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**The Effect of Local Government Debt for Infrastructure
Development on Economic Development Based
on K-means Clustering and Random Forest**

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Abstract

Some provinces in China have encountered local government debt issues. The main cause of government debt is the issuance of bonds by the government to raise funds for infrastructure development, aiming to leverage the positive externalities of infrastructure and the increased employment opportunities caused by infrastructure construction to drive local economic growth. However, if the economic benefits of funding infrastructure through government debt are limited, the government should focus on reducing its debt burden. The existing literature has shown divergent views on the relationship between government debt and economic development. Some studies argue that government debt hampers economic growth, while others believe that proactive government debt can stimulate economic development, and some suggest that an increase in government debt can promote local economic growth within certain thresholds, but beyond a certain point, it can impede economic development. This study examines the impact of local government debt on economic growth in different provinces of China using panel data from 2015 to 2021. Through K-means clustering, the 31 provinces of China are divided into three categories based on factors determining promotion and suppression effects. For each province category, this study employs a random forest model to predict the percentage increase in economic growth corresponding to the percentage increase in government debt, while controlling for other variables affecting economic growth. The predicted results from the random forest model demonstrate that the influence of increasing local government debt on economic development varies across different province categories. The main contribution of this study lies in the adoption of clustering of K-means to categorise the provinces, providing a targeted classification for debt-related issues.

Keywords: k-means clustering, random forest, government debt, economic growth, infrastructure construction.

JEL Classification: E61.

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1. Introduction

Government investment exerts a powerful impetus on economic development, especially in China, where government investment in infrastructure has become an important fiscal tool. However, due to the fact that government investment mainly focuses on public goods with longer return cycles and relatively low economic benefits, it is prone to increase government debt. In China, it is obvious that local governments' debt grows rapidly. The debt balance of local governments in China has increased to \$36 trillion in 2022. There is no doubt that the space for local government debt issuance continues to be rapidly compressed. Therefore, the following question should be addressed now: for which local governments still need to raise funds through debt to promote economic development by local government investment, and for which local governments should appropriately control the scale of debt.

2. Problem Statement

The theory of positive government debt emerged after the 1930s. For example, the study of Tiebout (1956) gives meaning to the issuance of bonds by local governments: It is more economically efficient to raise capital than taxation. Then Stiglitz (1974) and other scholars on government debt and fiscal risk led to the development of local debt theory. The study conducted by De Mello Jr. (2000) suggests that fiscal decentralisation and taxation systems have driven local governments to accumulate significant debt in order to invest in infrastructure and accelerate GDP growth. Furthermore, research conducted by Panizza and Presbitero (2014) and Owusu-Nantwi and Erickson (2016) indicates that government fiscal deficits and debt levels can promote development, regardless of the maturity of the debt.

At the same time, some studies have found a nonlinear relationship between government debt and private investment. Reinhart (2010) discovers that there is a threshold effect of government debt through empirical tests on developed and emerging market countries. Similar conclusions are obtained from the research of Checherita (2012): When the government debt reaches a certain level, it is expected to decelerate the growth of GDP by hampering the private savings and decreasing the total factor productivity. Law et al. (2021) suggest that the threshold debt value is around 51.65 % in developing countries.

In China, numerous papers on the topic have suggested that the nonlinear relationship between government debt and economic growth takes the shape of an inverted U. However, these studies are empirically derived from a sample of dozens or hundreds of countries, including China, while few studies have been conducted using specific provincial-level data from China.

The main contributions of this paper are as follows: First, this paper departs from most existing researches on local government debt issues in China and other countries by utilising provincial-level data from 2015-2021 instead of national-level data. Provincial-level data allows for more detailed analysis and enables this paper

to differentiate between provinces, with a particular focus on China's local government debt problem. Moreover, while most existing papers in terms of Cluster Analyses of China's local government debt problem categorise provinces mainly based on factors such as the eastern, central, and western regions of China, or different economic regions. There is no doubt that such classifications are only tangentially related to local government debt issues, which can lead to problems such as small category distinctions and unclear category characteristics. This paper employed the K-means Clustering to classify provinces based on factors that directly impact the relationship between government investment and private investment, which results in categories that are more distinct and meaningful.

3. Research Questions / Aims of the Research

The main reason for government debt is to raise funds for infrastructure construction. Government debt itself cannot promote economic development, but government investment that corresponds to government debt can. Therefore, studying the relationship between government debt and economic development actually involves a comprehensive investigation of both the hindering effect of government debt on economic development and the promoting effect of government investment on economic development. When the positive effect of government investment on economic growth is not significant, that is, when the negative impact of government debt on economic growth is dominant, there is a negative relationship between government debt and economic growth. When the positive effect of government investment on economic growth is significant, that is, when the positive effect of government investment on economic growth dominates, there exists a positive relationship between government debt and economic growth.

It should be noted that, for the task of promoting economic development, government investment largely relies on stimulating private investment rather than relying solely on government spending. This is because private investment tends to be more economically efficient than government investment, in that private investment is more willing to invest in industries which generate larger returns, such as high-tech industries and real estate industries, while the main purpose of government investment is not to obtain economic benefits, but to produce public goods such as infrastructure, thus exerting its positive externalities.

Therefore, when discussing the relationship between government debt and economic growth, it is necessary to first examine the relationship between government investment and private investment, specifically the crowding-out and crowding-in effects. The relationship between government debt and economic growth varies among provinces, with different levels of crowding-in or crowding-out effects of government investment on private investment.

4. Research Methods

4.1 K-means Clustering

To begin with, this study employs the k-means method to cluster Chinese provinces based on factors affecting the relationship between government investment and private investment, aiming to facilitate the subsequent investigation of the relationships between local government debt and economic growth in different categories of provinces.

4.1.1 Indicator Selection

In this paper, the following six indicators are chosen to classify provinces of China (excluding Hong Kong, Macao, and Taiwan). The data period is 2015-2021.

“Fiscal transparency (fis)”. A greater degree of fiscal transparency promotes openness and democracy in government investment decisions, which can increase investors' participation and understanding of policies. It is instrumental in increasing investors' confidence in investment and enhancing the crowding-in effect. On the contrary, provinces with low fiscal transparency tend to suffer from arbitrary decision-making and inadequate information disclosure in the investment process, which may even give rise to behaviours such as power rent-seeking. According to You and Xu (2016), rent-seeking behaviours and government corruption can inhibit private investment, as a deleterious business climate makes sound infrastructure less attractive for private investment. To represent the degree of transparency of the decision-making system, the fiscal transparency scores of the provincial governments are used (Data resource: China Fiscal Transparency Report).

“Population size (pop)”. The larger the population size of a province, the more likely it is to produce a network effect. The network effect creates an opportunity for private firms to reduce their marginal costs, making them more inclined to invest. As a result, government investment may exhibit a stronger crowding-in effect (Data resource: CEIC database; unit: million).

“Level of infrastructure construction (inf)”. According to Aschauer (1989), government investment can promote private investment by improving local infrastructure construction. However, it is obvious that the increase in private investment resulting from the improvement of infrastructure is subject to diminishing marginal returns. This is because, as the infrastructure in various cities in China gradually improves, the differences between cities become smaller and smaller, and small-scale improvements in infrastructure cannot attract more private investment. According to Jia et al. (2021), due to overcapacity, traditional infrastructure construction in some cities in the central region of China has already hindered private investment. In this paper, the ratio of road miles to the area of a province is used to measure the level of infrastructure construction in that province (Data resource: CEIC database).

“Liquidity (liq)”. One of the main reasons for the crowding-out effect of government investment is that it absorbs too much market liquidity, leading to higher market interest rates and increased financial constraints, which suppress private

investment. However, if the local financial development level is good and liquidity is relatively abundant, the crowding-out effect of government investment can be smaller. This is because when liquidity is sufficient, the impact of government borrowing on the local financial market is relatively small. In existing research, there are many variables used to represent liquidity, such as the M2, credit scale, and social financing scale. In this paper, the total loan amount of a province is used to measure local financial development (Data resource: CEIC database; Unit: Trillion RMB yuan).

“Foreign direct investment (fdi)”. According to Harrison et al. (2004), foreign direct investment can increase local liquidity, thereby driving domestic investment. In this paper, the ratio of FDI to local GDP is used to measure the level of local FDI inflows (Data resource: CEIC database; Unit: Billion RMB yuan).

“Investment attraction policy (policy)”. Osei-Kyei and Albert (2017) points out that one reason why infrastructure projects funded by government investment in most developing countries fail to attract private investment is due to insufficient tax reduction efforts by the government. According to Barbosa (2016), the government can implement subsidy policies or tax exemptions to attract private investment. For this reason, in order to increase the crowding-in impact of government investment, the government might reduce taxes, eliminate fees, and provide subsidies to make the area more appealing to private investors. Given data availability, this indicator is measured by the share of non-tax revenues in each province's general public budget revenues (Data resource: CEIC database; Unit: Trillion RMB yuan).

4.2 Random Forest

Next, this paper utilises the Random Forest to predict the percentage of economic growth that corresponds to the percentage increase in government debt growth for each category, assuming that all other conditions remain constant.

4.2.1 Indicators

To avoid endogeneity issues, this paper chooses the lagged one-year increase in government bond issuance volume (Δbond) as the explanatory variable, while the current year's growth rate of GDP (ΔGDP) is chosen as the dependent variable (Data source: CEIC database).

In addition, previous literature has shown that social capital stock (capital), human capital stock (human), urbanisation rate (urban), and degree of openness (open) all can influence the speed of economic development. These variables are selected as control variables.

Besides, since the amount of local government debt is not publicly available and many governments have a large amount of invisible debt, this paper only studies the impact of the increase in local governments' municipal bonds (bonds issued by local government-controlled enterprises for infrastructure construction).

The total amount of municipal bonds issued by each province in each year from 2015 to 2021 is used to estimate the local government debt of each province (Data source: Wind financial database).

According to Shan (2008), this paper uses a method that uses core factors such as fixed capital formation, depreciation rate, and investment price index to estimate the social capital stock for the current year (Data sources: China Urban Statistical Yearbook, China Industrial Statistical Yearbook).

The average years of education in each province are used to measure the human capital stock of each province (Data source: CEIC database).

The volume of each province's total imports and exports is used to determine its degree of openness (Data source: CEIC database). The urbanisation rate and GDP growth rate of each province are from the National Bureau of Statistics.

5. Results and Discussions

5.1 K-means Clustering Results

31 provinces in China are divided into three categories by K-means analysis. Since the silhouette score of the K-means classification results is 0.53, which is close to 1, the different categories are divided clearly.

Table 1. Results of K-means Clustering

Cluster	Provinces
Cluster 1	Inner Mongolia, Shanxi, Heilongjiang, Guangxi, Hainan, Guizhou, Yunnan, Tibet, Gansu, Qinghai, Ningxia, Xinjiang, Si-chuan, Fujian, Jiangxi, Anhui.
Cluster 2	Jiangsu, Shandong, Guangdong, Zhejiang, Henan.
Cluster 3	Beijing, Tianjin, Hebei, Liaoning, Jilin, Shanghai, Hubei, Hunan, Chongqing, Shaanxi.

Source: China Fiscal Transparency Report, CEIC database.

Table 2. Annual averages by dimension for Cluster 1 provinces

Year	fis	pop	inf	liq	fdi	policy
2015	32	2.4	0.31	1.57	1.53	0.043
2016	35	2.7	0.38	1.78	1.66	0.045
2017	37	2.9	0.41	2	1.42	0.044
2018	41	2.6	0.48	2.22	1.38	0.044
2019	36	2.9	0.51	2.46	1.25	0.048
2020	42	3.1	0.51	2.74	1.31	0.052

Source: China Fiscal Transparency Report, CEIC database.

Table 3. Annual averages by dimension for Cluster 2 provinces

Year	fis	pop	inf	liq	fdi	policy
2015	26	87.5	1.32	6.02	11.23	0.115
2016	33	88.7	1.34	6.82	13.45	0.133
2017	40	89.6	1.35	7.66	13.22	0.142
2018	41	90.8	1.37	8.78	13.38	0.137
2019	39	91.9	1.38	10.11	14.13	0.149
2020	40	92.9	1.4	11.72	13.95	0.163

Source: China Fiscal Transparency Report, CEIC database.

Table 4. Annual averages by dimension for Cluster 3 provinces

Year	fis	pop	inf	liq	fdi	policy
2015	34	24.5	1.51	3.01	6.88	0.071
2016	25	24.9	1.76	3.39	7.21	0.078
2017	38	25.3	1.81	3.8	8.39	0.075
2018	37	25.6	1.85	4.2	8.42	0.069
2019	36	25.6	1.88	4.68	8.48	0.077
2020	38	25.7	1.89	5.19	8.51	0.076

Source: China Fiscal Transparency Report, CEIC database.

5.2 Results of Random Forest

In this study, Random Forest is employed to examine the correlation between government debt and local economic development across three distinct clusters. Specifically, this paper studies the percentage change in GDP for 2023 that corresponds to incremental increases of 5%, 10%, and 30% in municipal bonds issued by provinces in each cluster in 2022. The predictive accuracy of each cluster's random forest model is reported in parentheses:

Table 5. Results of Random Forest

Δ bond	Δ GDP		
	Cluster 1	Cluster 2	Cluster 3
5%	6.1% (62.65%)	2.5% (71.35%)	1.8% (69.26%)
10%	6.8% (58.33%)	2.7% (70.11%)	2.0% (67.74%)
30%	7.1% (60.33%)	2.8% (70.36%)	1.6% (69.52%)

Source: CEIC database, Wind financial database, China Urban Statistical Yearbook, China Industrial Statistical Yearbook.

Derived from outcomes of Random Forest, local governments in provinces belonging to cluster 1 can consider increasing the scale of municipal bond issuance and expediting infrastructure development, as long as the debt crisis does not impede normal economic functioning. According to the average values of each dimension in K-means Clustering, there are several reasons why an increase in the amount of

municipal bonds will have a greater pulling effect on local GDP growth: First of all, considering that most of the provinces in cluster 1 are remote provinces in China and all have large areas. The infrastructure construction in these provinces is relatively poor. As a consequence, the new infrastructure will have a great impact on the local investment. The positive externality brought about by infrastructure is larger, and the crowding-in effect is stronger. Second, the provinces in cluster 1 have less non-tax revenue, which means the investment attraction policy is better and the local government encourages private investment. Considering the two reasons above, when local governments issue municipal bonds for infrastructure construction, it not only generates certain economic benefits through the infrastructure itself, but more importantly, it also creates a more favourable investment environment that attracts a large number of private investments, leading to significant local economic development.

For provinces in cluster 2, they should stop increasing the issuance of municipal bonds and gradually reduce the issuance of municipal bonds. Most of the provinces in cluster 2 are eastern provinces with large population, relatively large jurisdiction, and fast economic development. This paper argues that the economic benefits of municipal bonds in provinces located in cluster 2 are not as good as those in provinces located in cluster 1 considering that infrastructure construction is relatively well developed, and the marginal benefits from infrastructure construction are relatively small. However, government investment in these provinces still plays a certain role in promoting economic development. First, although infrastructure construction in these provinces is relatively high, but because of the large area of these provinces, the infrastructure in some areas is relatively imperfect, and the positive externalities and economic benefits brought by infrastructure construction are still large. Second, these areas have a larger population, which enhances the positive externalities and economic benefits brought about by infrastructure construction. Third, these regions attract a significant amount of FDI, which increases local liquidity and mitigates the crowding-out effect of government investment. Finally, these provinces have ample liquidity themselves, which weakens the crowding-out effect of government investment to a certain extent.

For provinces in cluster 3, they should reduce the issuance of municipal bonds and focus on solving the debt crisis of local governments. The provinces in cluster 3 are divided into two categories. One category is municipalities like Beijing, Shanghai, Tianjin, and Chongqing, which have large populations, well-developed infrastructure, small jurisdictions, high levels of economic development, and high urbanisation rates. For this category of provinces, the infrastructure construction is already well developed, and the increase in positive externalities from continuing infrastructure construction is small. As a result, government investment should be appropriately reduced in favour of strong private investment. Another category is the provinces of Liaoning, Jilin, Hubei, and Hunan. Government investment in infrastructure construction has limited effects on economic growth in these provinces: Firstly, these provinces, particularly Liaoning and Jilin, were among the earliest to develop industry provinces in China and have a relatively comprehensive

infrastructure. Therefore, the marginal benefits of continuing investment in infrastructure construction are low. Moreover, due to their early development, the existing infrastructure is relatively old, which means new infrastructure cannot be well-matched, leading to the need to demolish old structures and build a new one, further increasing the cost of infrastructure construction. Therefore, government investment in infrastructure construction is costly and yields limited returns, hindering local economic development. Furthermore, the weak economic growth in these provinces in recent years, coupled with nearby areas that have greater economic growth potential, has led to a large outflow of population, further reducing the positive externalities and economic benefits of government investment in infrastructure construction.

6. Conclusion

This paper conducts a cluster analysis of the relationship between local government debt and local economic development using the K-means Clustering and Random Forest. The primary findings of this study are outlined as follows: First, K-means Clustering findings show that China's 31 provinces can be roughly split into three groups based on the factors that affect the crowding-out or crowding-in effects. Second, according to the prediction results of random forest, the impact of the increase in local government debt on economic development is different for provinces in different categories. Overall, there is a positive correlation between the scale of local government debt and local GDP in China's remote provinces, and the increase in local government debt significantly promotes local economic development. For most of China's eastern provinces, there is also a positive correlation between the scale of local government debt and GDP. However, the rate of decrease in the effect of local government debt on economic development is comparatively steeper than China's remote provinces. Moreover, the influence of local government debt on economic development exhibits substantially lower significance compared to that in China's remote provinces. For China's municipalities, north-eastern provinces, and some central provinces, the increase in the scale of local government debt has a minor promoting effect on local economic growth. After the scale of local government debt increases to a certain extent, it even hinders local economic growth.

However, this paper still exhibits several inadequacies. Primarily, whether it concerns factors that influence the impact of local government investment on private investment or those that affect local economic growth, this paper unavoidably overlooks certain variables. Secondly, the study disregards the influence of policies implemented by the Chinese central government on the scale of local government debt.

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