

Estimation of prefecture-level local government efficiency in China and policy implications for efficiency improvement

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Abstract. This article is the first to study on prefecture-level local government efficiency in China. First part of this article is estimating the efficiency of 277 prefecture-level local governments in China with output-oriented Data Envelopment Analysis (DEA), and the second part is explaining why those local governments receive such efficiency scores and discussing about the policy implications, where censored linear regression model is utilized. As a result, 277 prefectures are estimated to only produce 83% of their possible outputs with given inputs on average when scale inefficiency factors are excluded. And mostly decreasing return to scale inefficiency approximately accounts for half of overall inefficiency. At last, we suggest that the Chinese government should invest more expenditure on the basic education (primary school to high school) and it is recommended to increase the period of compulsory education to 12 years. And decentralization is an important approach to improve local government efficiency by analyzing the performance disparity of special economic zone (SEZ) prefectures.

Keywords: Operational research; Prefecture, local government efficiency; Data Envelopment Analysis; Tobit model; Education; Compulsory education; Fiscal decentralization; Special economic zone.

1. Introduction

China's economy has experienced a boom for four decades, but the ability of efficiently using energy (Zhang and Chen, 2022) and governing is often questioned. The Chinese government has set a goal to modernize the governance system and governance ability in 2019. Therefore, it is a chance for us to clarify the degree of government efficiency in China and try to give the Chinese government some suggestions.

We would like to focus on prefecture-level local government efficiency for several reasons. Firstly, local governments accounted for 85% of the total public expenditure, while the central government accounts for only 15%. Secondly, there are 333 prefectures in China. It provides a large number of observations to us and make sure our research results remain to be meaningful when having dozens of indicators. In comparison, China has only 33 provinces. If we study on the province-level local government efficiency, then most of provinces will be considered as efficient due to the quotient of dividing the number of observations by the number of indicators is too small without empowering indicators. Thirdly, the performance of prefectures varies due to large disparity exists between prefectures. The most populated prefecture is Chongqing with over 32 million residents, and the least populated one is Nyingchi with about 239 thousand residents.

Local government efficiency problems have been discussed in many other countries previously including Geys, Heinemann and Kalb (2013) in Germany, Stastna and Gregor (2011) in Czech and Balaguer-Coll, Prior and Tortosa-Ausina (2009) in Spain. Before understanding the definition of local government efficiency, there are two other definitions that need to be understood in advance. Every decision-making unit in operation research utilizes inputs to produce outputs. So, efficiency is defined by how many outputs does a decision-making unit produce with given inputs or how few inputs does it cost to produce a given amount of outputs. The former measurement method is called output-oriented and the latter is called input-oriented. So, measuring local government efficiency is measuring the ability of local governments to produce outputs with limited amounts of inputs.

This article adds to literature that it is the first article studying the prefecture-level local government efficiency in China. This article reveals the different degrees of efficiency of local governments in governing millions of people, and analyzes the non-discretionary factors that affect

efficiency, thus providing new ideas for improving the governance system and governance ability in China and even developing countries.

This article is structured as follows. Section II reviews previous literature. Section III demonstrates the statistics of data and explains the methodology of data selection. Section IV presents the analytical framework of this article. Results of efficiency estimation and econometric regression are displayed in section V. At last, section VI concludes.

2. Literature review

Some literature has discussed the local government efficiency previously. European countries were the focus of previous studies. See, for example, Geys, Heinemann and Kalb (2013) and Asatryan and De Witte (2014) study the local government efficiency in Germany. Afonso and Fernandes (2006) implement the research in Portugal. Stastna and Gregor (2011) evaluate the local government efficiency in Czech. In addition, Balaguer-Coll, Prior and Tortosa-Ausina (2009) study the effect of decentralization on local government efficiency in Spain.

And however, the number of researches conducted in developing countries is relatively small. One of them is Paschoalotto, Passador, Passador and Oliveira (2020), who study the local government efficiency in Brazil. Gilbert (1997) talks about the decentralization and local governments in Latin America. And Rayp and Van De Sijpe (2007) compare cross-country government efficiency in developing countries.

Furthermore, when it comes to China, the largest developing county in world, relating researches are quite scarce. The existing two of them include Wu, Huang, Zhao and Pu, (2017), who study on province-level local government efficiency and focus on the impact of transfer payment, and Tang, Tang and Lee (2014), who traditionally compare different types of indices to analyze province-level local government efficiency.

Different methodologies have been utilized to estimate and analyze local government efficiency. They can be roughly classified into two types: parametric methods and non-parametric methods. Parametric methods include cost function method (article utilizes cost function method includes Geys and Moesen (2009)), directly empowering method, and other econometric methods. Some parametric methods such as translog cost function method allow distinguish between noise and inefficiency in the model. Non-parametric methods mainly include Free Disposal Hull (FDH) methods (Deprins, Simar and Tulkens, 1984) and Data Envelopment Analysis (DEA) methods (Charnes, Cooper and Rhodes, 1978). These non-parametric methods are repeatedly utilized. Narbón-Perpiñá and De Witte (2017) count that 41 papers used DEA and 13 used FDH are published.

We are going to estimate the relative efficiency of prefecture-level local governments in China with Data Envelopment Analysis (DEA). DEA's frontier is created as a piecewise linear envelope of the data (Kalb, Geys and Heinemann, 2011). Efficiency frontier of DEA is constructed by efficient units. And each deviation from the frontier is regarded as inefficiency. In fact, it is in line with Farrell (1957) for using the linear combination of different efficient DMUs to represent the properties of the DMU which is under estimation at current period. It avoids using artificial weights for different outputs and in fact transforms the weights of different outputs into the vector of linear combination of efficient DMUs by utilizing the nature of dual linear programming.

3. Data methodology

3.1 Data statistics

3.1.1 Inputs and outputs of local governments

Descriptive statistics of inputs and outputs are demonstrated in Table I. Data in 2019 are chosen. The year 2019 is a normal year with few abnormalities. It is the previous year of COVID-19 outbreak. It implies that we are collecting the latest data that are not affected by COVID-19. Some indicators especially the economic indicators of different local governments are vulnerable to COVID-19.

Choosing the period after 2019 could cause our results biased because of disturbance. Reasons for choosing these indicators will be discussed in the next sub-section.

Table 1. Descriptive statistics in efficiency estimation

Variable name	Mean	Standard deviation	Minimum	Maximum	Data resource
Current expenditure (yuan)	12814.06	6138.20	6206.61	51574.73	Local Bureau of Statistics
Built area (m ²)	44.37	27.04	5.73	224.92	MHURD
Street length (m)	0.335	0.248	0.036	1.858	MHURD
Street area (m ²)	6.60	4.34	0.59	29.68	MHURD
Garbage cleaned (kg)	157.17	96.58	21.44	581.47	MHURD
Water supply (m ³)	40.40	33.03	3.02	271.90	MHURD
Urban green space area (m ²)	5.13	3.69	0.78	27.56	MHURD
Hospital beds (bed owned by every thousand people)	6.17	1.52	2.03	10.6	National Bureau of Statistics
Primary school plus secondary school students' proportion (%)	12.62	4.02	1.85	25.07	National Bureau of Statistics
Public library book storage	68.30	63.34	2.92	552.67	National Bureau of Statistics
The proportion of residents that are paying for the urban old-age insurance (%)	21.90	13.19	0.85	70.96	National Bureau of Statistics

Notes:

1) MHURD represents Ministry of Housing and Urban-Rural Development.

2) All data has been transformed into the form of per capita or proportion.

3.1.2 Data on factors may affect the efficiency score

Table II describes the statistics of some factors that may affect the efficiency score. Reasons for choosing them will be discussed in next sub-section.

Table 2. Summary statistics of explanatory variables

Variable name	Mean	Standard deviation	Minimum	Maximum
GDP per capita (yuan)	63179.71	36650.43	14746	203489
College degree owners every one hundred thousand residents	13647.4	6332.21	864	41980
High school degree owners every one hundred thousand residents	14585.06	3355.23	808	25642
Average years of schooling	9.64	0.95	5.60	12.6
Distance to the supervisory government (kilometer)	228.66	212.64	0.85	2351
Local government expenditure reliance (%)	60.31	21.17	-3.75	95.15
Population density (people/square kilometer)	498.18	724.26	2.04	8564.9
Dummy variable: Whether is open coastal city	0.05	0.22	0	1
Dummy variable: Whether belongs to special economic zone	0.014	0.120	0	1

Notes:

1) GDP per capita, current expenditure and revenues are accessed from National Bureau of Statistics.

2) Average years of schooling and population density are collected from Local Bureau of Statistics.

3) Local government expenditure reliance means how much does local governments rely on transfer payment from central government instead of local revenue.

3.2 Data collection methodology

For we are going to estimating the efficiency of local governments and researching on the factors that affect it, we need two types of data (variable). Firstly, data for efficiency estimation. And efficiency estimation data can be classified into two different aspects: inputs and outputs. As one of the most important society governing institutions, the main input of local governments is monetary input. Monetary input is used for paying the salary of government employees and purchasing different types of resources. Government expenditure is officially classified into four parts: current expenditure, governmental funding expenditure, state-owned capital operational expenditure, and social security insurance funding expenditure, where the last three parts of expenditure can be called the same name capital expenditure. We only include current expenditure as single input indicator. Capital expenditure is not included since it has a high volatility.

Local governments have many different types of outputs, such as education provision and road maintenance. We select a set of indicators that could reflect local governments' duties and concerns the data availability. They are:

Citizens' life facilitation: Water supply and waste collection are selected.

Infrastructure construction: Built area is selected.

Traffic construction: Road length and road area are selected.

Environment protection: Urban green space is selected.

Medical services provision: The number of hospital beds is selected.

Educational services provision: The proportion of primary school students plus secondary school students is chosen. Notice that this indicator is selected because compulsory education lasts 9 years from primary school to secondary school in China.

Cultural services provision: The number of books storage in public libraries is chosen.

Business and economy development facilitation: The proportion of residents that are paying for the urban old-age insurance is selected. This indicator is usually correlated to local economic performance. And Narbón - Perpiñá and De Witte (2017) states that a higher proportion of residents that are paying for the urban old-age insurance indicates a stronger local economy.

Table 3. Comparison of OCC and SEZ

	Open Coastal Cities	Special economic zone
Less Economic Restrictions than inland area	Yes	Yes
Legislative Power	No	Yes
Establishment Year of the First	1984	1979

Notes:

1) Article 81 of The Law on Legislation of the People's Republic of China and the authorization of National People's Congress authorize SEZ legislative power. OCC does not own that.

2) The China government's document Reply of the State Council on Yingkou's status as partly Open Coastal City explains that an open coastal city is allowed to enjoy financial subsidies and preferential tax rates. In addition, an OCC is entitled a discretionary grant on small economic projects.

3) Yeung, Lee and Kee (2009) state that SEZ is encouraged to pursue pragmatic and open economic policies, which means less economic restrictions present in SEZ.

Secondly, we require the data for factors researching. Factors that may affect government efficiency include discretionary factors and non-discretionary factors, see Worthington and Dollery

(2001). Discretionary factors are somehow immeasurable due to mental procedure, and our focus should be put onto non-discretionary factors. Factors that may affect local government performance include local educational background, geographical conditions, local purchasing power (Afonso and Fernandes (2005) think high-income residents tend to put more pressure on local governments), pressure from the supervisory government, economic restrictions, local government policy-making freedom and so on. da Cruz and Marques (2014) include two dozen of factors in their excellent work, but we cannot include that number of factors due to data availability.

A set of explanatory variables are chosen for indicating above factors, see, in details in Table II. Here is the individual explanation for choosing some variables: GDP per capita (yuan) is an indicator of local purchasing power. The first dummy variable is whether is open coastal city (OCC). And the second one is whether belongs to special economic zone (SEZ). OCC and SEZ are two of the most important attempts of China to carry on decentralization reform. We will compare them in Table III to comfort readers' comprehension.

4. Analytical framework

4.1 Method for efficiency estimation: Data Envelopment Analysis (DEA)

Mathematically, both the constant return to scale model, DEA-CCR (Charnes, Cooper and Rhodes, 1978), and the variable return to scale model, DEA-BCC (Banker, Charnes and Cooper, 1984), are utilized.

The linear programming problem of output-oriented BCC model is:

$$\begin{aligned} & \text{Min } \sum_{i=1}^m v_i x_{i0} - v_0 \\ \text{subject to } & \sum_{r=1}^s u_r y_{r0} = 1; \sum_{i=1}^m v_i x_{ij} - \sum_{r=1}^s u_r y_{rj} - v_0 \geq 0, \text{ for } j = 1, 2, \dots, n; u_r, v_i \geq 0. \end{aligned}$$

Here, x_{ij} denotes i th input of j th DMU, and y_{rj} denotes r th output of j th DMU. The DMU under estimation is subscripted by 0 for writing consistency. v_0 is an indicator of return to scale for every DMU? This linear programming problem can be solved by solving the dual problem:

$$\begin{aligned} & \text{Max } d_1 - d_2 \\ & \text{subject to} \\ & y_{r0} d \leq \sum_{j=1}^n \lambda_j y_{rj}, \text{ for } r = 1, 2, \dots, s; x_{i0} \geq \sum_{j=1}^n \lambda_j x_{ij}, \text{ for } i = 1, 2, \dots, m; \lambda_j \geq 0. \end{aligned}$$

The form of the dual problem of both types of models are in line with the pioneering work of Farrell (1957) by using the linear combination of efficient DMUs to represent DMU0. It created an efficient frontier that a DMU could reach. So, we can also call DEA an efficient frontier analysis model.

This article uses DEA-Solver to solve these DEA problems.

Last but not least, the most limitation of DEA is that it is only estimating relative efficiency, which means that we cannot empower each indicator with DEA. Indicators do not have a trade-off relationship with each other. For example, each observation (DMU) with the highest value of single indicator will be regarded as efficient (consider we only include one input). That custom expenditure per capita means we at least have 10 efficient DMUs, which de facto weaken the power of efficient.

4.2 Method of research on factors that affect the efficiency score

After that, we analyze the factors that affect efficiency scores of Chinese local governments. We choose the first step estimation results as explained variable. Because efficiency scores are bounded between 0 and 1, censored linear regression is utilized.

The function of censored linear regression (Tobit model) is

$$Y_j = \beta_0 + \beta_1 Aveedu_j + \beta_2 rel_j + \beta_3 issez_j + \beta_4 isocc_j + \beta_5 popden_j + \beta_6 distrec_j + \beta_7 gdppc_j + \epsilon_j$$

for $j = 1, 2, \dots, n$.

The single dependent variable Y_j here denotes the efficiency scores solved in part A and is bounded by 0 and 1. $Aveedu_j$ denotes average years of schooling of each prefecture. rel_j denotes local government expenditure reliance. This article uses $(1 - \text{current revenue} / \text{current expenditure})$ to represent it. It is an indicator describing how much do prefecture-level local governments rely on transfer payment from the central government instead of local revenue. This indicator is included for the concern that residents may pay less attention on the money from the central government than from themselves. $issez_j$ is a dummy variable measuring whether this prefecture is in special economic zone (SEZ). And $isocc_j$ is a dummy variable, and denotes whether this prefecture is open coastal city. $popden_j$ denotes the natural log of population density. $disrec_j$ is the natural log of the reciprocal of distance from this prefecture-level local government to the supervisory government, which is inspired by Afonso and Fernandes (2005). $gdppc_j$ denotes the natural log of GDP per capita, it is introduced for concerning residents with high income could put more pressure on local governments (Afonso and Fernandes, 2005). ϵ_j denotes disturbance item.

5. Results and discussion

5.1 Efficiency estimation

5.1.1 Efficiency score results

Table IV summarizes the results of both DEA models. The average efficiency score is 0.83 for prefectures in the situation of variable return to scale (BCC model). This figure demonstrates that prefectures only produce 83% of outputs they are expected to produce. Or 17% of outputs are failed to be produced by prefectures due to discretionary and non-discretionary factors.

In addition, we also estimate the scale efficiency score. It is computed by $\frac{\text{Total Efficiency (CCR scores)}}{\text{Technical Efficiency (BCC scores)}}$. The figure 0.78 shows that mostly decreasing return to scale inefficiency accounts for almost half of overall inefficiency (CCR scores).

Table 4. DEA efficiency scores of Chinese prefectures- level local governments

Model type	Average efficiency score	Number of efficient governments	Minimum efficiency score
DEA-CCR	0.66	15	0.12
DEA-BCC(Output-oriented)	0.83	31	0.56
Scale efficiency (Output-oriented)	0.78		0.17
No. of DMUs with different types of return to scale	Decreasing: 241	Constant: 27	Increasing: 9

Notes:

1) The maximum score of DEA is 1 and the minimum is 0.

2) RTS is the abbreviation of return to scale.

3) The output-oriented efficiency score for each prefecture means $\frac{\text{The outputs this prefecture has produced}}{\text{The outputs this prefecture can produced}}$ by setting the inputs as constant.

5.1.2 Some discussion about efficiency scores of Chinese prefecture-level local governments:

Firstly, as aforementioned, mostly decreasing return to scale inefficiency accounts for almost half of overall inefficiency. It is contradicted to some previous cases in European countries such as da Cruz and Marques (2014). The possible explanation for it is that mostly decreasing return to scale inefficiency is concealed by the little internal disparity in their observations. It is highly likely that prefectures in China have a larger internal disparity than Portuguese municipalities (we cannot

directly compare them because they use regional expenditure instead of expenditure per capita as input). Prefectures in China have a very large quotient (0.47) of dividing standard deviation by the mean of current expenditure.

Secondly, mostly decreasing return to scale inefficiency can be explained from the perspective of cost. Prefectures with higher current expenditure per capita usually have higher minimum wage. It increases the cost of local governments to employ employees.

Thirdly, one ninth of prefectures are efficient and the minimum score of worst-performed prefecture is 0.56. We are going to analyze the factors in the next sub-section.

5.2 Factors that affect efficiency scores

5.2.1 Censored linear regression results:

Table V summarizes the results of Tobit model. The coefficients of average years of schooling, whether belongs to special economic zone and population density are significantly larger than 0. It means that average years of schooling, belongs to special economic zone and population density are positively related to local government efficiency. And the coefficient of whether is open coastal city is significantly smaller than 0, which means becoming an open coastal city has a negative impact on local government efficiency. Coefficients of other variables are not found significantly different from 0.

Table 5. Censored linear regression results I – Tobit model

Explanatory variable	Coefficient
Aveedu _j	0.042(***)
rel _j	0.110
issez _j	0.14(*)
isocc _j	-0.072(**)
popden _j	0.033 (***)
distrec _j	-0.0047
gdppc _j	0.0149
Constant term	-0.0058

Notes:

1) (*) implies the null hypothesis was rejected at 90% confidence level, while (**) means that was rejected at 95% confidence level. (***) implies that the null hypothesis was rejected at 99% confidence level.

2) issez_j and isocc_j are two dummy variables, which means whether this local government belongs to special economic zone (SEZ). All local governments belonging to SEZ were assigned the value of 1, and the rest were assigned 0.

5.2.2 Some discussions about the censored linear regression results:

5.2.2.1 Education

The coefficient 0.042 of education implies that 1-year improvement in average years of residents' schooling causes 0.042 efficiency score improvement of this local government. More evidence is given in Table VI, where describes the effect of the number of residents holding different degrees. Two approaches can explain this effect of education. Firstly, highly-educated residents tend to care more about government performance i.e., put more pressure on local governments. Secondly, highly-educated residents could respond to government policies more effectively, which decreases the cost of policy implement. It is notable that the figure 0.042 is quite large and education is a universal variable. So, it is crucial to improve the local education in order to improve local government efficiency. Policies in details remain to be discussed in future literature, but we suggest that extend compulsory education period (9 years currently) could be an appropriate approach because of the fact that the length of China's compulsory education ranks much lower than its GDP per capita. In addition,

more local government expenditure should be spent on education especially the basic education (primary school to high school) since China only has a national average year of schooling of 9.64.

Table 6. Censored linear regression results II – Tobit model

Explanatory variable	Coefficient
High school degree proportion	1.048(***)
College degree proportion	0.013

Notes:

1) This table shows the results after substituting high school degree proportion and college degree proportion for *aveeduj*.

2) (*) implies the null hypothesis was rejected at 90% confidence level, while (**) means that was rejected at 95% confidence level. (***) implies that the null hypothesis was rejected at 99% confidence level.

3) Results for control variables and the constant term are not shown for lucidity. Control variables include *gdppcj*, *relj*, *popdenj*, *distrecj*, and dummies.

5.2.2.2 Explain the dummies

We find that the coefficient of whether belongs to SEZ is positively significant. It implies that Special Economic Zone prefectures are available to provide more services with the same amount of expenditure. We argue that it is the benefits of decentralization. The first perspective is room for policy innovation. Yeung, Lee and Kee (2009) conclude that SEZ prefectures make many policies breakthroughs because of the legislative power given to them. And the policies breakthroughs allow local governments to provide services with less costs. The second perspective is shoe leather cost, which is an economic notation. It cost more for the decision to convey to local governments from the central government than made by themselves. This finding is in line with Balaguer-Coll, Prior and Tortosa-Ausina (2009) and Boetti, Turati and Piacenza (2012), and is consistent with the idea of decentralization and fiscal decentralization.

Something interesting about the results include that we find the coefficient of whether is open coastal city (OCC) is negative. It at least implies that only give subsidies and limited economic approval power to prefectures cannot significantly improve local government efficiency. This result is quite thought-provoking that the establishment of open coastal city seems to be a failure because of excessively conservative. There is too less power given to OCC compared with SEZ.

5.2.2.3 Insignificance of financial reliance

We do not find the significantly negative correlation between financial reliance and efficiency scores at prefecture level which was found in Wu et al. (2017) at provincial level. So, it is wise to not assess that public financial reliance is a negative reason for local government efficiency in China.

6. Conclusion

Modernizing the governance system and governance ability is not an easy task for all governments, especially the developing country governments. Developing country governments are confronted with more challenges than developed country governments such as autocracy, severe corruption, warlordism and poor education conditions. This article estimates the prefecture-level local government efficiency in China and find that prefectures only produce 83% outputs as they were expected. There is room for prefectures to improve their performance.

We appeal that decentralization and investing on education could be two feasible approaches to improve government efficiency. Some challenges need to be overcome for decentralization in China. The first is the overly conservative attitude of the Chinese government. The central government of China has transferred limited power to province-level government in fact. However, the degree is oft-questioned. And we have also criticized the Chinese government for overly conservative when establishing open coastal cities. The decentralization progress in China is relatively slow, especially considering that SEZ only includes five prefectures other than Hainan Island. The policy approaches

for decentralization are limited and most prefectures do not have the legislative power. The second challenge is provincial centralization. The power devolved to the province-level governments is partly reserved. Some decisions made by prefectures need to rely on the approval of province-level government according to the report of State Council. It essentially, according to the theory of fiscal decentralization, results in inefficiency of government expenditure.

Future study may develop in various ways. This article is limited by the accessibility of data, and it may cause our research results to be inaccurate and incomplete. In addition, we only utilize one method for efficiency estimation, future study can include different types of study for robustness. Furthermore, researching on whether the implement of 12-year compulsory education is a feasible and effective approach from different perspectives (not only from the perspective of management science) is meaningful. If the answer is yes, then implementing 12-year compulsory education would be an urgent and significant reform to realize the modernization of the governance system and governance ability.

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