

Empirical Analysis of the Efficiency of Provincial Debt Expenditure in China

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Abstract: Improving the efficiency of local government debt expenditure is the key to preventing and resolving local debt risks in China. Using a three-stage SBM-DEA model, an input-output index system was constructed to calculate and analyze the efficiency of government debt expenditure in 30 provinces and cities (districts) across the country. The results showed that the overall level of local government debt expenditure efficiency in the country was relatively high; There is a significant difference in the efficiency of local debt in the eastern, central, and western regions. The efficiency of local debt expenditure in the eastern region has significant advantages, while the efficiency of local debt expenditure in the western region urgently needs to be improved; The degree of financial deepening, population size, and local debt expenditure efficiency are significantly positively correlated, while fiscal expenditure decentralization is negatively correlated with local debt expenditure efficiency.

Keywords: Efficiency of local government debt expenditure, Debt risk, Three stage SBM-DEA.

1. Introduction

Local government debt, as a component of fiscal funds, not only effectively alleviates the central government's control over local government debt limits, allowing local governments to have more abundant funds for infrastructure construction and improving people's livelihoods, but also an important source of government expenditure[1]. After the implementation of the new Budget Law, local government debt was mainly issued through bonds, and the issuance scale continued to expand, while also accumulating a large amount of risks. How to mitigate the risks brought by the expansion of local debt scale has been studied by the academic community from the aspects of improving institutional constraints[2], designing budget mechanisms[3]and financial channels[4]. Improving the expenditure efficiency of debt funds is also a channel to resolve debt risks. Currently, the academic community mostly uses data envelopment method to evaluate the efficiency of local debt. Guo Yuemei et al. (2014) used a three-stage DEA model to calculate the efficiency of using special debt funds nationwide. Zhao Guizhi et al. (2019) found through the DEA method that there is significant room for improvement in the efficiency of local government debt expenditure in China. Improving internal management capabilities is an effective way to enhance the efficiency of local government debt expenditure. Zhang Hongmo (2020) empirically studied the efficiency of local government special debt utilization based on the super efficient DEA model. The article found that appropriately reducing the debt scale can improve the efficiency of debt utilization. Most of the local government debt data used in the literature are mostly special debt balances, which fail to take into account the general debt balance and can not truly reflect China's debt level. At the same time, unexpected outputs were not taken into account when constructing input-output indicators.

Based on this, this article uses the three-stage SBM-DEA model to calculate the local debt of 30 provincial-level administrative regions in China in the field of local government debt investment, analyzes the factors that affect the efficiency of debt expenditure, and provides suggestions

to improve the efficiency of local government debt expenditure.

2. Research Design

2.1. Research Methods

2.1.1. Phase 1 SBM Model

Scholar Tone[8] proposed an SBM model that includes unexpected outputs. The formula for calculating the efficiency of the SBM model is as follows:

$$\rho^* = \min \frac{1 + \frac{1}{m} \sum_{i=1}^m \frac{S_i^-}{X_{ik}}}{1 - \frac{1}{S_1 + S_2} \left[\sum_{r=1}^{S_1} \frac{S_r^g}{Y_{rk}^g} + \sum_{t=1}^{S_2} \frac{S_t^h}{Y_{tk}^h} \right]}$$

$$\begin{cases} \sum_{j=1}^n \lambda_j X_{ij} + S_i^- = X_{ik} \\ \sum_{j=1}^n \lambda_j Y_{rj}^g - S_r^g = Y_{rk}^g \\ \sum_{j=1}^n \lambda_j Y_{tj}^h + S_t^h = Y_{tk}^h \\ \lambda_j, S_i^-, S_r^g, S_t^h \geq 0 \end{cases} \quad (1)$$

In the formula, represents the redundancy of input indicators, and represents the insufficient expected output and excessive unexpected output, respectively. When=1, it indicates that DEA is relatively effective.

2.2. Phase 2: SFA regression

Construct a regression model between input relaxation variables, environmental factors, and random errors. The specific model is as follows:

In the formula, represents the decision unit, and represents the input slack of the decision unit; Represents environmental

values; The coefficient value representing environmental variables, representing environmental variables.

2.3. Third stage: Analysis of adjusted SBM efficiency

After removing the interference caused by the external environment in the second stage, the adjusted input and output values are recalculated, and the efficiency value obtained is closer to the true value.

3. Data Sources and Indicator Selection

3.1. Data sources

This paper takes the data of 30 provinces, cities and autonomous regions in China (Xizang, Hong Kong, Macao and Taiwan Special Administrative Regions in China, whose data are not covered due to lack of sample data) from 2015 to 2021 as the research sample. The data are mainly from the National Bureau of Statistics, wind data, Guotai'an, provincial statistical yearbooks, and China Bond Information Network.

3.2. Index system construction

When using the DEA model for efficiency measurement, the selection of input and output data is a key element. Based on the purpose of local government debt, the investment field, and the effectiveness and accessibility of the data, the selection of input and output variables is as follows:

1. Investment indicators. Select the sum of the general debt and special debt balances that the government has direct

repayment responsibility for as the local government debt balance, and apply per capital processing to maintain comparability between different regions. The stock indicator selects the per capital local government debt balance, while the incremental indicator selects the per capital newly issued local government bonds.

2. Output indicators. Following the approach of Hong Yuan et al. (2014), the expected output indicators are selected from three aspects: infrastructure construction, economic and social benefits, and public welfare projects. Specifically, it includes: (1) Infrastructure construction: selecting four indicators: green coverage rate in built-up areas, number of mobile base stations, highway network density, and daily urban sewage treatment capacity. (2) Economic and social benefits: Select two indicators: per capital GDP and employment rate. (3) Public welfare project: Select three indicators: the number of students in primary and secondary schools per thousand people, the number of beds in health institutions per thousand people, and the proportion of farmland irrigation area. (4) The unexpected output indicator selects sulfur dioxide emissions to measure the degree of environmental pollution.

3. Selection of environmental variables. Drawing on existing research, select the following environmental variables. (1) Financial deepening degree: the ratio of added value of the financial industry to GDP (2) Population size: the number of permanent residents in the region. (3) Fiscal expenditure decentralization: The ratio of local government fiscal expenditure to central fiscal expenditure.

Table 1. Evaluation Index System for Efficiency of Local Government Debt Expenditure

Indicator Type	First Level Indicator	Second Level Indicator	
Input indicator		Local government debt balance	
		Increase in local government debt	
Expected output indicators	Infrastructure construction	Urban sewage daily treatment capacity	
		Green coverage rate in built-up areas	
	Economic and social benefits	Number of mobile base stations	
		Highway network density	
Public welfare projects		Per capital GDP	
		Employment rate	
		Primary and secondary school population per 1000 population	
Unexpected output indicator	Environmental pollution	Number of beds in health facilities per 1000 population	
		The proportion of farmland irrigation area	
Environmental variables	Economic environment Social environment Policy environment	sulfur dioxide emissions	
			Financial deepening degree
			population size
		Fiscal expenditure decentralization	

4. Analysis of Empirical Results

4.1. phase I: Calculation of initial value of local government debt expenditure efficiency

After data selection and processing, the efficiency of local government debt expenditure in 30 provinces and cities from 2015 to 2021 was calculated by using MATLAB software and SBM-DEA model. The results are shown in Table 2.

The average national debt efficiency is between 0.7 and 0.9, and the overall level is relatively high. The highest average efficiency of 30 provinces is 1, and the lowest is 0.22. The average efficiency value of 15 provinces including Beijing, Shanghai and Jiangsu reached 1, and the use of debt funds was in the optimal state. From the analysis of regional

differences, nine provinces in the eastern region are at the best efficiency, and three provinces in the central and western regions are at the best efficiency. Due to the rapid economic development, comprehensive infrastructure construction and high level of environmental governance in the eastern region, the efficiency of debt expenditure is in a leading position. The average efficiency of the central region is second only to that of the eastern region. The average efficiency of most provinces in the western region is low, and only Guangxi, Guizhou and Xinjiang have the best efficiency. Inner Mongolia's debt capital efficiency is the lowest and its debt scale is larger than that of other provinces, but the infrastructure construction is backward and the capital allocation is unreasonable, so the debt expenditure efficiency

is low.

Table 2. Efficiency of debt expenditure in phase 1 (2015-2021)

region	province	2015	2016	2017	2018	2019	2020	2021	average	ranking
Eastern	Beijing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Tianjin	1.00	1.00	1.00	0.52	0.50	0.42	0.42	0.69	22
	Hebei	0.61	0.54	0.56	0.46	0.45	0.54	0.57	0.54	24
	Liaoning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shanghai	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Jiangsu	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Zhejiang	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Fujian	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shandong	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Guangdong	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
Central	Hainan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shanxi	0.36	0.41	0.43	0.46	1.00	1.00	1.00	0.67	23
	Jilin	0.66	0.53	0.43	0.53	0.35	0.28	0.30	0.44	29
	Heilongjiang	1.00	1.00	0.63	0.69	1.00	0.46	1.00	0.83	20
	Anhui	1.00	1.00	1.00	0.58	0.45	0.73	1.00	0.82	21
	Jiangxi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Henan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Hubei	1.00	1.00	1.00	1.00	0.69	1.00	0.61	0.90	17
	Hunan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Inner Mongolia	0.17	0.23	0.18	0.19	0.29	0.24	0.25	0.22	30
Western	Guangxi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Chongqing	1.00	1.00	1.00	1.00	0.53	0.48	1.00	0.86	19
	Sichuan	1.00	1.00	1.00	1.00	0.53	1.00	0.63	0.88	18
	Guizhou	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Yunnan	1.00	0.34	0.32	0.31	0.40	0.40	0.34	0.45	28
	Shanxi	0.46	0.64	0.62	0.67	0.36	0.45	0.49	0.53	25
	Gansu	1.00	1.00	0.43	0.41	0.26	0.28	0.25	0.52	26
	Qinghai	1.00	1.00	1.00	1.00	0.37	1.00	1.00	0.91	16
	Ningxia	1.00	1.00	0.17	0.12	0.09	0.20	1.00	0.51	27
	Xinjiang	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
average	0.91	0.89	0.83	0.80	0.74	0.78	0.83	——	——	

4.2. Phase 2: SFA regression analysis

Perform SFA maximum likelihood regression using the per capital local debt balance and per capital excess investment in local debt increase obtained in the first stage as the dependent

variables, and indicators such as financial deepening, population size, and fiscal expenditure decentralization as the explanatory variables. The following table shows the regression results.

Table 3. SFA Regression Results

	Relaxation variable of per capital local debt balance		Relaxation variable of per capital local debt increase	
	coefficient value	T	coefficient value	T
Constant term	530.70	0.63	221.13	2.49
Fiscal expenditure decentralization	15566.04***	16.42	303.13	0.64
Population size	-15617.19***	-11.60	-658.57*	-1.52
Financial depth	-6235.20*	-3.73	-477.87*	-2.11
σ^2	45352500	40443875	595873.51	48602.04
γ	0.84	54.01	0.79	36.62
Log LR		-1993.61		-1576.13
LR		164.24		151.81

Note: ***, **, * respectively indicate that the coefficient values have passed the significance test at the 1%, 5%, and 10% levels.

The LR value is a unilateral likelihood ratio statistic of the model, with a critical value of 10.501 at the 1% level. The LR values of the regression results of both models in the above table are greater than the critical value of 10.501, indicating that using the SFA regression model is reasonable. The T-value is used to determine whether each environmental

indicator has a significant impact on input redundancy. From Table 3, it can be seen that all environmental indicators have passed the significance test. So further research can be conducted on the correlation between environmental indicators and the efficiency of local debt expenditure. According to the regression analysis of Table 3, the

decentralization of fiscal expenditure is positively correlated with the relaxation of per capital local debt balance, indicating that a higher decentralization index of fiscal expenditure will lead to an increase in investment redundancy, which is not conducive to improving the efficiency of local debt expenditure. The coefficients of the indicators of population size and financial deepening are negative, indicating that an increase in population size and a higher level of financial deepening will reduce investment redundancy, which is beneficial for improving the efficiency of local debt expenditure.

4.3. Third stage: Analysis of efficiency values after removing environmental impacts

According to the second stage SFA regression analysis, environmental variables have a significant impact on debt expenditure efficiency. Therefore, we separate environmental factors and adjust the original input value reasonably. The adjusted and optimized input variables and original output variables were used as the input-output values for the third stage, and the SBM model was used to calculate the adjusted efficiency value of local debt expenditure. The results are shown in Table 4.

After adjustment, the average efficiency of national debt

expenditure in 2015-2021 is between 0.8-1, which is higher than that in the first stage. This indicates that the traditional SBM-DEA model will underestimate the efficiency of local debt expenditure due to the impact of external environment and random interference. The average efficiency value of 30 provinces is the highest at 1, while the efficiency of Inner Mongolia's debt expenditure has slightly increased compared to the first stage efficiency value, but it is still at the lowest level, at 0.39. The average efficiency of 15 provinces, including Beijing, Shanghai, and Jiangsu, is 1. After removing environmental factors, the efficiency value remains unchanged and is at the forefront of efficiency.

The average efficiency of other provinces has improved after adjustment, with Shanxi and Tianjin both reaching high efficiency levels. From the perspective of regional differences, after adjustment, the average efficiency of each province in the eastern region is in the range of 0.7-1, and the efficiency of local debt expenditure is at a high efficiency level. There is one inefficient province in the central region and four inefficient provinces in the western region. Compared to the eastern and central regions, there is still a gap in debt expenditure efficiency in the western region, due to poor debt management, relatively backward infrastructure construction, and difficulty in issuing bonds.

Table 4. Adjusted debt expenditure efficiency of provinces (2015-2021)

region	province	2015	2016	2017	2018	2019	2020	2021	average	ranking
Eastern	Beijing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Tianjin	1.00	1.00	1.00	0.61	0.56	0.49	0.52	0.74	23
	Hebei	0.75	0.70	0.70	0.68	0.59	0.65	0.70	0.68	24
	Liaoning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shanghai	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Jiangsu	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Zhejiang	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Fujian	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shandong	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Guangdong	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Hainan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Shanxi	0.55	0.55	1.00	0.58	1.00	1.00	1.00	0.81	22
	Jilin	0.75	0.60	0.59	0.64	0.49	0.41	0.41	0.55	29
	Heilongjiang	1.00	1.00	1.00	1.00	1.00	0.57	1.00	0.94	17
Central	Anhui	1.00	1.00	1.00	0.69	0.60	0.80	1.00	0.87	21
	Jiangxi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Henan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Hubei	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.96	16
	Hunan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Inner Mongolia	0.43	0.45	0.40	0.39	0.43	0.34	0.30	0.39	30
	Guangxi	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
Western	Chongqing	1.00	1.00	1.00	1.00	0.61	0.59	1.00	0.89	20
	Sichuan	1.00	1.00	1.00	1.00	0.69	1.00	0.72	0.92	18
	Guizhou	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	Yunnan	1.00	0.53	0.52	0.49	0.56	0.56	0.47	0.59	28
	Shanxi	0.65	0.72	0.76	0.79	0.50	0.55	0.59	0.65	26
	Gansu	1.00	1.00	1.00	0.49	0.34	0.36	0.34	0.65	26
	Qinghai	1.00	1.00	1.00	1.00	0.46	1.00	1.00	0.92	18
	Ningxia	1.00	1.00	0.28	0.22	0.15	1.00	1.00	0.66	25
	Xinjiang	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
	average	0.94	0.92	0.91	0.85	0.80	0.84	0.86	—	—

5. Conclusion and Policy Recommendations

Based on China Bond Information Network, Statistical Yearbook and other data, from the investment direction of government debt funds, combined with external environmental factors, build an efficiency evaluation system. Using a combination of three-stage DEA and SBM models, this study empirically evaluated the efficiency of local debt expenditure in 30 provinces (cities, districts) in China from 2015 to 2021, and analyzed the environmental factors that affect debt efficiency. The following conclusions were drawn. (1) The overall level of debt expenditure efficiency across the country is relatively high (2) There are significant differences in debt expenditure efficiency between the eastern, central and western regions. (3) The degree of financial deepening and population size have a positive impact on improving the efficiency of local debt expenditure, while fiscal expenditure decentralization has a negative impact on improving the efficiency of local debt expenditure.

Based on the above research conclusions, the following three policy recommendations are proposed: (1) Improve the government debt management mechanism and strengthen the supervision and assessment of local government debt. (2) Deepen the reform of the fiscal system and scientifically adjust the fiscal revenue and expenditure relationship between the central and local governments. (3) Adapt to local conditions and adopt differentiated regulatory policies based on one's own actual situation.

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