323
LN	0.9803	1.0432	1.0227	HI	0.9734	1.0014	0.9748
SH	1.0857	0.9680	1.0510	IM	1.0041	1.0184	1.0226
JS	1.0089	1.0314	1.0406	GX	1.0006	1.0262	1.0269
ZJ	0.9987	1.0097	1.0084	CQ	0.9937	0.9159	0.9101
FJ	1.0148	0.9489	0.9630	SC	0.9627	1.0390	1.0002
SD	0.9549	1.0647	1.0167	YN	0.9933	1.0239	1.0170
GD	1.0005	1.0222	1.0228	GZ	1.0091	1.0213	1.0306
HE	0.9950	1.0265	1.0214	XZ	0.9238	1.0045	0.9279
SX	1.0089	1.0145	1.0235	SN	1.0197	1.0140	1.0339
JL	0.9999	1.0383	1.0383	GS	1.0078	1.0246	1.0326
HL	1.0003	1.0196	1.0199	QH	0.9154	1.0014	0.9167
AH	0.9839	1.0256	1.0091	NX	0.9940	0.9962	0.9902
JX	1.0237	1.0368	1.0613	XJ	1.0046	1.0140	1.0187
HA	0.9999	1.0277	1.0275				
mean value	0.9968	1.0160	1.0123				

3 Summary

This paper uses Super SBM model and Malmquist index model to comprehensively analyze the efficiency of financial subsidies for agricultural insurance in 31 provinces, autonomous regions and municipalities directly under the central government from static and dynamic perspectives from 2017–2020. The main conclusions are as follows:

Based on the static analysis of Super SBM model, from 2017 to 2020, while the average annual efficiency of agricultural insurance financial subsidies in various provinces in China showed an upward trend of fluctuation as a whole, there was also a periodic decline in 2018 and 2019. It shows that in recent years, although the amount of financial subsidies for agricultural insurance provided by governments at all levels have increased year by year, the financial subsidies for agricultural insurance in China have not reached the optimal allocation of resources. Secondly, the efficiency of financial subsidies for agricultural insurance in China varies significantly between provinces. Significant regional

differences are the main characteristics of China's agricultural insurance financial subsidy system at present. The efficiency of the eastern provinces is higher than that of the western provinces, while most of the impoverished population in China are concentrated in the West.

Based on the dynamic analysis of Malmquist index, the Malmquist index of the overall efficiency of agricultural insurance financial subsidies in China has increased year over year, showing an upward trend. The efficiency level of fiscal subsidy policy in most provinces has a clearer growth trend from 2017 to 2020, and the social and economic benefits of premium subsidy policy are better. But there are still a small number of provinces with a Malmquist index less than 1, which may have experienced a decline in efficiency due to declining economies of scale. Local governments also need to adapt to regional conditions.

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