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POWER PYRAMID, HIDDEN DEBT, AND CHINA'S URBAN EXPANSION

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Abstract. Chinese urban spatial expansion leads to inefficient use of land resources. This study uses the data of 289 cities from 2007 to 2018 and uses panel data models to test the driving mechanism of urban expansion. The study derives three conclusions. First, there is a significant positive correlation between urban power hierarchy and urban spatial expansion. If the urban administrative power hierarchy is high, then the urban built-up area increases more. Second, there is a significant positive correlation between the scale of hidden debt and the expansion of urban space. The increase of the urban investment bonds' scale will promote the expansion of urban built-up areas. Third, there is a significant positive correlation between the quantity of bond issuers and urban spatial expansion.

Keywords: spatial expansion, power hierarchy, hidden debt, financing platform, China.

Introduction

With the development of industrialization, urbanization is mainly characterized by urban population changes and land expansion (Schneider & Mertes, 2014; Scott & Storper, 2015; Sun & Zhao, 2018). China is undergoing rapid urbanization, with the rural residents changing to urban residents. The population urbanization rate increases from 45.89% in 2007 to 60.60% in 2019. The local governments promote the rapid increase of urban built-up areas and the outward migration of urban boundaries through the adjustment of administrative divisions and the planning of new towns, new districts, development zones, industrial parks, and sub-cities, respectively. The urban built-up areas expand from 35469.65 km^2 in 2007 to 58,455.66 km^2 in 2018, with an average annual growth rate of 4.65%. Considering the relatively high level of economic development, the effect of population and industrial agglomeration is evident. The built-up areas of cities with high power hierarchy increase more and faster than those of other cities. For example, the built-up areas in Chongqing expand from 667.45 km^2 in 2007 to 1,496.72 km^2 in 2018, with an average annual growth rate of 7.62%.

However, some researchers pointed out that China's urbanization process is faced with the problem of factor imbalance. The growth rate of the urban land area continues to be higher than the population, and the expansion of urban land area exceeds the amount needed for population growth. In addition, the risk of excessive development of urban land exists (Zhang, 2000; Chen et al., 2016a; Wei et al., 2017; Guan et al., 2020). As shown in Figure 1, the average growth rate of built-up areas of 289 prefecture-level and above cities from 2007 to 2018 is 4.99%, whereas the population growth rate is 2.91%. Zhang (2000) noted that urban sprawl refers to the disproportionate expansion of urban land areas and population. Urban sprawl brings about problems, such as extensive use of land, unaffordable cost of public services, and price bubbles of real estate (Milan & Creutzig, 2016).

In addition, China's *New Budget Law* implemented in 2015 stipulates that local governments can only raise debt within the limit set by the central government (*State Council*). Local governments need to raise money to support urban development, municipal utilities, and public services to meet the needs of the new residents. The rapidly increasing public service cost and infrastructure construction expenditure bring pressure to local governments. Therefore, supporting urban expansion through hidden debt has become an important option (Milan & Creutzig, 2016). By the end of 2021, the balance of local government debt is 30.47 trillion yuan, but the scale of interest-bearing debt of local financing platforms is up to 43.99 trillion yuan. The scale of hidden debt far exceeds

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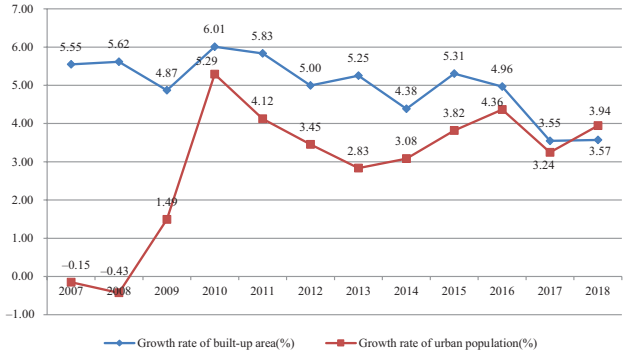
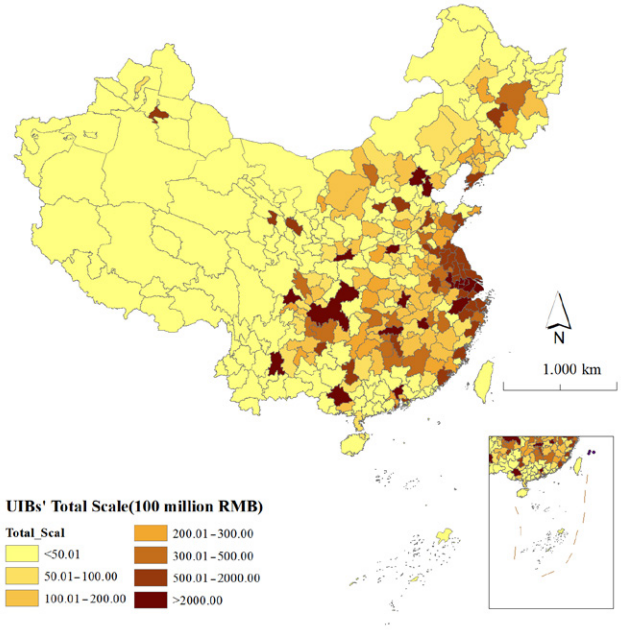


Notes: The data is from China urban construction statistical yearbooks (2007–2018) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2018). The study sorts and calculates the built-up area and urban population of the selected 289 prefecture-level and above cities. The urban population is the sum of the urban permanent population. The growth rate of built-up and population areas are compared with those of last year.

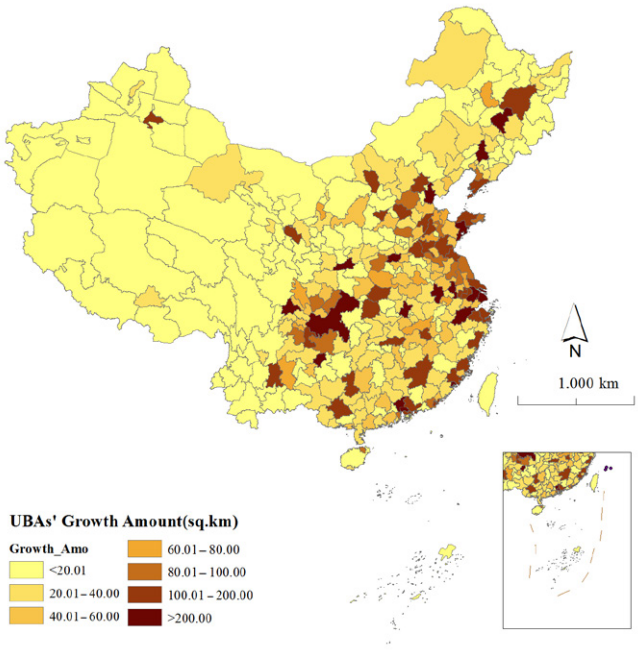
Figure 1. Growth rate of built-up areas and population in 289 cities in 2007–2018



Notes: Data on UIBs are collected from *Wind Economic Database* (Wind Information Co., Ltd., 2019).

Figure 2. Total amount of UIBs issued in 289 cities from 2007 to 2018

that of conventional debt by government. Known as "quasi-municipal bonds", urban investment bonds (UIBs) are corporate bonds issued by local financing platforms (LFPs, local state-owned enterprises, SOEs) to support local infrastructure construction. Although UIBs are corporate bonds, the funds are mainly used for urban development and infrastructure construction. The UIBs are hidden debts of local governments. As shown in Figure 2 and Figure 3, a correlation exists in the spatial distribution between the issuance of UIBs' total scale and the added value of built-up areas in 2007–2018.

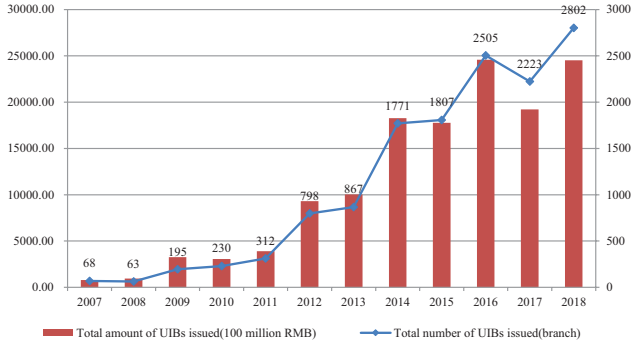


Notes: The data of urban built-up areas are derived from the China urban construction statistical yearbooks (2007–2018) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2018).

Figure 3. Expansion of urban built-up area of 289 cities from 2007 to 2018

For cities with a larger issuance of UIBs' total scale, the added value of built-up areas is relatively higher. Moreover, the cities with a high-power hierarchy have larger issuance of UIBs' total scale, and the added value of built-up areas is also larger. The issuance of UIBs may provide financial support to promote the increase of urban built-up areas, thereby promoting urban spatial expansion.

However, local governments use LFPs to raise money through the issuance of bonds to support urban development and infrastructure construction. So, the local government is ultimately responsible. As shown in Figure 4, according to *Wind Economic Database*, the UIBs' number and scale issued by 289 cities in China from 2007 to 2018 have grown steadily. The total issuance number of UIBs is 13641 branches, and the total scale is 13.56 trillion RMB over this timeframe. The LFPs raise money mainly to support the construction of municipal and public infrastructure, which have a long construction period and limited profitability. LFPs are dependent on future land leasing revenue to repay the debt. The price fluctuations in the real estate market will affect land leasing revenue, which will not only threaten the revenue of local governments but also seriously weaken the ability to repay hidden debts. The increased uncertainty in the land market leads to land depreciation, which causes not only the failure of LFPs to repay bank loans but also systemic financial risks (Pan et al., 2017). Therefore, the increase of UIBs' scale has certain fiscal and financial risks, thereby damaging the social economy and the urban sustainable development.



Notes: UIBs data are from *Wind Economic Database* (Wind Information Co., Ltd., 2019). To improve the data accuracy, this study excludes the corporate bonds of the LFPs listed in Shanghai and Shenzhen (to avoid duplication of bonds), and 13,641 UIBs data were collected from 2007 to 2018.

Figure 4. Amount and number of UIBs issued in 289 cities in 2007–2018

This study uses the data of 289 cities from 2007 to 2018 and a panel data model to conduct exploratory research on the driving factors of urban spatial expansion. The study mainly answers the following three questions: (1) Is there a positive correlation between urban power hierarchy of the city and urban spatial expansion? (2) Is there a positive correlation between the UIBs' scale issued by LFPs and urban spatial expansion? (3) Is there a positive correlation between the quantity and credit rating of bond issuers and urban spatial expansion? The remainder of this paper is organized as follows. Section 1 presents theoretical analysis and discusses the research hypotheses. Section 2 presents the empirical model. Section 3 explains the research area and variable description. Section 4 presents the empirical results and section 5 discusses the results. The last section is conclusion.

1. Theoretical analysis and research hypothesis

1.1. Urban spatial expansion and the main drivers

Urban geography and urban planning scholars focus on urban spatial expansion. The researchers have conducted considerable research on the driving mechanism and measurement indicators of urban spatial expansion. The monocentric model, represented by Alonso, Mills, Muth and later developed by Wheaton and Bruckner et al., believes that city size is mainly driven by population size, income level, farmland price and commuting cost (Alonso, 1964; Mills, 1967; Muth, 1969; Wheaton, 1974; Brueckner & Fansler, 1983). The central place theory proposed by Christaller believes that the city, as a central place, provides various goods and services to residents living in the surrounding areas. The geographic distance converted by currency value is an important factor that determines the scope of the supply of goods and services in the center. The transportation development is of great significance to the formation and development of the central place.

Based on the theory, some research shows that socioeconomic, demographic, and urban traffic development are important driving factors of urban spatial expansion (Zhang & Su, 2016; You & Yang, 2017; Shu et al., 2018; Li et al., 2018; Zhang et al., 2018). Economic growth, industrial development, and economic structural transformation are key economic determinants. Economic development plays a leading role in the urban spatial expansion. With the improvement of the economy and the transformation of the industrial structure, the urban–rural income gap and the demand for labor drive rural population to migrate to cities are reduced, thereby leading to the increase of urban built-up area and pushing the urban boundaries outward. The change in population size and demographic structure is one of the main driving forces of urban expansion in China. The rapid urbanization allows the continuous increase of the urban population size, which prompts local governments to accelerate the urban expansion to meet the living space demands of the new population. The improvement of urban traffic conditions can increase spatial accessibility and reduce residents' commuting costs, thereby promoting the agglomeration of industries in suburbs and the outward migration of living space. Weilenmann et al. (2017) found that the improvement of traffic convenience was the key factor affecting the urban spatial expansion in Switzerland. The opening of high-speed rail has significantly promoted urban spatial expansion (Long et al., 2018; Deng et al., 2020; Zhu et al., 2020).

Some researchers combine the data of land use and population size to measure urban spatial expansion. The changing rate of per capita urban land (Liu et al., 2018b; Jia et al., 2020), the population growth to urban expansion ratio (Chen et al., 2014), and the difference between the growth of urban areas and the population (Guan et al., 2020) are used. Some researchers directly use the changing rate and proportion of urban land area (Zhang & Su, 2016; Wei et al., 2017; Yu et al., 2019), urban built-up areas (Li et al., 2018; Tiitu, 2018; Deng et al., 2020), and urban construction land area (Li et al., 2015; Luo et al., 2018) to measure urban spatial expansion. Urban spatial expansion can be captured using three major data sources. The first is the Landsat TM satellite images (Deng et al., 2008; Li et al., 2013; Liu et al., 2018a; Liu et al., 2018b; Yu et al., 2019). Then, the second is the DMSP/OLS night lights that reflect the characteristics of human activities (Zhang & Su, 2016; You & Yang, 2017; Fan & Zhou, 2019; Guan et al., 2020). The third is to obtain land use data, such as urban built-up area or urban construction land area, directly from the official statistical data (Li et al., 2015; Deng et al., 2020).

1.2. Power pyramid and urban spatial expansion

China's rapid urbanization and economic development plans have been carried out simultaneously. Some urban policies and local government administrative means have greatly influenced China's urbanization process (Liu et al., 2012). Jia et al. (2020) found that regional development policies, the household registration (*hukou*) system, and

urban land and housing market policies have different effects on the urban expansion of different categories. Then, Fan and Zhou (2019) divided the intergovernmental competition into three dimensions, namely, fiscal, investment attraction, and promotion environment competitions. They found that intergovernmental competition has a significant positive impact on urban spatial expansion. In addition, the administrative division adjustment, as an important policy tool for spatial management, has an important impact on urban expansion in different regions of China (Feng & Wang, 2021).

Chinese cities show an evident hierarchical structure at different administrative ranks, and the power of decision-making and the development resources are unbalanced (Liu et al., 2018a). The cities with a higher power hierarchy have stronger power for policy-making and land-leasing and can attract more investment from the central government and foreign investors (Chen & Partridge, 2013; Wei et al., 2017). Moreover, these cities have higher land-use efficiency and are more competitive in land development. Therefore, they are more likely to obtain construction land quotas for development and have higher urban expansion and economic development potential (Schneider & Mertes, 2014; Zeng et al., 2017). Li et al. (2015) found that cities with higher power hierarchy tend to expand more rapidly while controlling for other economic and demographic drivers of urban expansion. Based on the analysis, the hypotheses are presented as follows.

Hypothesis 1: there is a positive correlation between power hierarchy and urban spatial expansion.

1.3. Land finance and urban spatial expansion

After China's tax-sharing reform between central and local governments in 1994, high-quality tax sources are allocated to the central government, which have a great impact on the fiscal revenue of local governments (Zheng et al., 2014). With the acceleration of urbanization, local governments are facing increasing financial pressure to afford the construction of urban infrastructure and municipal public facilities. The local governments have to turn to "land finance". Land leasing revenue, land-related tax, and land mortgage are the main source of local urban construction funds (Wang et al., 2018; Gao, 2019). The Ministry of Finance noted that the land leasing revenue was 6.5 trillion RMB in 2018, having an increase of 25% compared with that of last year. The land leasing revenue was approximately 66.48% of the local general public budget in the same period and even exceeded the general budget revenue in some regions.

Land market revenue becomes a veritable "secondary finance" for local governments. Under the unique fiscal and land management system in China, some researchers found that land leasing revenue has become a significant driving force to promote urban spatial expansion (Zhang, 2000; Tian, 2015; You & Yang, 2017; Liu et al., 2018a; Gao, 2019). On the one hand, local governments use land expropriation to transfer rural collective land into urban construction land. Then, they lease land to urban real estate and industrial development through bidding, auction, and listing, resulting in a continuous increase of the built-up area. On the other hand, land leasing revenue provides funds for infrastructure construction, which makes urban expansion financially possible.

Land value appreciation in the urbanization process has triggered market speculation. Under the pressure of guaranteeing economic growth and promotion, local governments have increased their dependence on land finances. There is a significant positive correlation between residential land price and land hoarding area by local governments. And land speculation in the China's eastern region is more pronounced than that in central and western regions (Zhang et al., 2020). As the collateral for the issuance of UIBs, land leasing revenue is the fund that is used to repay the debt with large-scale land hoarding and increasing land price due to China's rapid urbanization. Both the land hoarding scale and land price exhibit a positive influence on the UIBs' scale and risk (Zhang et al., 2021). However, there is a lack of literatures on the impact of UIBs on urban expansion.

LFPs are state-owned enterprises established by local governments to help them access the capital. They undertake the investment and financing functions of the government in urban construction (Cong et al., 2019; Chen et al., 2020; Luan & Li, 2022). Local governments expand the asset scale of LFPs and build them into economic entities with financing capacity through financial allocation or injection of land, equity, fees and other assets (Wu, 2022; Feng et al., 2022). LFPs raise money from banks, stock exchanges and other financial institutions through issuing urban investment bonds, bank loans and other channels for infrastructure and public facilities construction (Zhang et al., 2021; Chen & Wu, 2022). At the same time, LFPs are also responsible for land consolidation, real estate development and construction projects. The issuance of urban investment bonds provides financial support for the increase of urban built-up areas. And LFPs are institutions that help local governments to promote land development. Both of them promote urban expansion. The quantity of LFPs that have issued UIBs may affect the opportunity to issue bonds, thereby affecting the issuance of UIBs' scale and promoting urban spatial expansion. The LFPs with higher credit ratings have a relatively small default risk and strong debt repayment ability. Moreover, these LFPs will tend to issue more UIBs, thus affecting the urban spatial expansion. Based on the analysis, the hypotheses are presented as follows.

Hypothesis 2: there is a positive correlation between the UIBs' scales issued by LFPs and urban spatial expansion.

Hypothesis 3: there is a positive correlation between the LFPs' characteristics and urban spatial expansion.

Based on the research on the measurement indicators and driving mechanism of urban spatial expansion, this study examines the driving mechanism of urban spatial expansion from the perspective of cities' power hierarchy

and hidden debt. Compared with the existing literatures, the main contributions of this study are as follows. First, from the perspective of cities' power hierarchy, this study examines the influence of the provincial, sub-provincial, and provincial capital cities on the urban spatial expansion. The study emphasizes the role of the power hierarchy system in urban spatial expansion. Second, this study explores urban spatial expansion from a new perspective and assesses the impact of the issuance of UIBs' scale on the built-up area. The result provides a basis for managing and preventing the hidden debt risk of local governments. Third, the new framework is proposed for the analysis of urban spatial expansion. The characteristic of LFPs is incorporated into the empirical model to evaluate the impact of LFPs' quantity and quality on urban spatial expansion, and provides a new literature basis for scholars to study the driving factors of urban spatial expansion.

2. Model specification

2.1. Model selection

Considering that the provincial, sub-provincial, and provincial capital cities remain unchanged from 2007 to 2018, the two dummy variables that measure the power hierarchy are omitted when using the fixed-effect model. Therefore, the choice is made between mixed models and random-effects models. The Lagrange Multiplier test strongly rejects the null hypothesis that "there is no individual random effect" at the significance level of 1%. The test results indicated that the random effects models should be used for estimation.

However, the random effects estimation assumes that individual effects is uncorrelated with independent variables, and this assumption is unlikely true in urban studies. Therefore, according to Tang et al. (2022) and Song et al. (2015), this paper also uses Hausman-Taylor estimation to estimate the model including power hierarchy. Hausman-Taylor estimation can solve the endogenous problem caused by the correlation between city effects and explanatory variables (Hausman & Taylor, 1981). In Model 7–9 without power hierarchy, we select the fixed-effect model to estimate the time-varying variables of the UIBs' scale and LFPs' quantity and quality based on the results of F statistics and Hausman test, as shown in Table 1.

2.2. Empirical models

Based on the results of LM test, this paper selects random-effects GLS regression to estimate the impact of power hierarchy and hidden debt on the urban spatial expansion. Equation (1) presents the empirical model.

$$Area_{it} = \beta_0 + \beta_1 Scale_{i,t-1} + \beta_2 Quantity_{i,t-1} + \beta_3 Quality_{i,t-1} + \beta_4 PL_{it} + \beta_5 SPL_{it} + \sum \beta_6 x_{it} + u_i + \varepsilon_{it},$$

where: $Area_{it}$ is the built-up area of i city in t year; $Scale_{i,t-1}$ is the UIBs' scale issued by i city in $t-1$ year. If the city does not issue UIBs, the value is 0; $Quantity_{i,t-1}$ is the quantity of LFPs that issued UIBs of i city in $t-1$ year; $Quality_{i,t-1}$ is the quality of LFPs that issued UIBs of i city in $t-1$ year; PL_{it} and SPL_{it} are dummy variables that measure whether the city's power hierarchy is at the provincial level (PL), sub-provincial level (SPL), or provincial capitals. For PL_{it}, if the hierarchy of i city is at the PL in t year, then the value is 1; otherwise, 0. For SPL_{it}, if the hierarchy of i city is at the SPL or provincial capitals in t year, then the value is 1; otherwise, 0. x_{it} is a set of control variables that affect urban spatial expansion, including the factor of socio-economic development, urban population, and traffic. Finally, u_i is the individual effect of i city, and ε_{it} is the random error term.

3. Research area and variable description

3.1. Research area and data source

Some prefecture-level cities' data are not available in Tibet Autonomous Region, Qinghai Province, and Hainan Province. Therefore, this study takes 289 prefecture-level and above cities as the research objects and collected the data of power hierarchy, UIBs, and urban spatial expansion data from 2007 to 2018 for analysis. The built-up area, urban population size, urban population density, urban rail transit, and urban road area are derived from the *China urban construction statistical yearbooks* (2007–2018) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2018). Moreover, the power hierarchy, per capita GDP, foreign direct investment, and industrial structure are derived from the *China city statistical yearbooks* (2008–2019) (National Bureau of Statistics of China, 2019b) and *Wind Economic Database* (Wind Information

Table 1. The results of LM test, F test and Hausman test

Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 7	Model 8	Model 9
LM test (chibar2(01))	9392.48	8254.92	8372.17	8178.30	9281.14	–	–	–
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	–	–	–
F statistics	–	–	–	–	–	92.87	96.46	70.77
P-value	–	–	–	–	–	0.0000	0.0000	0.0000
Hausman test (Chi-Square Statistics)	–	–	–	–	–	358.80	363.62	252.20
P-value	–	–	–	–	–	0.0000	0.0000	0.0000

Co., Ltd., 2019). The average exchange rate and consumer price index data sources are from the *China statistical yearbooks* (2008–2019) (National Bureau of Statistics of China, 2019a). Then, UIB data are from *Wind Economic Database* (Wind Information Co., Ltd., 2019). To improve the data accuracy, this study excludes the corporate bonds of the LFPs listed in Shanghai and Shenzhen stock market (to avoid duplication of bonds), and 13,641 UIBs data were collected from 2007 to 2018. Then, the UIBs' scale, LFPs' quantity, and quality are calculated manually in each city.

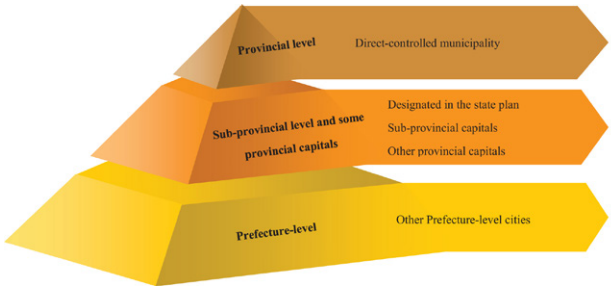
3.2. Definition of variables

3.2.1. Explained variables

Following Deng et al. (2020), we select the urban built-up area to measure urban spatial expansion. The urban built-up area (*Area*) refers to the construction area in the city that has been developed on a large scale and has basic public facilities and utilities. In the process of urban spatial expansion, most cities in China show an increasing trend in urban built-up areas. Therefore, this study uses the variable of built-up area to measure the urban spatial expansion, and the unit is square kilometers.

3.2.2. Explanatory variables

There are differences in resource provision and decision-making power among cities at different administrative hierarchy in China, which are endowed by the administrative system (Ma, 2005). Chinese cities show an obvious hierarchical structure, which can be divided into municipalities, vice-provincial cities, prefecture-level cities and county-level cities (Ma, 2005; Sun & Zhao, 2018). This study selects prefecture-level and above cities as the research object for empirical analysis. The power pyramid structures of the Chinese cities are shown in Figure 5. Cities with higher administrative hierarchy have better public resources and more decision-making power (Jia et al., 2021). These power differences give cities with higher administrative hierarchy the financial resources of productivity advantages and political favoritism. They also attract more investment from the central government, domestic and foreign and have better social and economic performance (Chan & Zhao, 2002; Li et al., 2015). The level of urbanization in these cities are relatively high (Gao et al., 2022). Therefore, the administrative hierarchy is used to measure the power hierarchy of cities in this study.



Notes: There are four direct-controlled municipalities, including Beijing, Shanghai, Tianjin and Chongqing; There are five cities designated in the state plan, including Dalian, Qingdao, Ningbo, Xiamen and Shenzhen; and ten sub-provincial capitals including Harbin, Changchun, Shenyang, Jinan, Nanjing, Hangzhou, Guangzhou, Wuhan, Chengdu and Xi 'an. The other provincial capitals include 17 cities including Shijiazhuang, Taiyuan, Hohhot, Hefei, Fuzhou, Nanchang, Zhengzhou, Changsha, Nanning, Haikou, Guiyang, Kunming, Lhasa, Lanzhou, Xining, Yinchuan and Urumqi. Other prefecture level cities include Tangshan, Qinhuangdao, Handan, Xingtai and other 253 cities.

Figure 5. The power pyramid structure of the Chinese cities

Li et al. (2015) considered the provincial and sub-provincial cities when setting the power hierarchy dummy variables and did not consider some provincial capitals. China's provincial capital cities have a relatively more favorable investment environment and a higher level of economic development. Thus, the provincial capital cities have more motivation and resources to develop land. A high correlation is observed between urban expansion and economic growth in provincial capital cities (Wei et al., 2017).

Therefore, this study sets two dummy variables to measure the cities' power hierarchy at the *PL*, *SPL*, or provincial capitals. If the city's hierarchy is at the PL, then the value of *PL* is 1; otherwise, 0. Moreover, if the city's hierarchy is at the SPL or provincial capitals, then the value of *SPL* is 1; otherwise, 0. Appendix Table A1 shows the classification of the urban power hierarchy.

The hidden debt of local governments refers to the debt that exceeds the legal limit of government debt and is promised to repay with financial funds or illegally guaranteed by local governments. The main channels of hidden debt of local governments are local financing platforms, public-private partnerships (PPP) and government service purchases. Due to the availability of data, this study uses LFPs as a proxy variable for local hidden debt and selects UIBs' scale and the characteristics of the issuer (the quantity and quality of LFPs) as the core explanatory variables. (1) UIBs' scale (*Scale*): This variable indicates the total amount of UIBs issued by LFPs every year. If the city does not issue UIBs, then the value is 0, and the unit of UIBs' scale is 100 million RMB. (2) The LFPs' quantity (*Quantity*): This variable indicates the number of LFPs that issued UIBs. If the city does not issue UIBs, then the value is 0, and the unit of LFPs' quantity is the number. (3) The LFPs' quality (*Quality*): This variable refers to the LFPs' ability to repay debts. The LFPs with strong debt repayment ability are more inclined to issue UIBs. The credit rating agencies give credit ratings to LFPs based on regional economic environment, local government credit (economic strength, debt balance, comprehensive financial resources), LFPs' own credit (operational risk, financial risk), and local government support, etc. The credit ratings of LFPs are classified as AAA, AA+, AA, AA– and A+. The LFPs with high credit rating have stronger ability to repay the debt, and are not vulnerable to adverse economic environment. The default risk of them is lower. According to *Wind Economic Database*, the credit rating of the issuers of UIBs in China mainly concentrates on AA and above. This study uses the proportion of bond issuers with a credit rating of AA+ and above to assess the LFPs' quality.

3.2.3. Control variables

To avoid estimation errors caused by missing variables, this study selects the factor of socio-economic, demographic, and urban traffic development as control variables. Following You and Yang (2017), this study uses per capita GDP, foreign direct investment, and industrial structure to evaluate the impact of socio-economic factors on urban spatial expansion. (1) Per capita GDP (*PCGDP*): With the increase of per capita GDP, the urban economic development is better and can attract more population and industrial agglomeration. In addition, the income of urban areas is relatively higher so that the population flows from the countryside to the city, which makes the urban spatial expansion correspondingly (Deng et al., 2008). The unit of per capita GDP is RMB. (2) Foreign direct investment (*Invest*): The increase in foreign investment may promote urban spatial expansion because foreign investment is mostly concentrated in development zones, which are often located in the periphery of cities (Li et al., 2015). We select the amount of foreign capital used by each city as foreign direct investment and convert it into RMB according to the average exchange rate against the US dollar every year. The unit of foreign direct investment is 100 million RMB. (3) Urban industrial structure (*Structure*): This study uses the proportion of tertiary industry in total GDP to express the industrial structure. Chen et al. (2016a) found that urban land expansion is highly correlated with the growth of the tertiary industry. The increase in the proportion of the tertiary industry means that additional labor will migrate to cities, which leads to the need for more land to accommodate the growing labor force.

Li et al. (2018) noted that the demographic factor is an important factor that triggers rapid urban expansion. We use urban population size and density to assess the impact of the demographic factor on urban spatial expansion. (1) Urban population size (*People*): The urban spatial expansion is also related to the size of the urban population, which may affect urban expansion through land prices and commuting costs (Liu et al., 2018b). To correspond to the definition of urban built-up area, this study uses the sum of the urban permanent population to measure urban population. The unit of urban population size is 10,000 persons. (2) Urban population density (*Popden*): This variable indicates the degree of population density in the urban area. A higher population density indicates that the development potential of urban construction land is low, thereby inhibiting urban spatial expansion (He et al., 2014). The unit of urban population density is person per square kilometer.

In addition, urban spatial expansion is related to the improvement of transportation infrastructure. Optimizing road networks and improving traffic accessibility will effectively guide the direction and speed of urban expansion. The urban rail transit (light rail, subway, and high-speed rail) has become the most important transportation project in each city, which has an increasingly important influence on urban expansion. This study sets up dummy variables to assess the influence of the construction of urban rail transit on urban spatial expansion. Moreover, this study uses the urban road area to assess the impact of urban traffic development on urban space expansion. (1) Urban rail transit (*Rail*): If the city has a subway, light rail, and other rail transit, then this variable is assigned a value of 1; otherwise, 0. (2) Urban road area (*Road*): This variable refers to the surface area of roads and squares, bridges, and tunnels connected to roads. The unit of the urban road area is 10,000 m^2.

The data of money value variables from 2007 to 2018 were reduced to 2007 according to the consumer price index to eliminate the effect of inflation and reflect the actual change of variables with 2007 as the research base year. Table 2 shows the descriptive statistics of the variables. The variables, such as per capita GDP, foreign direct investment, urban population size, urban population density, and urban road area, fluctuate greatly. To make the fluctuations of the variables relatively stable and alleviate the heteroscedasticity, these variables are logarithmic in the regression analysis.

4. Research results

Before the regression analysis, the variables are tested for collinearity. The results showed that the variance inflation factor was less than 10 and no multicollinearity existed. This study introduces the power hierarchy, UIBs' scale, LFPs' quantity and LFPs' quality one by one based on the inclusion of control variables, and estimate by random effects in Models 1, 2, 3, 4 and 5. This study also uses Hausman-Taylor and fixed effects to estimate. Model 6 contains only power hierarchy variables and control variables and is estimated by Hausman-Taylor. The UIBs' scale, LFPs' quantity and LFPs' quality are introduced one by one and are estimated by fixed effects in Models 7, 8 and 9. Model 10 includes all variables and is estimated by Hausman-Taylor. Table 3 shows the empirical results.

4.1. Influence of power hierarchy on urban spatial expansion

According to the results of Models 1, 5, 6, and 10. There is a significant positive correlation between urban power hierarchy and urban built-up area. The PL is positively correlated with the urban built-up area, and statistically significant at the 1% level of significance (the coefficient is 614.196). Moreover, the cities at the SPL or provincial capital are positively correlated with the urban built-up area, and statistically significant at the 1% level of significance (the coefficient is 136.296). The result shows that the urban built-up area of the cities with higher power hierarchy increases more and urban spatial expands faster.

4.2. Influence of hidden debt on urban spatial expansion

According to the results of Models 2, 5, 7, and 10, there is a significant positive correlation between UIBs' scales and

Table 2. Definitions and descriptive statistics of variables

Variables	Definition	Code	Unit	N	Mean	S.D.	Min	Max
Urban spatial expansion	Urban built-up area: The variable refers to the construction area in the city that has been developed on a large scale and has basic public facilities and utilities	*Area*	km^2	3,468	128.897	177.121	6.570	1,496.720
	Urban construction area: The variable refers to area of land except water area and land for other purposes, including land for residential development, administration and public services, commercial and business facilities, industrial, manufacturing, logistics and warehouse, road, street and transportation, municipal utilities, green space and square	*CArea*	km^2	3,452	133.829	215.996	0.050	2915.560
Urban power hierarchy	PL cities: If the power hierarchy is at the PL, then the value is 1; otherwise, 0	*PL*	dummy	3,468	0.014	0.117	0.000	1.000
	SPL or provincial capitals: If the power hierarchy is at the SPL or provincial capitals, the value of SPL is 1; otherwise, 0	*SPL*	dummy	3,468	0.111	0.314	0.000	1.000
Local hidden debt	UIBs' Scale: The variable is the UIBs' scale issued by i city in t year. If the city does not issue UIBs, then the value is 0	*Scale*	100 million RMB	3,468	39.110	122.309	0.000	1,858.900
	The LFPs' quantity (Quantity): This variable indicates the number of LFPs that issued UIBs. If the city does not issue UIBs, then the value is 0	*Quantity*	number	3,468	1.908	4.637	0.000	66.000
	The LFPs' quality: This variable indicates the proportion of bond issuers with a credit rating of AA+ and above	*Quality*	%	3,468	17.157	32.849	0.000	100.000
Socio-economic development	Per capita GDP: This variable measures the level of economic development	*PCGDP*	RMB	3,468	35,553.289	24,132.217	3,398.000	213,122.870
	Foreign Direct Investment: This variable is the amount of foreign capital actually used by each city	*Invest*	100 million RMB	3,253	46.488	107.006	0.002	1,610.327
	Urban industrial structure: This variable is the proportion of tertiary industry in total GDP	*Structure*	%	3,468	38.639	9.579	8.580	80.980
Urban population	Urban population size: This variable is the sum of the urban permanent and temporary population	*People*	10,000 persons	3,468	122.199	222.226	5.000	2,425.680
	Urban population density: This variable indicates the degree of population density in the urban area	*Popden*	person/km^2	3,468	3,833.167	2,754.063	248.000	20,093.000
Urban traffic	Urban rail transit: If the city has a subway, light rail, and other rail transit, then this variable is assigned a value of 1; otherwise, 0	*Rail*	dummy	3,468	0.064	0.245	0.000	1.000
	Urban road area: This variable refers to the surface area of roads and squares, bridges, and tunnels connected to roads	*Road*	10,000 m^2	3,468	1,705.381	2,309.704	27.000	20,378.200

Notes: The data is derived from the *China urban construction statistical yearbooks* (2007–2018) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2018), *China city statistical yearbooks* (2008–2019) (National Bureau of Statistics of China, 2019b), *Wind Economic Database* (Wind Information Co., Ltd., 2019), and *China statistical yearbooks* (2008–2019) (National Bureau of Statistics of China, 2019a). UIBs data is from *Wind Economic Database* (Wind Information Co., Ltd., 2019).

urban built-up area at the 1% level of significance (the coefficient is 0.119). The result shows that cities with a larger scale of UIBs issuance promote the construction of municipal public facilities and infrastructure, thereby promoting the expansion of urban space. With the UIBs' scale increasing 100 million, the urban built-up area would increase by 0.119 km^2.

According to the results of Models 3, 5, 8, and 10, there is a significant positive correlation between LFPs' quantity issued UIBs and urban built-up area at the 1% level of significance (the coefficient is 3.606). The result shows that if LFPs are qualified to issue bonds, then the urban built-up area will expand rapidly. As the money raised by LFPs increases, the urban space will expand more. According to the results of Models 4, 5, and 10, there isn't a significant correlation between the LFPs' quality issued UIBs and the urban built-up area.

4.3. Other drivers of urban spatial expansion

In addition, according to the results of Models 1–10, the estimated coefficient of urban industrial structure is significantly positive, and the increase of the tertiary industry will promote the increase of the urban built-up area. Moreover, the coefficient of urban population size is significantly positive, indicating that the increase in urban population significantly promotes urban spatial expansion. The coefficients of rail transit construction and urban road area are significantly positive, indicating that cities with rail transit are likely to expand outward. A well-developed transportation infrastructure will improve the accessibility of cities and reduce commuting costs. Then, urban space will expand along the transportation lines.

In addition, this study selects the area of urban construction to measure urban spatial expansion for a robustness test. The estimated results are shown in Appendix Table A2. From the results of Models 11–20, the coefficients of variables measuring local hidden debt and urban power hierarchy are significantly positive. Furthermore, the coefficients of the core explanatory variables in the model have not changed significantly, and they are consistent with the estimated results of Models 1–10, indicating that the estimated results are robust.

5. Discussions

Hypothesis 1 is verified. There is a significant positive correlation between power hierarchy and urban spatial expansion. The decision-making power of local government in administrative and financial aspects is largely dependent on the administrative hierarchy of the cities (Jia et al., 2021). The cities with high administrative hierarchy have productivity advantages and financial resources that are biased by policies (Chan & Zhao, 2002; Ma, 2005). These cities can obtain more urban construction land quotas to promote the construction of new districts, development zones, and industrial parks to meet the increasing demand for urban space (Sun & Zhao, 2018). The cities also have better social and economic performance than other cities, and attract more investment from the central government and other countries (Chan & Zhao, 2002; Gao et al., 2022). Therefore, the built-up areas of cities with high administrative hierarchy increase more and urban spatial expansion is serious (Li et al., 2015; Wei, 2015).

Hypothesis 2 and 3 are verified. There is significant positive correlation between UIBs' scales, LFPs' quantity and urban spatial expansion. Local governments promote the construction of urban infrastructure or public welfare projects by setting up LFPs (Cong et al., 2019; Chen et al., 2020; Feng et al., 2022). LFPs provide financial support for urban construction through bank loans or issuance of UIBs, which continuously improve municipal and public facilities and promote the continuous expansion of urban space (Wu, 2022; Chen & Wu, 2022; Luan & Li, 2022). As the main body of land development and real estate construction, LFPs increase the built-up area of cities and promote the urban spatial expansion. The LFPs' quantity can also affect the built-up area by influencing the ability to issue bonds.

However, China's urban space is overexpanded, which is seriously incompatible with the population growth. The speed of land urbanization is faster than that of population urbanization (Chen et al., 2016b; Wei et al., 2017; Guan et al., 2018). Local governments over-rely on LFPs to raise money and launch a large number of urban construction projects, which are divorced from the actual needs of some urban development. This accelerates the imbalance of land and population factors in urbanization (Hong et al., 2017; Ji et al., 2019; Wang & Zhang, 2022). The rapid expansion of Chinese cities has resulted in the loss of high-quality arable land, the phenomenon of "ghost cities" is increasingly serious and the efficiency of land use is low (Tu et al., 2021; Wang et al., 2021). The hidden debt of local governments is mainly invested in municipal public facilities and infrastructure projects with large capital requirements and long payback period, and these projects have low ROI and efficiency (Ma, 2013; Han et al., 2021). The repayment money mainly come from the land leasing revenue. The volatility of the real estate market leads to the uncertainty of money repayment and increases the financial risks of local governments (Wu et al., 2016; Zhang et al., 2021).

Conclusion

Research conclusion

The irrational expansion of urban leads to inefficient use of land resources and UIBs' risk. This study selects the data of power hierarchy, UIBs, and urban spatial expansion in 289 prefecture-level and above cities from 2007 to 2018. The study also uses panel data models to explore the impact of power hierarchy and local hidden debt on the urban spatial expansion. The following results are obtained. Firstly, the cities with high administrative hierarchy expand rapidly in urban space. In provincial, sub-provincial and some provincial capitals with high

Table 3. Estimation results of the panel data models

	Random-effects GLS regression					Hausman-Taylor	Fixed-effects regression			Hausman-Taylor
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
PL	586.368***				584.760***	613.770***				614.196***
	(18.895)				(18.615)	(16.117)				(15.617)
SPL	88.745***				120.060***	103.149***				136.296***
	(7.320)				(9.857)	(6.922)				(8.946)
L.Scale		0.235***			0.118***		0.238***			0.119***
		(32.733)			(8.959)		(35.106)			(9.225)
L.Quantity			6.088***		3.488***			6.259***		3.606***
			(32.914)		(10.193)			(5.452)		(10.773)
L.Quality				0.028	0.029				0.008	0.029
				(1.077)	(1.414)				(0.309)	(1.461)
lnPCGDP	16.158***	−2.221	−6.244**	6.008**	2.414	1.454**	9.309***	4.996	17.700***	5.062**
	(6.246)	(−0.879)	(−2.457)	(2.047)	(0.995)	(2.031)	(3.606)	(1.333)	(5.686)	(2.002)
Structure	1.266***	0.605***	0.467***	1.133***	0.487***	19.410***	0.691***	0.541***	1.204***	0.525***
	(9.276)	(4.966)	(3.829)	(7.968)	(4.243)	(7.013)	(5.864)	(2.947)	(8.513)	(4.559)
lnInvest	1.419**	1.683***	1.664***	2.197***	0.776	1.311***	0.500	0.463	1.155	0.613
	(1.974)	(2.692)	(2.672)	(2.982)	(1.320)	(9.364)	(0.830)	(0.749)	(1.586)	(1.048)
lnPeople	70.231***	84.523***	81.934***	97.990***	59.376***	62.509***	50.110***	46.821***	65.752***	50.015***
	(17.164)	(23.347)	(22.535)	(23.730)	(16.247)	(13.404)	(11.920)	(5.299)	(13.025)	(12.406)
lnPopden	−3.744**	−3.734***	−3.631**	−4.476***	−3.065**	−3.599**	−2.752**	−2.637	−3.541**	−2.717**
	(−2.377)	(−2.585)	(−2.523)	(−2.634)	(−2.269)	(−2.226)	(−1.974)	(−1.494)	(−2.103)	(−2.001)
Rail	84.402***	45.290***	47.746***	80.104***	40.319***	78.940***	37.746***	40.077***	71.410***	36.653***
	(19.517)	(11.848)	(12.617)	(18.407)	(11.214)	(18.367)	(10.417)	(2.902)	(16.921)	(10.381)
LnRoad	11.377***	11.431***	11.562***	11.862***	11.679***	10.925***	11.001***	11.178***	11.789***	11.400***
	(5.187)	(5.917)	(6.008)	(5.206)	(6.453)	(4.935)	(5.950)	(2.867)	(5.278)	(6.340)
_cons	−460.277***	−294.523***	−240.948***	−450.704***	−258.940***	−462.152***	−270.299***	−210.742***	−439.304***	−250.279***
	(−19.847)	(−12.639)	(−10.200)	(−16.744)	(−11.614)	(−19.595)	(−12.217)	(−5.871)	(−16.773)	(−11.161)
N	3253	2979	2979	2979	2979	3253	2979	2979	2979	2979
R^2	0.8468	0.8018	0.7969	0.7698	0.8462	–	0.6053	0.6098	0.4244	–

Notes: ***, **, and * denote variables that are statistically significant at the 1%, 5%, and 10% levels, respectively. The values of *z* or *t* are in parentheses.

administrative hierarchy, the urban built-up area increase more. Secondly, urban investment bonds issued by local financing vehicles promote urban spatial expansion. Urban investment bonds are mainly used for infrastructure construction to promote the increase of urban built-up areas. Finally, local financing platforms are an important channel for local governments to raise money for urban construction, as well as the main body to undertake land consolidation, real estate development and construction projects. They promote urban spatial expansion from the aspects of capital and factor support.

Chinese government plays an important role in promoting urbanization, and urban expansion is largely influenced by administrative measures of governments at all levels (Chan & Zhao, 2002; Sun & Zhao, 2018). This paper quantifies the driving factors of urban spatial expansion from the perspectives of power hierarchy and hidden debt, so as to promote the understanding of urban expansion in China and further expand the theoretical framework. At the same time, the paper discusses the inefficient land use resulting from local government-led urban expansion and the risks of urban expansion driven by hidden debt. The paper puts forward some policy implications on urban expansion and hidden debt based on the discussion.

Policy implications

The excessive expansion of urban built-up area leads to inefficient land use, and the increase of UIBs' scale has certain fiscal and financial risks. Both are detrimental to the healthy, stable and sustainable development of cities. Based on the perspective of power hierarchy and hidden debt, this study puts forward some policy recommendations to excessive urban expansion and regulate local hidden debt.

To avoid the irrational urban spatial expansion, the central government should promote the coordinated development of cities at different administrative hierarchy. Urban administrative system exacerbates the unequal distribution of economic resources and other driving forces behind urban development in China (Li et al., 2015). It is necessary to fundamentally change the administrative hierarchy tendency in resource allocation. Land resources should be rationally allocated based on demand-oriented factors such as economic level and population size of each city. At the same time, the central and provincial government should improve the land development policy and rationally plan the proportion of different uses of land to avoid the imbalance of urban land supply structure.

In order to regulate local hidden debt, it is necessary to promote the market-oriented transformation of LFPs is essential to standardize the local hidden debt, thereby separating government credit from corporate credit, to cut off the asset extension and risk guarantee of local governments to the LFPs. Clarifying the LFPs' repayment, guarantee, and rescue responsibilities is helpful. Moreover, establishing a local debt risk monitoring indicator system based on the existing hidden debt scale, utilization efficiency, economic development, and financial situation of local governments is necessary. The cities should control their debt scale below the risk warning line. Furthermore, urban development and construction should broaden and standardize the financing channels of local governments.

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Conflict of interests

The authors declare no conflict of interests.

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Appendix

Table A1. The classification of urban administrative hierarchy

Administrative hierarchy	City title	Cities
Provincial level	Direct-controlled municipality	Beijing, Tianjin, Shanghai, Chongqing
Sub-provincial level and some provincial capitals	Designated in the state plan	Dalian, Qingdao, Ningbo, Xiamen, Shenzhen
	Sub-provincial capitals	Harbin, Changchun, Shenyang, Jinan, Nanjing, Hangzhou, Guangzhou, Wuhan, Chengdu, Xian
	Other provincial capitals	Shijiazhuang, Taiyuan, Hohhot, Hefei, Fuzhou, Nanchang, Zhengzhou, Changsha, Nanning, Haikou, Guiyang, Kunming, Lhasa, Lanzhou, Xining, Yinchuan, Urumqi
Prefecture-level	Prefecture-level cities	Hebei province: Tangshan, Qinhuangdao, Handan, Xingtai, Baoding, Zhangjiakou, Chengde, Cangzhou, Langfang, Hengshui Shanxi province: Datong, Yangquan, Changzhi, Jincheng, Shuozhou, Jinzhong, Yuncheng, Xinzhou, Linfen, Luliang Inner Mongolia: Baotou, Wuhai, Chifeng, Tongliao, Ordos, Hulunbuir, Bayannaoer, Ulanchabu Liaoning Province: Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Panjin, Tieling, Chaoyang, Huludao Jilin Province: Jilin, Siping, Liaoyuan, Tonghua, Baishan, Songyuan, Baicheng Heilongjiang Province: Qiqihar, Jixi, Hegang, Shuangyashan, Daqing, Yichun, Jiamusi, Qitaihe, Mudanjiang, Heihe, Suihua Jiangsu Province: Wuxi, Xuzhou, Changzhou, Suzhou, Nantong, Lianyungang, Huai'an, Yancheng, Yangzhou, Zhenjiang, Taizhou, Suqian Zhejiang Province: Wenzhou, Jiaxing, Huzhou, Shaoxing, Jinhua, Quzhou, Zhoushan, Taizhou, Lishui Anhui Province: Wuhu, Bengbu, Huainan, Maanshan, Huaibei, Tongling, Anqing, Huangshan, Fuyang, Suzhou, Chuzhou, Lu'an, Xuancheng, Chizhou, Bozhou Fujian Province: Putian, Sanming, Quanzhou, Zhangzhou, Nanping, Longyan, Ningde Jiangxi Province: Jingdezhen, Pingxiang, Jiujiang, Fuzhou, Yingtan, Ganzhou, Ji'an, Yichun, Xinyu, Shangrao Shandong Province: Zibo, Zaozhuang, Dongying, Yantai, Weifang, Jining, Taian, Weihai, Rizhao, Linyi, Dezhou, Liaocheng, Binzhou, Heze Henan Province: Kaifeng, Luoyang, Pingdingshan, Anyang, Hebi, Xinxiang, Jiaozuo, Puyang, Xuchang, Luohe, Sanmenxia, Nanyang, Shangqiu, Xinyang, Zhoukou, Zhumadian Hubei Province: Huangshi, Shiyan, Yichang, Xiangyang, Ezhou, Jingmen, Xiaogan, Jingzhou, Huanggang, Xianning, Suizhou Hunan Province: Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Changde, Zhangjiajie, Yiyang, Chenzhou, Yongzhou, Huaihua, Loudi Guangdong Province: Shaoguan, Zhuhai, Shantou, Foshan, Jiangmen, Zhanjiang, Maoming, Zhaoqing, Huizhou, Meizhou, Shanwei, Heyuan, Yangjiang, Qingyuan, Dongguan, Zhongshan, Chaozhou, Jieyang, Yunfu Guangxi: Liuzhou, Guilin, Wuzhou, Beihai, Fangchenggang, Qinzhou, Guigang, Yulin, Baise, Hezhou, Hechi, Laibin, Chongzuo Hainan Province: Sanya Sichuan Province: Zigong, Panzhihua, Luzhou, Deyang, Mianyang, Guangyuan, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang'an, Dazhou, Ya'an, Bazhong, Ziyang Guizhou Province: Liupanshui, Zunyi, Anshun, Bijie, Tongren Yunnan Province: Qujing, Yuxi, Baoshan, Zhaotong, Lijiang, Pu'er, Lincang Shaanxi Province: Tongchuan, Baoji, Xianyang, Weinan, Yan'an, Hanzhong, Yulin, Ankang, Shangluo Gansu Province: Jiayuguan, Jinchang, Baiyin, Tianshui, Wuwei, Zhangye, Pingliang, Jiuquan, Qingyang, Dingxi, Longnan; Ningxia: Shizuishan, Wuzhong, Guyuan, Zhongwei Xinjiang: Karamay, Turpan, Hami

Notes: The classification of urban administrative hierarchy is derived from the *China city statistical yearbooks* (2008–2019) (National Bureau of Statistics of China, 2019b).

Table A2. The results of robustness test

	Random-effects GLS regression					Hausman-Taylor estimation	Fixed-effects (within) regression			Hausman-Taylor estimation
	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20
PL	970.308***				961.284***	957.543***				953.137***
	(16.869)				(17.069)	(15.067)				(14.779)
SPL	89.283***				110.187***	101.185***				124.958***
	(4.051)				(5.086)	(4.139)				(5.024)
L.Scale		0.181***			0.085***		0.185***			0.087***
		(17.012)			(4.099)		(17.837)			(4.245)
L.Quantity			4.732***		2.795***			4.893***		2.913***
			(17.127)		(5.189)			(18.156)		(5.478)
L.Quality				0.043	0.046				0.025	0.046
				(1.256)	(1.453)				(0.746)	(1.482)
lnPCGDP	10.804***	−8.811**	−12.284***	−2.452	−4.474	0.990	1.243	−2.103	7.640*	−2.822
	(3.124)	(−2.295)	(−3.178)	(−0.611)	(−1.178)	(1.062)	(0.316)	(−0.533)	(1.839)	(−0.718)
Structure	0.902***	0.367**	0.262	0.761***	0.293	12.630***	0.438**	0.328*	0.834***	0.277
	(5.047)	(2.010)	(1.428)	(3.998)	(1.640)	(3.527)	(2.430)	(1.811)	(4.399)	(1.538)
lnInvest	1.040	1.222	1.245	1.620*	0.477	0.903***	0.052	0.029	0.532	0.252
	(1.111)	(1.310)	(1.335)	(1.651)	(0.523)	(4.984)	(0.056)	(0.032)	(0.546)	(0.276)
lnPeople	69.969***	85.372***	83.903***	95.710***	64.955***	62.459***	53.357***	50.452***	65.229***	55.565***
	(12.232)	(14.759)	(14.500)	(15.918)	(11.138)	(10.212)	(8.301)	(7.844)	(9.645)	(8.818)
lnPopden	−1.623	−1.956	−1.850	−2.570	−1.395	−1.273	−0.831	−0.673	−1.480	−0.770
	(−0.788)	(−0.907)	(−0.858)	(−1.134)	(−0.665)	(−0.610)	(−0.390)	(−0.317)	(−0.658)	(−0.364)
Rail	70.555***	41.211***	43.092***	67.399***	37.389***	68.876***	35.942***	37.496***	62.382***	34.623***
	(12.654)	(7.242)	(7.611)	(11.684)	(6.701)	(12.388)	(6.466)	(6.792)	(11.009)	(6.265)
lnRoad	8.793***	9.080***	9.168***	9.529***	8.823***	9.476***	9.101***	9.210***	9.775***	9.661***
	(3.089)	(3.160)	(3.189)	(3.151)	(3.145)	(3.315)	(3.223)	(3.268)	(3.272)	(3.448)
_cons	−385.732***	−208.424***	−165.909***	−329.077***	−191.910***	−380.860***	−184.969***	−137.871***	−314.070***	−179.954***
	(−12.639)	(−5.930)	(−4.643)	(−9.076)	(−5.518)	(−12.349)	(−5.475)	(−4.014)	(−8.966)	(−5.137)
N	3237	2965	2965	2965	2965	3237	2965	2965	2965	2965
R^2	0.7149	0.6203	0.6200	0.6042	0.7049	–	0.6226	0.6218	0.6058	–

Notes: ***, **, and * denote variables that are statistically significant at the 1%, 5%, and 10% levels, respectively. The values of *z* or *t* are in parentheses.