

# An evaluation of the spatio-temporal evolution of the efficiency of China's rural financial markets

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**Abstract:** *Adopting the super-efficient SBM model to measure the efficiency of China's rural financial market in 30 provinces and cities from 2017-2021, and while analysing its temporal changes, it uses Origin to explore the spatial changes in the efficiency of China's four major regions of the rural financial market, and Kernel Density Estimation to analyse the trend of the dynamic evolution of the efficiency of China's rural financial market, and finds that: China's rural The overall efficiency of China's rural financial market is low, with large fluctuations in provinces and cities; as of 2021, only five provinces and cities have fully efficient rural financial markets, accounting for 16.67%, and the proportion of less efficient cities is still large; from a regional perspective, the efficiency of China's rural financial market shows a pattern of "higher in the Northeast - medium in the Middle East - lower in the West", with the following pattern: "Higher in the Northeast - medium in the Middle East - lower in the West". From a regional perspective, the efficiency of China's rural financial market shows the spatial characteristics of "higher in the northeast - medium in the middle of the Middle East - lower in the west"; during the observation period, the efficiency of the rural financial market in each province and city has a certain degree of differentiation.*

**Keywords:** *Rural financial market efficiency, Super-efficient SBM model, Kernel density estimation, Spatio-temporal evolution*

## 1. Introduction

Rural revitalisation is the "ballast" of high-quality development and an important part of the comprehensive construction of a modern socialist country, and the development of the rural economy is indispensable for realising this long-term and arduous task. As we all know, rural finance is at the heart of the modern rural economy, and the efficient service of rural finance to the rural economy is an important guarantee and support for the comprehensive revitalisation of the countryside in the future. Academic research on the efficiency of the rural financial market can be broadly divided into two types: one is to rationally explore the current situation of China's rural financial efficiency, and summarise the ways and concepts to achieve China's rural financial efficiency by the corresponding problems. The second is to use the DEA model to measure the efficiency of the rural financial market, analyse the spatial and temporal changes in efficiency, and explore the mechanism of its role. Although existing studies based on theoretical discussion or empirical analysis have identified the reasons for the inefficiency of rural financial markets to some extent, there is less literature that can further analyse the efficiency of China's rural financial markets from the perspective of time, space and dynamic development, the construction of the indicator system is not yet perfect, and there is a lack of consideration of unwanted output variables, and there have been fewer relevant studies in recent years. Research on the efficiency of rural financial markets is less likely to lead to a mismatch between past countermeasures and current obstacles, and so on. This paper measures the rural financial market efficiency of 30 Chinese provinces and cities (excluding Hong Kong, Macao, Taiwan and Tibet) from 2017 to 2021 based on the super-efficient SBM model, analyses the spatial and temporal changes in the efficiency of China's rural financial market, and analyses the dynamic trend of its changes using kernel density estimation, so as to provide the theoretical basis for effectively improving the efficiency of the rural financial market in different parts of China and promoting rural revitalization.

## 2. Research Methodology and Indicator System Construction

### 2.1. Research Methodology

#### (1) Super-efficient SBM model

Compared with the traditional DEA model, the super-efficient SBM model takes into account the slack variables, and in the empirical process, it not only eliminates the errors and role effects due to changes in choices such as angle, effectively solves the problem of input and output variables, but also further evaluates the decision-making units with efficiency values greater than 1, so as to obtain more realistic efficiency results. The specific formula is shown in equation (1):

$$\rho_k = \min \frac{\frac{1}{m} \sum_{i=1}^m \frac{\bar{x}}{x_{ik}}}{1 / (r_1 + r_2) \left( \sum_{s=1}^{r_1} \frac{y}{y_{sk}} + \sum_{q=1}^{r_2} \frac{\bar{b}}{b_{qk}} \right)}$$

$$s.t. \begin{cases} \sum_{j=1, j \neq k}^n x_{ij} \lambda_j \leq \bar{x} & (i = 1, 2, \dots, m) \\ \sum_{j=1, j \neq k}^n y_{sj} \geq \bar{y} & (s = 1, 2, \dots, r_1) \\ \sum_{j=1, j \neq k}^n b_{qj} \leq \bar{b} & (q = 1, 2, \dots, r_2) \end{cases} \quad (1)$$

In equation (1):  $\rho$  indicates the value of rural financial market efficiency;  $n$  indicates the number of decision-making units,  $m, q$  indicates the number of inputs and outputs, respectively, for each decision-making unit,  $r_1$  indicates desired output,  $r_2$  indicates non-expected outputs,  $x, y, b$  are elements of the corresponding input matrix, desired output matrix and undesired output matrix,  $\bar{x}, \bar{y}, \bar{b}$  Relaxation variables representing input, desired output and non-desired output indicators, respectively. When  $\rho \geq 1$  indicates that this decision module is valid. When  $0 \leq \rho < 1$  indicates that this decision module needs to be adjusted. For example, improving the ratio of inputs to outputs to achieve optimal efficiency. In this paper, the super-efficient SBM model is used to measure the efficiency of China's rural financial market.

#### (2) Kernel-Density estimation

Kernel-Density estimation is the application of kernel smoothing to probability density estimation, i.e. a non-parametric method of estimating the probability density function of a random variable using kernels as weights, so as to simulate the real probability distribution curves and to make inferences about the totality of the population on the basis of a limited sample of data. Let there be a total of  $n$  sample points with probability density function  $f$ . The kernel density estimation formula is given in equation (2) [1]:

$$\hat{f}_h(x) = \frac{1}{n} \sum_{i=1}^n K_h(x - x_i) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right) \quad (2)$$

In equation(2),  $K(\cdot)$  is the kernel function (satisfying the properties: non-negative, integrating to 1, satisfying the probability density property, and having a mean of 0),  $h > 0$  is a smoothing parameter called the bandwidth or window,  $x$  is a subset of the  $n$  samples. In this paper, the Kernel-Density method is used to analyse the dynamic evolution trend of rural financial market efficiency in 30 provinces and cities in China.

### 2.2. Construction Of the Indicator System

Li Mingxian (2002) [2] has pointed out that the rural financial system plays an important role in the development of the rural economy, so in the process of building China's rural financial system, efforts must be made to improve the efficiency of the rural financial market. It is clear that the efficiency of the rural financial market should be improved without delay. In this paper, based on the findings of scholars such as Zheng Qunzhe (2022) [3] and others, we select agricultural insurance premium income, financial deposit and loan ratios, and agricultural inputs as input indexes of rural financial market efficiency to generate desired outputs such as food production, agricultural gross output value, and agricultural product

exports. However, the actual problem often produces undesired output carbon emissions, so when constructing the rural financial market efficiency evaluation index system, the index of undesired output carbon emissions is included. Finally, the constructed rural financial market efficiency evaluation index system is shown in Table 1.

Table 1: System of indicators for evaluating the efficiency of rural financial markets.

Categories	Evaluation indicators	unit (of measure)
Input indicators	Agricultural insurance premium income	million dollars
	Financial loan-to-deposit ratio	%
	Agricultural inputs	ten thousand yuan
Expected output indicators	Grain production	tonnes
	Gross agricultural output	ten thousand yuan
	Agricultural exports	ten thousand yuan
Non-expected output indicators	Carbon footprint	ton (loanword)

### 3. Empirical analysis

#### 3.1. Source of data

Given that there are more residual data for Tibet, and that data for Hong Kong, China, Macau, China and Taiwan, China are difficult to obtain, the article selects China's panel data for 30 provinces (municipalities and districts) for the period 2017-2021 in terms of data availability. Data were obtained from the National Bureau of Statistics, the China Statistical Yearbook, provincial and municipal statistical yearbooks, the China Financial Statistical Yearbook, and relevant government statistical bulletins and data published by the China Urban Greenhouse Gas Working Group.

#### 3.2. Time change

Table 2: China's Rural Financial Market Efficiency, 2017-2021.

Region/Year	2017	2018	2019	2020	2021	Averages
Beijing	0.0473	0.5627	1.0609	0.4287	0.3501	0.4899
Tianjin	0.1567	0.1372	0.1433	0.1554	0.1623	0.1510
Hebei	0.2571	0.2797	1.0094	0.2379	0.2570	0.4082
shanxi	0.0387	0.0400	0.0365	0.0381	0.0485	0.0403
Inner Mongolia	0.1275	0.1412	0.1384	0.1313	0.1344	0.1346
Liaoning	0.5083	0.4984	0.4883	0.4502	1.0357	0.5962
Jilin	1.0475	0.4880	0.6425	0.2964	0.6427	0.6234
Heilongjiang	1.0234	0.9491	0.8744	1.0013	1.0260	0.9748
Shanghai	0.0832	0.0823	0.0701	0.0665	0.0703	0.0745
Jiangsu	0.5032	0.4728	0.3820	0.3429	0.3475	0.4097
Zhejiang	0.3385	0.3153	0.2959	0.2690	0.2528	0.2943
Anhui	0.3030	0.2989	0.3435	0.2088	0.2182	0.2745
Fujian	1.1818	1.0050	0.9245	0.8727	1.1451	1.0258
Jiangxi	1.0007	0.1534	0.1331	0.0953	0.0988	0.2963
Shandong	1.0731	1.0659	1.0106	0.9279	1.0535	1.0262
Henan	1.0425	0.6831	0.5611	1.0066	1.0101	0.8607
Hubei	1.1045	0.4637	0.3291	0.3060	0.3426	0.5092
Hunan	0.1957	0.1863	0.1801	0.2177	0.2590	0.2078
Guangdong	1.0083	0.5233	0.5179	0.4257	0.3864	0.5723
Guangxi	1.0754	0.3939	0.3985	0.2657	0.2484	0.4764
Hainan	0.1634	0.1247	0.1179	0.1042	0.1073	0.1235
Chongqing	0.1650	0.0835	0.0566	0.0455	0.0551	0.0812
Sichuan	0.1197	0.1269	0.1337	0.1118	0.1401	0.1264
Guizhou	0.1601	0.1346	0.1214	0.0907	0.1324	0.1279
Yunnan	0.4563	0.4093	0.3829	0.3975	0.3754	0.4043
Shaanxi	0.2089	0.1770	0.1283	0.1262	0.1172	0.1515
Gansu	0.0929	0.0736	0.0646	0.0556	0.0551	0.0683
Qinghai	0.0174	0.0093	0.0075	0.0074	0.0144	0.0112
Ningxia	0.0763	1.0253	0.7308	0.5091	0.1980	0.5079
Xinjiang	0.1371	0.1286	0.1217	0.0967	0.1042	0.1177
Nationwide	0.4571	0.3678	0.3802	0.3096	0.3463	0.3722

The super-efficient SBM model is used to measure the efficiency of rural financial markets in China's 30 provinces and municipalities (excluding Hong Kong, Macau, Taiwan and Tibet) from 2017 to 2021, and the results are shown in Table 2.

In the analysis of the efficiency results after using the super-efficient SBM model, only "1" is used as a boundary, with greater than 1 being "efficient" and less than 1 being "non-efficient". This is too rough and absolute a basis for judging the efficiency of rural financial markets, and can lead to a wide gap between the "efficient" and the "non-efficient". Based on this, this paper adopts the natural discontinuity method to classify the efficiency of China's rural financial market into four levels: less efficient (score: 0-0.3), moderately efficient (score: 0.3-0.7), more efficient (score: 0.7-1), and fully efficient (score: more than 1), and analyses the their efficiency trends.

As can be seen from Table 2, the average value of the efficiency of China's rural financial market during the five-year period is only 0.3722, and the overall efficiency is not high, which may be related to the fact that the input resources such as agricultural insurance premium income, financial deposit and loan ratios, and agricultural expenditure are not fully utilised, resulting in a structural mismatch with the desired outputs such as food production, agricultural output value, and agricultural export volume, indicating that this input-output decision needs to be further improved. From the perspective of the trend of change in the efficiency of the rural financial market, 2017-2021 always shows a cross trend of "falling-rising-falling-rising", indicating that the efficiency of China's rural financial market is not stable enough. The efficiency of China's rural financial market is not stable enough. Second, in terms of provincial and municipal efficiency scores, the efficiency of rural financial markets across provinces and municipalities is uneven, with large gaps and varying degrees of fluctuation. For example, in addition to Heilongjiang, Fujian and Shandong's rural financial market efficiency value as a whole remains above 0.7, in a more efficient or fully efficient, the efficiency status of other provinces and municipalities are unstable, and most of them have been in the state of medium efficiency and lower efficiency for a long time, even Tianjin, Shanxi, Inner Mongolia, Shanghai, Jiangsu, Zhejiang, Anhui, Hunan, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai and Xinjiang have never had a period of high or higher efficiency. And we can see that over the five-year period, the cities where the efficiency of the rural financial market declined faster were Jilin, Shanghai, Jiangsu, Zhejiang, Jiangxi, Hubei, Guangdong, Guangxi, Hainan, Chongqing, Guizhou, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang, and the cities where the efficiency of the rural financial market increased faster were Liaoning and Sichuan. Among them, Jilin, Jiangxi, Hubei, Guangdong, and Guangxi are all moderately and less efficient in the following years after reaching full efficiency in 2017, and the same situation also occurs in Beijing, Hebei, and Ningxia, especially in Jiangxi, where the decline is the largest, from 1.0007 in 2017 to 0.0988 in 2021. Once the above provinces and cities have switched from 'fully efficient' to other efficiencies, it is difficult to return to 'fully efficient' status. By 2021, only five provinces and municipalities - Liaoning, Heilongjiang, Fujian, Shandong and Henan - will have "fully efficient" rural financial markets, and no province or municipality will be more efficient.

To further explore the change in the level of efficiency of China's rural financial market, the low efficiency, medium efficiency, high efficiency and fully effective percentages were counted separately, and the results are shown in Table 3.

Table 3: Percentage of Efficiency Levels in China's Rural Financial Market, 2017-2021. unit:(%).

percentage	2017	2018	2019	2020	2021
Less efficient	53.33	53.33	50.00	63.33	63.33
Medium efficiency	16.67	33.33	30.00	23.33	20.00
More efficient	0.00	3.33	10.00	6.67	0.00
Completely effective	30.00	10.00	10.00	6.67	16.67

As can be seen from Table 3, from 2017 to 2019, the fully efficient share of China's rural financial market decreased from 30% to 10%, the low efficiency decreased to 50%, and the medium efficiency and high efficiency increased to 30.00% and 10.00%, respectively. And overall, the share of higher and higher efficiency decreased in 2019 compared with 2017, which to some extent reflects that the efficiency of China's rural financial market is on a downward trend in the period 2017-2019. The share of low efficiency increases to 63.33 per cent in 2019-2021, medium efficiency decreases to 20 per cent, and the share of high and above efficiency decreases by 3.33 per cent in 2021 compared to 2019. Because the period of 2019-2021 has experienced the special situation of epidemic, how to make scientific decisions to minimise the impact of the epidemic is a problem that every province and city should focus on, so here we put the changes in the efficiency of China's rural financial market in 2020-2021 for another analysis, from the 2021 From the results of each efficiency ratio, the percentage of higher and above efficiency is 3.33% higher than that of 2020, indicating that some provinces and cities have indeed changed the input-output ratio on the original basis appropriately, so that they can better adapt to the rural financial market and improve the efficiency of the rural financial market, but there are also some provinces and cities that are standing still, and the bifurcation is gradually appearing..

### 3.3. Spatial variations

According to the National Bureau of Statistics on the release of the division of China's economic region into four major regions: eastern, central, western and northeastern ", based on the results of the rural financial market efficiency in Table 2 using Origin to plot the trend of rural financial market efficiency in the four major regions of China's eastern, central, western and northeastern, as shown in Figure 1.

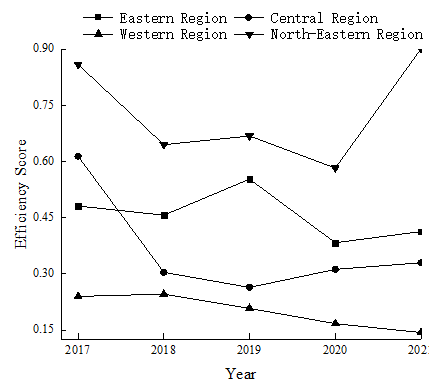


Figure 1: Financial Market Efficiency Trend in China's Rural Areas, 2017-2021.

As shown in Figure 1, the efficiency of China's rural financial market has a spatial characteristic of "high in the northeast, medium in the middle east, and low in the west". The efficiency of the rural financial market in the Northeast region can basically be maintained at a high level or above, and is in the leading position among the four major regions. However, the rural financial market efficiency in the Northeast and East and Central regions fluctuates significantly up and down, with a downward trend in 2020 compared to 2017, but the improvement effect is significant between 2020 and 2021, especially in the Northeast, where the rural financial market efficiency increased by 0.3189. The efficiency of rural financial markets in the Western Region has declined over the years, with the exception of 2018, when there was a slight increase and all with lower efficiency. In 2017, the rural financial market efficiency of the central region was much higher than that of the eastern region, but in 2018 and later, especially in 2019, the rural financial market efficiency of the eastern region quickly surpassed that of the central region, creating a large gap with a difference value of 0.2894. After 2019, the difference in rural financial market efficiency between the two regions gradually narrows, indicating a close status.

### 3.4. Dynamic evolution

Using kernel density estimation to analyse the dynamic trend of rural financial market efficiency, it can be seen from Figure 2 that the centre of the kernel density estimation curve of China's rural financial market efficiency is gradually shifting to the right, there is some fluctuation, and the stability is not strong. Its main peak is similar to the U-shaped potential, which shows a downward - upward trend, and at the same time the width of the main peak curve becomes larger and then smaller, which means that the difference in the efficiency of the rural financial market becomes larger and then smaller. There is a huge distribution of kernel density curves during the observation period, which means that the efficiency of China's rural financial market is generally unstable, and there is a more obvious phenomenon of divergence.

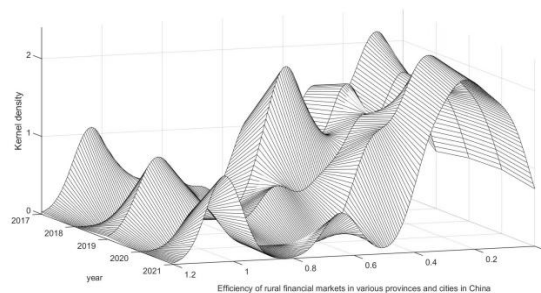


Figure 2: Dynamic evolution of efficiency in China's rural financial market, 2017-2021.

#### 4. Conclusions and recommendations

Based on the constructed rural financial market efficiency evaluation index system, this paper adopts the super-efficient SBM model to measure the rural financial market efficiency of 30 provinces and cities (excluding Hong Kong, Macau, Taiwan and Tibet) in China from 2017 to 2021, and explores its temporal, spatial and dynamic evolutionary changes. And the results show that: (1) the average value of China's rural financial market efficiency in the past 5 years is only 0.3722, the overall efficiency is not high, and the ratio of input-output structure is poor. By 2021, only six provinces and municipalities, namely Beijing, Jilin, Jiangsu, Hubei, Guangdong and Yunnan, are in the medium efficiency category, and five provinces and municipalities, namely Liaoning, Heilongjiang, Fujian, Shandong and Henan, are in the fully efficient rural financial market category with an efficiency score of 1 or higher. The proportion of provinces and municipalities with low efficiency is still high at 63.33%. (2) The efficiency of China's rural financial market shows the spatial characteristics of "Northeast > East > Central and West". The efficiency of the rural financial market in the northeastern region is maintained at a medium or higher level, ranking first among the four major regions; however, in terms of volatility, the efficiency of the rural financial market in the northeastern, eastern and central regions fluctuates considerably, and is on the rise since 2020. On the contrary, the efficiency of the rural financial market in the Western Region is clearly on the decline. (3) Differences in the efficiency of rural financial markets across regions become larger and then smaller, and overall efficiency is unstable over the period, with more pronounced polarization.

Based on the above findings, this paper suggests that (1) For Xinjiang, Gansu, Qinghai, Ningxia, Inner Mongolia, Sichuan, Shaanxi, Shanxi, Hebei, Guizhou, Hunan and other regions with low rural financial market efficiency, ways should be found to overcome the severe difficulties and pain points they face in rural financial reform and development; and to intensify rural financial publicity and improve the service capacity and management of local small and medium-sized rural banking institutions. (2) To pay close attention to the situation in which the efficiency of rural financial markets in provinces and cities such as Jilin, Jiangxi, Hubei, Guangdong, Guangxi, Beijing, Hebei and Ningxia has changed from "fully effective" to other efficiencies, and to find out the reasons in time to avoid the phenomenon of "rework". (3) Optimise the structure of financial deposit and loan ratios, improve the structure of the financial system and enhance the efficiency of rural capital use and risk resistance; innovate financial instruments according to the actual needs of rural finance and provide multiple sources of funds for farmers. (4) Provinces (municipalities and regions) need to regulate their own resources for urban and rural financial services, rationally manage the scale of financial spending, optimise the structure of spending, adjust the focus of financial support and improve the efficiency of the rural financial market, thereby promoting rural revitalization. (5) While support for rural financial markets in the eastern and central regions continues to be strengthened, special measures have been formulated for the development of rural finance in the western region.

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