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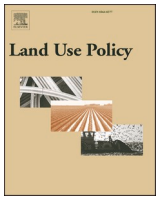

Understanding local government debt financing of infrastructure projects in China: Evidence based on accounting data from local government financing vehicles

Helen X.H. Bao [a,*], Ziyou Wang [b], Robert Liangqi Wu [a]

[a] Department of Land Economy, University of Cambridge, CB39EP, UK
[b] University of Reading, RG6 6UD, UK

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ABSTRACT

This study develops an analytical framework to investigate the complex relationship between local government debt issuing for infrastructure financing, state control, land finance, and development activities in the private sector in China. Using local government financing vehicles' accounting data, we find that local governments are working creatively to meet infrastructure development targets handed down by the central government. Moreover, local government financing vehicles became more responsive to development activities from the private sector in their debt-issuing decisions after the regulations of local government debt issuing in 2013/14. By modelling the effect of three distinct forces, i.e., the central government, local governments, and the market, in one unified framework, our study provides reliable evidence of how infrastructure financing works in China. Our research extends the studies of land finance into the infrastructure development domain. The findings are also helpful for studies on China's land use policy under its leasehold land right system, particularly the impacts of different land planning uses on infrastructure development.

1. Introduction

Infrastructure investment is an important tool for the Chinese government to stimulate economic growth (Wu, 2010), counter regional and global economic crises (World Bank, 2010), and promote its geopolitical agenda (Mohan and Tan-Mullins, 2019). Consequently, infrastructure development has always been an integral part of the central government's master plans. For example, infrastructure investment in roads and bridges is central to the Belt and Road Initiative. Since the beginning of its economic reform in the 1980 s, China has been investing heavily in infrastructure projects in and outside the country. According to the World Bank, China's share of gross fixed capital formation in GDP increased from 24% in 1990 to 42% in 2021, while its GDP has been growing at an impressive rate over the same period (see Fig. 1). Although a high level of investment in infrastructure is expected among emerging economies, China's commitment to infrastructure is considerably higher than that of India, Russia, or Brazil (i.e., the rest of the BRIC block), of which the gross fixed capital formation in GDP ranges between 19% and 29% in 2021.

Although China has been transforming from a central planning system to a market-oriented economy in the last four decades, strategically important sectors, such as telecommunications and construction, are still firmly controlled by the central government. This is a defining feature in China's socialist market economy regime, where the control by the central government in key sectors is often described as an 'iron fist' (Gong et al., 2013; Tan et al., 2007; Xia, 2010). Given the pivot role of infrastructure investment in economic development and political stability, it is not surprising for the power of the central government to be felt in many aspects of infrastructure development in China (see, for example, Feng et al., 2022a; Li et al., 2020; Wu, 2023).

Meanwhile, local governments are also heavily involved in infrastructure development in China. In the last three decades, many developing countries have embarked on fiscal decentralisation, transferring the responsibility of public goods provision from the central government to local governments (Bardhan and Mookherjee, 2006). Recently, the responsibilities of infrastructure provision have been gradually shifted to the local governments in China as well. Furthermore, China's 1994 tax-sharing reform transferred the bulk of tax revenues to the centre, leaving local governments with significant fiscal shortfalls. In less than 20 years, local governments' share of national government revenues has

* Corresponding author.
E-mail address: hxb20@cam.ac.uk (H.X.H. Bao).

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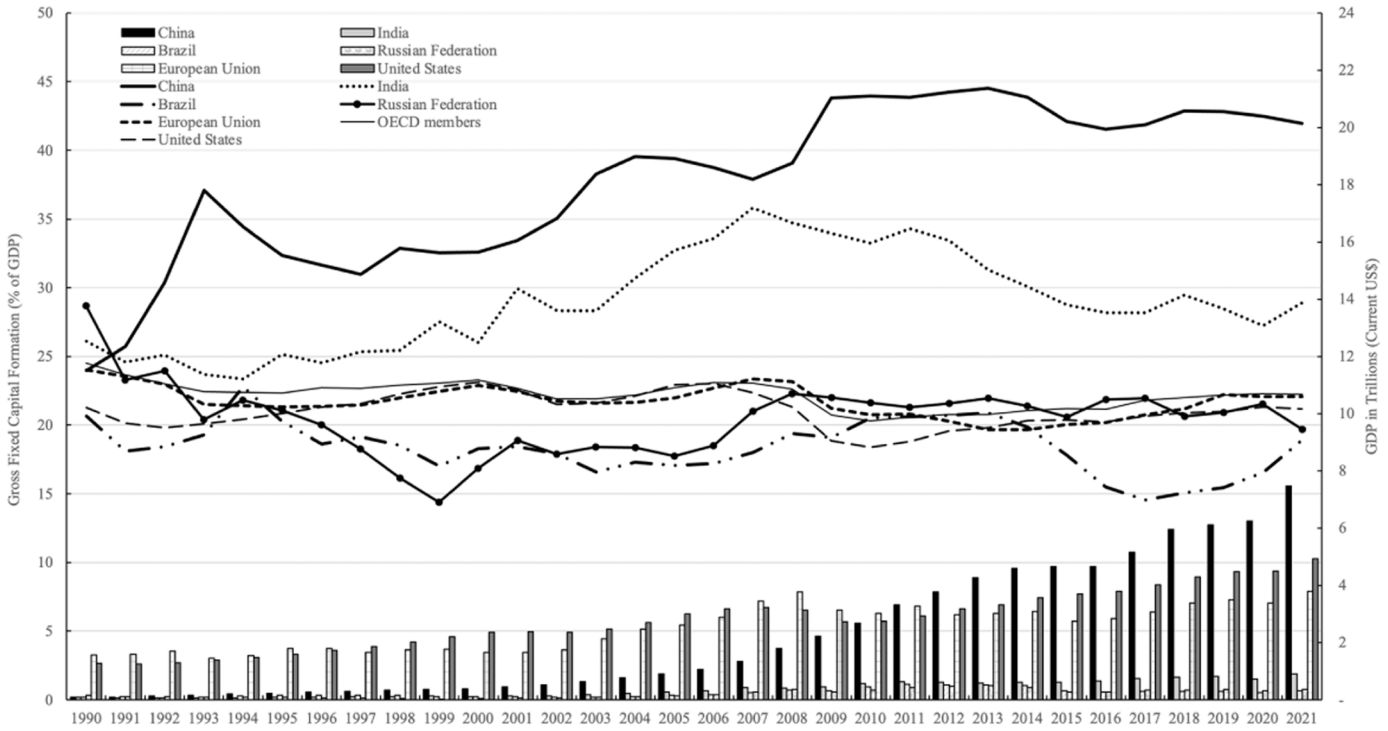


Fig. 1. Gross Fixed Capital Formation (% of GDP) and National GDP in Trillions (current US$), 1990 – 2021.
Source: The World Bank (https://data.worldbank.org/indicator/NE.GDI.FTOT.ZS and https://data.worldbank.org/indicator/NE.GDI.FTOT.CD).

dropped below 40%, while their share of national government expenditure rose above 60% (Fan and Lv, 2012; Shen et al., 2014). This fiscal institutional change and the GDP-orientated cadre evaluation system strongly motivate local governments to seek extra-budgetary and off-budgetary revenue (Ong, 2012). In other words, local governments need to mobilise all resources available to facilitate infrastructure development, and the most convenient and powerful tool in the hands of local governments is the distribution of land use rights for urban development.

China has a leasehold land rights system, where all land is owned by the state, and land development rights are leased out by local governments. Consequently, land leasing revenue, accounting for the lion's share of extra-budgetary revenue, has become an important funding source for urban infrastructure (Ding et al., 2014; Feng et al., 2015; Wang et al., 2011; Wu, 2010). This phenomenon is referred to as "land finance" in the literature and public media (see, for example, Tang et al., 2019; Xu, 2019; Zhong et al., 2019). In 2018, China's total land leasing revenue reached 39.9% of local government revenue. Local governments also hoard land to control land supply and to raise land prices (Du and Peiser, 2014). This strategy helps local government collect more revenue from land leasing to fund infrastructure projects (He et al., 2014), resulting in an upward spiral among land prices, land revenue, and infrastructure investment (Guo and Shi, 2018; Zhang et al., 2021; Zheng et al., 2014). Both policymakers and researchers have been increasingly concerned about the over-reliance on land finance by local government, as the evidence of its adverse effects on various aspects of the economy accumulates (see, for example, Liu et al., 2018; Wang et al., 2021; Zhang and Xu, 2017).

Besides land finance, local governments also borrowed aggressively to finance local development projects. After the 2008 financial crisis, local government debt has become another important financing method for infrastructure development. China introduced an economic stimulus plan in 2009 for large-scale infrastructure investment (Shi and Huang, 2014). Meanwhile, the central government liberalised the financial market for local governments (Bai et al., 2016). Both the countercyclical policy and financial liberalisation enabled local governments to secure credits from the financial market for infrastructure development. As China became the biggest spender on fixed investment (in absolute value) in the world, this debt-driven infrastructure financing fever also made China the most indebted country among emerging markets (Dobbs et al., 2015).

In the context of infrastructure financing, local government's strategies to negotiate between state control and the market-oriented decentralisation have been of great interest to researchers and policymakers (Tsui, 2011; Wang et al., 2011). This issue is especially prominent in China, where rapid urbanisation and economic development put increasing pressure on local governments to finance infrastructure development (He et al., 2016). Although the role of land finance on various aspects of urbanisation has been tested extensively in China, most land finance studies still need a unified framework where both the central government and the private sector are also considered. This is particularly true regarding local government debt financing of infrastructure projects. Data limitations further complicate the issue. Specifically, although data on overall local government borrowing is generally available, debts explicitly raised for infrastructure development are often mixed in the big picture and cannot be separated accurately.

To bridge this gap in the literature, we develop an analytical framework to answer the research question, "how is local government debt issuing for infrastructure development affected by three different forces: the central government, local governments, and the market?" While existing studies investigated the three forces in isolation, our study puts them under one overarching framework. This is an important step to understand the complex relationship between the control by the central government, the working of local governments, and the role of the private sector.

Our strategy to solve the data limitation issue is to use accounting data from local government financing vehicles (LGFVs). LGFVs are set up by local governments to borrow from banks and bond markets for infrastructure financing and construction. Therefore, LGFVs' cash flow data can reliably measure the level of borrowing for infrastructure development at the local level. Meanwhile, LGFVs are owned by local

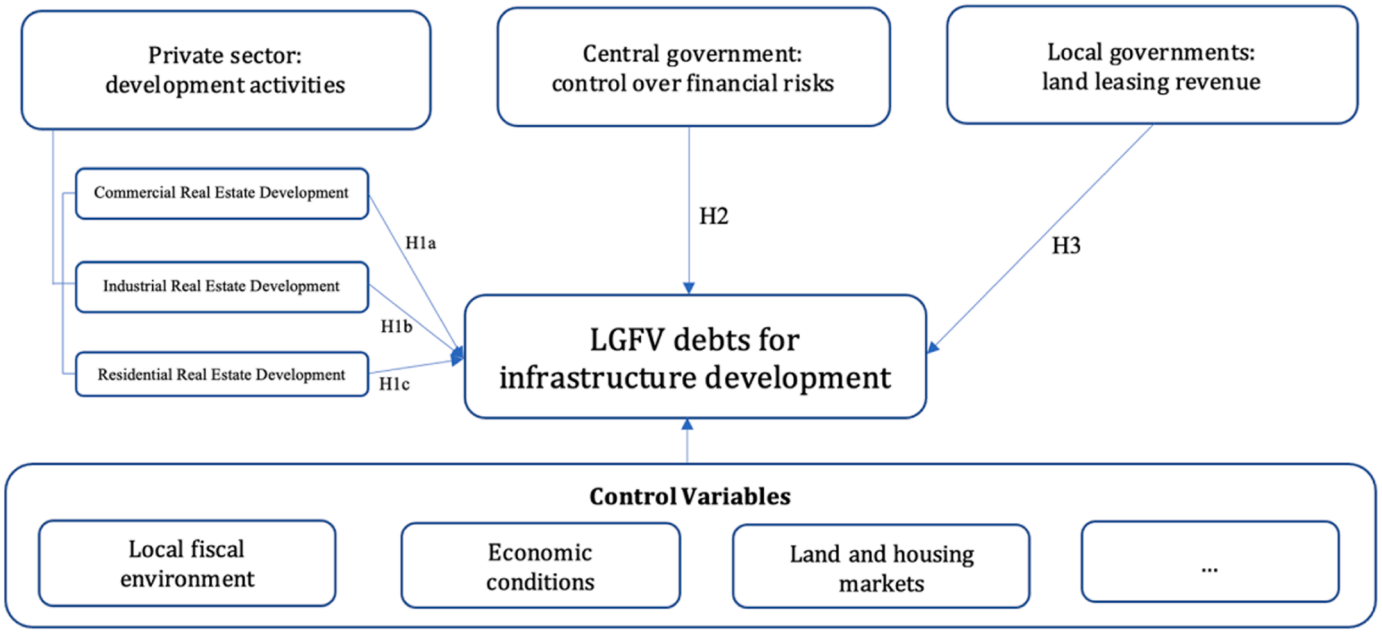


Fig. 3. Analytical Framework.

governments; most of them received land as capital injection from local governments, and their debts are implicitly backed by local governments. They are essentially state-owned corporate entities disguised as private companies and consequently are often treated as actors from the private sector (see, for example, Fig. 1 in Zhan et al., 2018, page 11). The central government encourages local governments to use LGFVs to achieve two goals: to access and leverage financial resources in the private sector and to strike a balance between financial risk and return based on market information. However, local governments are much more interested in the first goal than the central government. To resolve this conflict of interests, the central government had to step in several times to regulate the LGFV market directly or indirectly (see the discussions in Section 2). In other words, LGFVs are where the central government, local governments, and the free market meet. It offers a unique setting to investigate the impact of state control, local government incentives, and market information on local governments' infrastructure financing decisions.

Our theoretical model predicts that if local governments consider business activities from the private sector in debt issuing decisions, the local government debt level should be determined by the land demand for private development, and a higher level of land revenues should encourage local governments to borrow more from the credit market. The effect of state control is verified by detecting a structural break surrounding the implementation of several important government policies in 2013 and 2014. We then use accounting data from LGFVs from 33 major cities in China between 2009 and 2017 to empirically test the theoretical model and the hypotheses.

This research contributes to the literature in multiple ways. First, it offers a unified framework and new empirical evidence on alternative funding and financing models of infrastructure projects in China. Because the share of LGFV debts in infrastructure financing has been rising steadily and rapidly in recent years (see Fig. 3 in Wu, 2023, page 11), our study lays the foundation for systematic investigation of this alternative funding model for infrastructure financing in China. Second, our research extends the studies of land finance into the infrastructure development domain. As revealed in our literature review (see Section 3), this is an important yet under-researched area. Our findings are helpful for studies on China's land use policy under its leasehold land rights system, particularly the impacts of different land planning uses on infrastructure development. Finally, on the policy front, our paper provides a timely assessment of how the central government, local governments, and the market are working together on infrastructure provisions. In May 2020, the Chinese government announced its new development strategy in the latest Five-Year Plan: the Dual Circulation strategy. It is a new balance away from global integration (i.e., the first circulation) and toward increased domestic reliance (i.e., the second circulation) (Blanchette and Polk, 2020). Such a strategy requires infrastructure development decisions to be more responsive to the demand from domestic markets (Buckley, 2020). Our findings suggest that the reforms of local government debt markets in the last decade have paved the road for this transition.

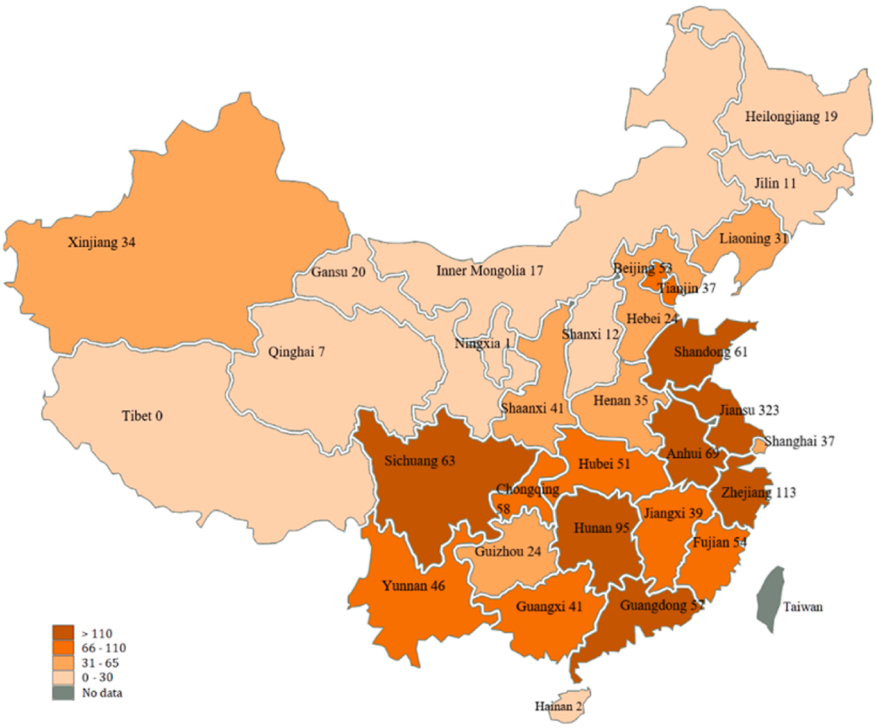
The rest of the paper is organised as follows. Section 2 gives a review of local government debt and LGFVs in China, followed by a systematic review of related literature in Section 3. The development of a theoretical framework and testable hypotheses can be found in Section 4. Empirical implementation is presented in Section 5, and findings are discussed in Section 6. The last section gives policy implications and conclusions.

2. Local government debt and LGFVs in China

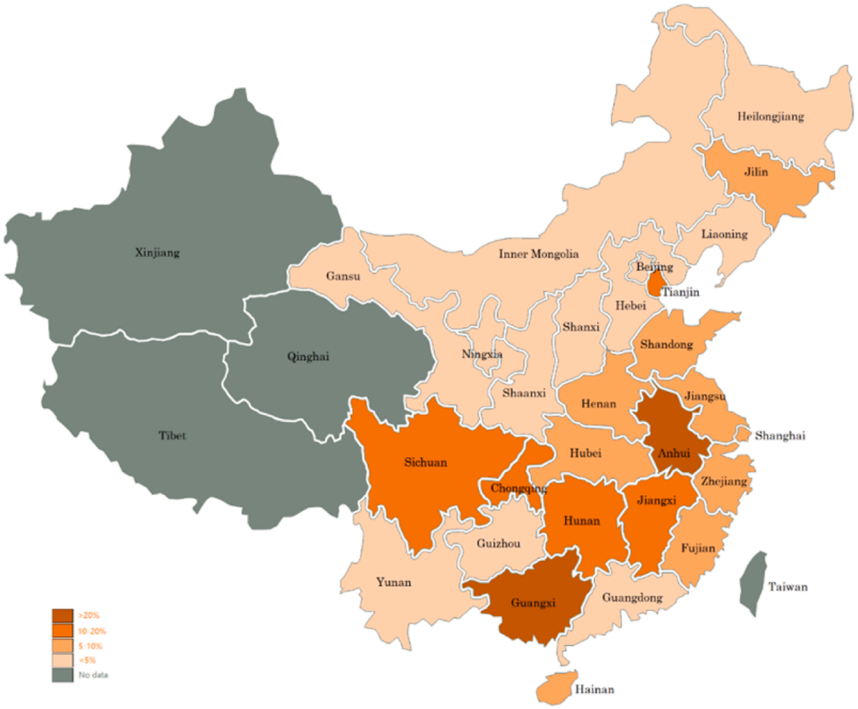
2.1. Institutional background

China's political institution can be described as a "regionally decentralized authoritarian regime" (Xu, 2011), which is a highly hierarchical system that allows the central government to set the criteria of promotion (and demotion) for subordinate governments at the province, municipal, and county levels. Since the economic reform in the 1980 s, greater weight has been put on local economic growth, as measured by the local GDP growth rate. This results in a GDP-orientated cadre evaluation system. Not surprisingly, local governors are highly motivated to boost the GDP growth in their jurisdiction to compete with their peers (Chen et al., 2017; Li and Zhou, 2005).

Meanwhile, subordinate governments are also granted some degree of autonomy over local economic activities, as well as discretion over the use and distribution of local endowments such as land and financial resources. Land and infrastructure are crucial to the growth in productivity and economic development as they provide the space and public services to support the expansion of the economy. They have become two critical factors in many important decisions by local developments



Panel A: Total number of LGFV in 2017



Panel B: Proportion of LGFV debts in total investment in infrastructure development (Accumulation between 2009-2017)

Fig. 2. local governments' dependence on LGFV in infrastructure development.

under China's GDP-orientated cadre evaluation system. For instance, Ding et al. (2014) note that local governments tend to channel a large proportion of land revenue toward growth-orientated infrastructure such as urban roads and highways rather than welfare spending. In addition, land revenue has been invested in specific infrastructure that is more likely to attract foreign direct investment, stimulating economic growth in the urban area (He et al., 2014; Tao et al., 2010). Such land use strategies in China indeed improve local governors' chances for promotion. Chen and Kung (2016) find that other things being equal, land leasing is positively related to the likelihood of promotion of city

governors. Local governors turn to land leasing to finance urban development and ultimately advance their political careers.

2.2. LGFVs in China's land and financial markets

In the aftermath of the financial crisis in 2008, the central government orchestrated the stimulus plan and credit relaxation. The Ministry of Finance and China Bank Regulation Committee opened a new credit channel by encouraging the establishment of LGFVs to invest in infrastructure (Chen et al., 2017). Since then, LGFVs have become active and important players in the land market (Huang and Du, 2018) and a major funding source for local government financing (see Fig. 3 in Wu, 2023). The central government also gradually opened the market of private projects, such as commercial and residential development, to LGFVs (Bai et al., 2016). To raise funds from banks and bond markets, local governments injected public assets such as land and budgetary funds into LGFVs to improve their balance sheets. By doing so, LGFVs can meet the requirements for bond issuance, such as the minimum total net asset volume and the debt-to-equity ratio set by regulatory bodies.

As the monopoly supplier in the urban land market in China, local governments can choose between two options for injecting land to LGFVs: state allocation (*huabo*) and conveyance (*churang*). Land transferred to LGFVs through state allocation is free but for public use only, such as infrastructure construction or military uses. In addition, the law prohibits state-allocated land from transferring, leasing, and mortgage lending.

Land injected through land conveyance is not free but can be used in for-profit projects. LGFVs must pay the fee to secure land use rights from local governments. The conveyance of land use rights is conducted through tender, auction, or listing, with listings accounting for over 70% of all transactions (Huang and Du, 2017). In addition to infrastructure projects, LGFVs can use the land they leased from local governments for commercial projects, such as residential or commercial real estate development (Bai et al., 2016).

LGFVs also borrow heavily from the financial market to finance both their public and private projects. By 2009, more than 90% of LGFVs' debts were in the form of bank loans (Bai et al., 2016), which amounted to 5.57 trillion RMB (Pan et al., 2017). Although the average maturity of these loans is three to five years, LGFV projects usually last for more than a decade. To deal with this maturity mismatch, LGFVs' borrowing channel has shifted from bank loans to bond markets since 2013 (Chen et al., 2017). Local government debt in China reached 17.89 trillion RMB in 2013, accounting for 31.5% of the GDP that year (Wu et al., 2018). There is a great level of variation in both the geographical distribution and the level of local governments' dependence on LGFV in infrastructure development, as illustrated in Fig. 2.

2.3. Regulations of LGFV debt

LGFV, essentially local government debt, can expose the central and local governments to substantial systemic risks. First, LGFVs are established to be off-budget entities of local governments and run as a corporate. The lack of transparency and accountability in LGFVs could be detrimental to the financial system. Second, although local governments are monitored and not allowed to run their fiscal budget in deficit, LGFVs as separate entities are permitted to have a budget deficit. In addition, local governments have reserved a proportion of fiscal revenues for LGFVs' solvency. Therefore, the rapid accumulation of LGFV debt has become a great concern for the central government.

In response to the growing risks associated with the ballooned local government debt volume, the central government released a series of regulations to curb debt growth. In 2010 and 2013, the National Audit Office carried out two nationwide audits to identify and classify the outstanding amount of local government debt. In a document issued in 2013, the Organization Department of the China Communist Party (ODCCP) included outstanding local government debts as an important criterion for local cadres' promotion. In 2014, the State Council issued the *'No.43 Document'* that imposed strict restrictions on LGFVs to initiate new debt. In the same year, the ODCCP added outstanding municipal debt as a criterion to the cadre evaluation system. These regulations from the central government might have resulted in some fundamental changes in LGFVs' debt financing strategy. In 2015, the *Amended Budget Law* took effect and allowed the local governments to raise new debt. Afterwards, the Ministry of Finance initiated a large-scale debt swap program, under which a considerable amount of LGFV debt can be swapped with the general obligation municipal bond issued by the central government. This, to a certain extent, reduces the financial risk associated with local government debt.

3. Literature review

This study is built upon two important streams of research in the infrastructure financing literature. The first strand focuses on the participation of private players, such as (non-state-owned) real estate developers and overseas investors. Zhan et al. (2017) defined three stages in urban development financing in China: planned economy (1949–1977), reform and opening-up (1978–1993), and socialist market economy (1994 to present). This definition indicates a gradual shift of funding sources from public to private funds and the control and management of funding from the central government to local governments. The idea is that there is more supply of funds from the private sector, and the participation of private players could make the process more efficient and transparent. More importantly, this also could potentially solve the high-indebtedness problem facing local governments.

However, the Chinese government has viewed funding independently and solely through the private sector as problematic. This approach has not been widely adopted unless there are severe funding shortfalls. For example, Du (2019) surveyed the funding models in peasant relocation programmes in five Chinese cities. The infrastructure construction projects in those programmes were carried out primarily by the private sector. Although this approach alleviated the funding difficulties faced by local governments, '[c]apital chains rupture and the subsequent construction delay, as well as capital flight, result in serious harm to peasant households.' (Luo and Chen, 2019) The conclusion is that state regulation and intervention are necessary.

Zhan et al. (2018), among others, explored an alternative venue to incorporate the private sector in infrastructure funding, i.e., Public and Private Partnership (PPP). Their generic model of funding infrastructure development has a clear separation between the public and the private sector, emphasising the latter (Zhan et al., 2018, Fig. 1, Page 11). In this model, players from the private sector are heavily involved, with local governments and even the central government participating throughout the whole process as well. However, this model was developed based on two unique, high-profile urban infrastructure development projects in Tianjin and Shanghai, respectively (Zhan and de Jong, 2018; Zhan et al., 2017). The nature and scale of these projects drew international attention, and consequently, both foreign governments and overseas investors are involved in the joint venture. The benefit of such case choices is that their model is in the most general form, i.e., including domestic and overseas players from multiple sectors. However, the model cannot be applied to most of the cities in China without removing the international nodes and their connections to the domestic parts because the infrastructure development in Chinese cities is still predominantly funded by local governments. More importantly, the role of the central government and local governments cannot be adequately and correctly reflected in this model. For example, in their Fig. 1 on page 13, LGFVs are listed as private players, which is not entirely correct because they are essentially state-owned companies. Not surprisingly, there is evidence showing that PPP is unlikely to solve the problem of infrastructure funding problem (Tan and Zhao, 2019; Wang and Ma, 2021; Zhao et al., 2018).

To understand why PPP does not work as intended, a good

understanding of the state's role is necessary, leading us to the second stream of research in this literature. Although China has opened up its market significantly since the 1980 s, the control by the central government has neither been removed nor meaningfully weakened. This is still a process of state-led financialisation and state-entrepreneurship (Feng et al., 2022a; Wu, 2023), or state corporatist urbanism (Jiang and Waley, 2018, 2020, 2022). To make this process even more complex, the goals of the central government and local governments are not aligned in terms of infrastructure development. Specifically, the central government wants to promote growth and mitigate financial risks simultaneously; however, local governments weigh the former target heavier, and the central state focuses more on the latter (Feng et al., 2022a). This complex relationship is best reflected in LGFVs.

LGFVs are firms set up by local governments to raise funds for specific urban and infrastructure projects.[1] Local governments not only inject assets (mainly in the form of land) into LGFVs to enable them to borrow from banks but also implicitly back their loans. Therefore, LGFVs offer two benefits for local governments. Firstly, they raise funds from both public players, such as state-owned banks, and private actors, such as individual investors. Secondly, and more importantly, LGFV borrowings are not on local governments' balance sheets and hence not directly regulated by the central government. Unlike direct local government borrowings, which are subject to approval by many layers above, LGFV borrowings are very much under the control of local governments. Consequently, as pointed out by (Wu, 2023), LGFVs became the largest funding source for infrastructure development in many parts of China since 2008 and continue to grow despite the tightened regulations by the central government in 2014 (see Fig. 3 in Wu, 2023).

Given the important role of LGFVs in infrastructure financing in China, researchers have endeavoured to understand how they operate and interact with other parts of the social and economic systems. Appendix 1 lists 16 LGFV studies published between 2015 and 2023. The majority of these papers study the financial aspects of LGFVs and their bonds, such as the return on assets or equity (Guo et al., 2020; Qian, 2018), bond yield and yield spread (Luo and Chen, 2019; Walker et al., 2021), leverage ratio (Liang et al., 2017), as well as financial risks (Tao, 2015; Ye et al., 2022; Yu et al., 2022). Using accounting data primarily, these studies identified important determinants of the financial performance and risk profile of LGFVs and their bonds, such as credit rating and government interventions (e.g., anti-corruption campaigns). The second group of papers investigates the contribution of LGFVs to urban development and New Town Development in particular (Han et al., 2021; Li and Chiu, 2018). Using data from Shanghai, (Jiang and Waley, 2020) emphasise the unique role of LGFVs in China's urban development: they are state-owned corporate entities able to raise funds and act as if they were private companies; they "are the driving force behind China's urban entrepreneurialism and are without a clear parallel elsewhere." (Jiang and Waley, 2020, page 363). Feng et al. (2022b) use the Jiaxing *Chengtou* to demonstrate how LGFVs act as financial intermediaries in urban development.

Despite the importance of the land market and state control in the setup and management of LGFVs, there is only one study that has investigated the influence of LGFVs on land auctions (Huang and Du, 2018). The role of state control in LGFVs has been investigated through case studies and interviews only (Feng et al., 2022a, 2023; Jiang and Waley, 2018). The role of the market has not been explored. Our study aims to address this gap in the literature. An analytical framework is developed based on the literature review, as outlined in the next section.

[1] In other studies, LGFVs are also called urban investment and development companies, local government financing platforms, or Chengtou (see, for example, Jiang and Waley, 2020 & 2021, and Wu 2021).

4. Analytical framework

This study aims to determine how local government debt issuing for infrastructure development is affected by three different forces: the central government, local governments, and the market. Therefore, it is essential to have an overarching analytical framework that incorporates the three factors in one model. For this reason, we choose LGFVs, given their unique structure and role in infrastructure financing in China. LGFVs are designed by the central government as vehicles to meet the shortfall of infrastructure funding by mobilising financial resources from the private sector. Taken at face value, decisions made by LGFVs, such as issuing bonds, should be based on market information. However, in reality, given local governments' explicit ownership of LGFVs and implicit backing of their debts, local governments have a strong incentive to use LGFVs to serve their (often short-term) local development goals (Feng et al., 2022a). This will be captured by the influence of land finance, which is largely under the control of local governments, on LGFV debt-issuing decisions. In summary, LGFV debt issuing provides a good test group to analyse the role of the central government, local governments, and the private sector in local governments' debt issuing for infrastructure development.

Based on the Cobb-Douglas productivity function, we develop a theoretical model to capture the complex relationship between LGFV debt financing for infrastructure development and the three forces: the private sector, the central government, and local governments (see Fig. 3 below). We start with the premise that local governments aim for a certain level of infrastructure development while supporting industrial development and repaying the principal and interest of existing debts. Local governments balance the fiscal expenditure by using general budgeted revenues (most constituted by taxes), revenue from land leasing, and debt finance. Hence, the revenue generated significantly affects the size of new debts for infrastructure development. We then derive the three testable hypotheses based on the First Order Condition of the equation. The analytical framework is depicted in Fig. 3. For brevity, we leave the mathematical derivation of the propositions in Appendix 2. This section provides a non-technical description of the analytical framework.

A key assumption in our model is that real estate development activities, land finance, and central government control over financial risks are the most significant and representative factors to capture the main effects from the private sector, local governments, and the central government, respectively. This is because both the income and expenditure of LGFVs are closely linked to the transaction price and volume of land parcels, and the control of financial risks has been at the core of the central government's regulation of LGFV operations. Including all factors that could affect LGFV debt issuing in each force will make the model overly complicated and hinder its tractability. Our strategy is to choose each force's most significant and representative factor to capture the main effect. For those factors with secondary impacts, we include them as control variables. This strategy gives us three testable hypotheses, one for each of the forces considered, as outlined below.

4.1. The private sector

The relationship with the private sector is the most challenging to untangle. As indicated in the literature review, there are few theoretical or empirical studies on this topic. Consequently, we derive the relationship mathematically by focusing on the role of real estate development activities from the private sector. Among the wide array of activities from the private sector, real estate development activities are the most relevant to local infrastructure development and LGFV debt financing decisions. We use the total land area acquired by real estate developers as the measurement of development activities. This is a better estimate than land leasing revenue because the latter can be skewed by a few land parcels leased at high prices (e.g., 'Land Kings' in CBD). On the other hand, larger land lease areas generally lead to more

properties to be developed and, hence, more activities in the real estate development sector.

We further classify real estate development into commercial, industrial, and residential development because they affect LGFV debt issuing decisions differently. The supply of commercial land parcels is limited in our theoretical model because land parcels for commercial development are primarily located in the developed area (e.g., the city centre). Although redevelopment and regeneration projects could potentially free up new land for commercial development, it usually takes years for the new supply to enter the market. Consequently, an increase in commercial land transfer volume usually generates substantial land revenue and boosts the balance sheet of local governments, putting them in a good position to raise debts for infrastructure development in the next period; it also increases productivity by providing more space for high-value-added industries such as banking and finance. Our mathematical model shows that activities in the commercial real estate sector positively affect local government debt issuing through commercial land leasing revenue and potential improvement of productivity. We form the first testable hypothesis as follows.

Hypothesis 1a. **(H1a)**: Land acquired for commercial real estate development positively affects the amount of LGFV debts devoted to infrastructure development.

The development in the industrial sector, on the other hand, has a substitute effect on infrastructure investment (e.g., Shi and Huang, 2014). China has a long-standing practice of promoting industrial development through heavily subsidised or discounted land leasing fees. Local governments in China have been keeping industrial land prices low, sometimes even for free or at a net loss, to boost local economic growth (Cao et al., 2008). Industrial land parcels typically are located in a city's peripheral or even rural area; the price elasticity of supply for industrial land is higher than that of commercial land parcels. Consequently, industrial land leasing usually does not generate positive income, e.g., the land price is equal to or less than the cost of land clearance. Our mathematical model shows that the net effect of industrial real estate sector activities on LGFV debt financing decisions also depends on the ratio of productivity to the cost when investing in industry and infrastructure, respectively. Infrastructure development shows a substitute effect as it brings more efficiency to boost the local economy than industrial development in China (e.g., Shi and Huang, 2014). Overall, our models predict a negative relationship between the activities in the industrial real estate sector and LGFV debt issuing, as indicated in the following hypothesis.

Hypothesis 1b (H1b). : Land acquired for industrial real estate development negatively affects the amount of LGFV debts devoted to infrastructure development.

The role of the residential real estate sector is complicated. Although residential real estate development and transactions have contributed significantly to local and national economic growth, there has long been suspicion of a 'crowding-out' effect on non-real estate investments (Chen and Wen, 2017). Evidence shows that higher returns from the residential real estate sector attract lenders to favour residential real estate projects over other types of investments (Allen, Qian et al., 2019). Thus, residential development could stimulate the capital cost of debt in the local economy. In other words, the interest payment is positively influenced by the residential sector due to the crowding-out effect. Our models predict a negative relationship between residential land transactions and LGFV debt issuing for infrastructure investment.

Hypothesis 1c. **(H1c)**: Land acquired for residential real estate development negatively affects the amount of LGFV debts devoted to infrastructure development.

4.2. The central government

The role of the central government is tested indirectly by comparing the effect of the private sector before and after 2013, when the central government changed policies towards LGFV significantly. Hypotheses 1a, 1b, and 1c are used to verify the role of the private sector in LGFV debt-issuing decisions. If LGFVs have been operating as what they are designed for (i.e., an effective financing platform to leverage resources from the private sector), their debt financing decisions should be responsive to real estate development activities in the private sector as indicated in these hypotheses. The support for these hypotheses is also a sign of the effectiveness of the central government's regulation of the LGFV industry in reducing local governments' exposure to debt risks. Therefore, we use these hypotheses to test whether the risk control by the central government over LGFV debt issuing is effective. Specifically, if the support for these hypotheses is stronger after the start of the policy changes in 2013 to curb LGFV debt growth, we can conclude that the control by the central government is effective.

Hypothesis 2. **(H2)**: The effect from the private sector is stronger after the central government started to tighten the control of LGFVs in 2013.

4.3. Local governments

We now turn our attention to the role of local governments. We focus on the most important financing source for local governments, i.e., land finance, which has been an effective tool for generating development finance through land development (Wu, 2022). Land finance is routinely measured by land leasing revenue. All else being equal, higher land revenue improves cash flow and balance sheet and hence puts local governments in a good position to raise debts for infrastructure development. More importantly, an increase in land revenue is often taken by the local government as a signal of strong land demand from the private sector, which will lead to an increase in the demand for infrastructure. Meanwhile, a higher level of land revenue is also associated with optimistic anticipation of economic growth. This gives the local government both the incentive and the confidence to issue new government debts to finance infrastructure projects. The proposition derived from our mathematical models suggests a positive relationship between land leasing revenue and LGFV debt issuing. We form the last testable hypothesis accordingly.

Hypothesis 3. (H3): Land finance positively affects the amount of LGFV debt devoted to infrastructure development.

4.4. Other Factors

Of course, other sources of local government incomes, such as general budgetary revenues (GBR), should also be considered in the model. We include the 'Local Fiscal Environment' factor in the control variable group to account for this effect. The spending of GBR covers a wide range of public services such as education, energy conservation and environmental protection, general administration, hygiene and health, public security, science and technology, and social security. Local governments usually run a deficit in this account and largely rely on off-budget revenues (mainly land leasing revenue) to finance local infrastructure development (Ding et al., 2014). Therefore, its role in LGFV debt issuing decisions is secondary compared to local governments' land leasing revenue. It is more appropriate to include GBR as a control variable.

Similarly, we include control variables such as economic conditions and house prices in the analytical framework to account for factors that could potentially affect LGFV debt-issuing decisions. These factors are held constant in our mathematical models to analytically derive the main effects of the three driving forces (see Appendix 2 for details). However, in empirical analyses, they must be included as control variables in order to reliably estimate the net effect of the central

Table 1
Variable definitions and descriptive statistics.

Variable	Definition	Data Source	Mean	Std. Dev	Min	Max
InvCF	The cash outflow of LGFV investments in a city (unit: Billion RMB)	*WIND*	61.832	110.944	0	1125.362
OpCF	The cash inflows of LGFV operating activities in a city (unit: Billion RMB)	*WIND*	2.482	12.486	-84.246	91.423
GCF	Gross cash flow of LGFVs in a city (unit: Billion RMB), $GCF = InvCF - OpCF$	*WIND*	59.368	111.458	-21.546	1176.655
IndTran	Total industrial land sale area (unit: 1000,000 m^2)	*WIND*	1.213	1.547	0	14.874
ResTran	Total residential land sale area (unit: 1000,000 m^2)	*WIND*	1.077	1.312	0	16.444
ComTran	Total commercial land sale area (unit: 1000,000 m^2)	*WIND*	0.298	0.359	0	3.166
IndRev	Total industrial land revenue (unit: Billion RMB)	*WIND*	0.560	0.761	0	7.651
ResRev	Total residential land revenue (unit: Billion RMB)	*WIND*	8.170	11.345	0	94.338
ComRev	Total commercial land revenue (unit: Billion RMB)	*WIND*	2.014	3.685	0	38.578
TotalRev	Total land revenue (unit: Billion RMB)	*WIND*	10.744	13.689	0	110.404
FIP	Change in the price index of fixed investment	*WIND*	0.013	0.033	-0.077	0.101
r	Capital cost, the three-year central government bond rate	*WIND*	3.243	0.768	1.600	4.340
GDP	GDP growth rate in a city	*WIND*	0.026	0.093	-1.006	0.687
indpr	The growth rate of land price of industrial sector in a city	*WIND*	0.008	0.034	-0.498	0.497
respr	The growth rate of land price of residential sector in a city	*WIND*	0.026	0.086	-0.389	1.092
compr	The growth rate of land price of commercial sector in a city	*WIND*	0.023	0.094	-0.500	1.679
hpr	The growth rate of local house prices in a city	*WIND*	0.018	0.049	-0.243	0.770
FisRev	Local government's total budgetary revenue (unit: Billion RMB)	*WIND*	21.364	26.243	0.276	213.100
slope	The average slope of terrain in a municipal	*GIM cloud* (http://www.dsac.cn/DataProduct/Detail/200803)	2.155	1.708	0.055	5.768
crp	The corruption index measured by the total number of misconduct officials divided by the total number of officials in each province	*Annual Report on the work of each province's procuratorate*	0.003	0.001	0.001	0.013
lhp	local housing demand (Log housing price) in a city	*WIND*	9.151	0.512	7.893	10.915

government control, local governments' land leasing revenue, and development activities from the private sector. The empirical implementation of the analytical framework in Fig. 3 is discussed in the next section.

5. Empirical implementation

We collected data from WIND database to facilitate the empirical analysis. The data set covers 33 major cities[2] in China between 2009 and 2017 because LGFVs activities were limited before 2009. Variable definitions and descriptive statistics of all variables are shown in Table 1. All data are in quarterly frequency.

5.1. The measurement of LGFV debt for infrastructure development

To test the hypotheses in Section 3, we need a reliable measurement of local government debt for infrastructure development. Some existing studies used LGFV bonds as the proxy, and the data between 2009 and 2017 were available (see, for example, Pan et al., 2017). Technically, LGFV bonds should be primarily used for infrastructure projects. In practice, it is not the case, as a part of the fund raised in LGFV bonds is often used for commercial development or public spending (Bai et al., 2016). It is difficult to distinguish the proportion of LGFV bonds for infrastructure financing from other uses because such information is not available to the public. Consequently, LGFV bonds are not a reliable measurement of LGFV debts used for infrastructure development.

To address this issue, we use cash flow data of LGFVs to reliably identify the proportion of funds used for infrastructure development because cash flow data gives micro-level accounting information subject to annual auditing. Our procedure involves three steps to estimate the debt the local government raised for infrastructure investment.

The first step is to obtain the cash outflow of investments (*InvCF*). Under China's accounting standards, it consists of four sub-accounts: 1) *cash paid for purchasing and constructing fixed assets, intangible assets, and other long-term assets*, 2) *cash paid for investment*, 3) *net cash amount paid for acquiring subsidiaries and other business units*, and 4) *cash paid for activities related to investment*. The first sub-account records the cash outflow related to LGFVs' infrastructure investment. We also include the other three as it is a common practice that LGFVs manipulate the account and require their subsidiaries to construct infrastructure behind the scenes.

The second step is calculating the cash inflow of operating activities (*OpCF*) containing several sub-accounts. The largest sub-account is *cash inflow from selling goods and providing services*, representing LGFV's actual earnings under the cash basis accounting system. Using this sub-account, we can estimate the cash inflow related to commercial earnings. The rationale behind this practice is that only commercial activities can generate cash inflows, while most infrastructure projects cannot produce cash inflow into LGFV accounts. The constructed infrastructure will be transferred from *construction in progress* into *account receivable*. It will be kept on the balance sheet generating zero cash inflow until the local governments pay and take it over.

Finally, we calculate the gross investment cash flow of LGFVs (*GCF*) as the difference between the cash outflow of investments and cash inflow of operating activities, i.e., $GCF = InvCF - OpCF$. This forms our measurement of the debts raised by local governments for total infrastructure investment in a city.

5.2. The measurement of investment from private sectors and land finance

Data were obtained from WIND to measure land finance and investments from private sectors. To gauge investment activities from the private sector, we collected data on land acquisitions in the industrial, residential, and commercial sectors (denoted as *IndTran, ResTran, ComTran*, respectively, as defined in Table 2). These variables give the total area (in square metres) of land parcels leased out by the local governments, determining how much new space will be created in the commercial, industrial, and residential property markets. Hence, they are valid measurements of real estate development activities in these sectors.

The measurement of land finance (*LandFin*) is challenging. We focus on land revenue, i.e., the income (in RMB or Chinese Yuan) generated by these land leases, because it indicates how much income local governments generate from these transactions. Land revenue affects local governments' balance sheets and cash flow significantly and, consequently, their decisions to raise debts for infrastructure development.

We consider three alternative measurements as outlined below. The first variable is the total revenue of land leasing (*TotalRev*). It is the leasing revenues of industrial (*IndRev*), commercial (*ComRev*), and residential (*ResRev*) land combined and is commonly used in the land

[2] . The 33 cities are selected from the list of 35 major cities, excluding Lhasa and Ürümqi. The list is defined by the National Bureau of Statistics

Table 2
Estimation outputs of fixed effect panel regressions (Dependent variable: *lnGCF*).

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$IndTran_{i,t-1}$	-0.013 *	-0.012 *	-0.012 *	-0.011	-0.013 *
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$ResTran_{i,t-1}$	0.001	-0.000	-0.005	-0.007	0.006
	(0.007)	(0.007)	(0.008)	(0.008)	(0.006)
$ComTran_{i,t-1}$	0.011	0.010	0.011	0.017	0.012
	(0.021)	(0.022)	(0.023)	(0.022)	(0.022)
$Land2Fis_{i,t-1}$	0.017 *				
	(0.009)				
$Land2GDP_{i,t-1}$		0.221 *			
		(0.115)			
$TotalRev_{i,t-1}$			0.002 * **		
			(0.001)		
$ResRev_{i,t-1}$				0.003 * **	
				(0.001)	
$ComRev_{i,t-1}$					0.001
					(0.001)
$FIP_{i,t-1}$	0.694 * **	0.695 * **	0.630 * **	0.641 * **	0.696 * **
	(0.147)	(0.146)	(0.152)	(0.150)	(0.149)
$r_{i,t-1}$	-0.019 * *	-0.019 * *	-0.020 * *	-0.020 * *	-0.020 * *
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
$GDP_{i,t-1}$	0.003	0.009	-0.000	-0.000	0.004
	(0.027)	(0.026)	(0.026)	(0.026)	(0.027)
$indpr_{i,t-1}$	0.093	0.100	0.089	0.085	0.097
	(0.106)	(0.107)	(0.102)	(0.101)	(0.107)
$respr_{i,t-1}$	0.161 * *	0.167 * *	0.154 * *	0.155 * *	0.172**
	(0.069)	(0.071)	(0.068)	(0.067)	(0.070)
$compr_{i,t-1}$	-0.109 *	-0.114 *	-0.100 *	-0.102 *	-0.114 *
	(0.057)	(0.058)	(0.053)	(0.052)	(0.056)
$hpr_{i,t-1}$	-0.006	-0.017	-0.034	-0.041	0.005
	(0.053)	(0.053)	(0.050)	(0.051)	(0.052)
const.	5.292 * **	5.297 * **	5.296 * **	5.297 * **	5.300 * **
	(0.033)	(0.032)	(0.029)	(0.029)	(0.032)
Seasonal FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
# of obs.	1155	1155	1155	1155	1155
F test	11.08 * **	17.16 * **	25.82 * **	24.58 * **	15.28 * **
R^2	0.524	0.524	0.532	0.533	0.522
Hausman test	814.97 * **	682.03 * **	116.28 * **	124.99 * **	346.30 * **

Notes: significance levels: * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. The standard errors are clustered at the city level and shown in parentheses. The panel regression is run with fixed effect and random effect. The table shows the results of the fixed-effect model only as the fixed-effect model performs better than the random-effect model according to Hausman tests.

finance literature (Pan et al., 2017). We also constructed two variables to quantify land finance. The first is the ratio of the total land revenue (*TotalRev*) to the total budgetary revenue (*FisRev*) of the local government (*Land2Fis*). This ratio measures the fiscal reliance of local governments on land revenue (Mo, 2018). In addition, land revenue to GDP (*Land2GDP*) is adopted in our models as an alternative measurement to *Land2Fis* (Mo, 2018). *Land2Fis* and *Land2GDP* are better measurements of the local government's reliance on land sale revenues.

There are potential multicollinearity issues by simultaneously including land transaction volume and revenue in the model, as indicated by the pairwise correlation coefficients in Table A1 in Appendix 3. However, our strategies of using one and only one of the five alternative land revenue variables in the model circumvent the multicollinearity. As a result, the correlation among the variables included in our empirical models does not lead to serious concern about multicollinearity. Specifically, the VIFs for all models in Table A2 in Appendix 3 are well below 10. Therefore, although land transfer and land revenue are correlated, the multicollinearity issue is not serious enough to cause concern.

5.3. Empirical Model

With the variables defined above, we estimate the following equation

$$\ln GCF_{i,t} = \alpha_0 + \alpha_1 IndTran_{i,t-1} + \alpha_2 ResTran_{i,t-1} + \alpha_3 ComTran_{i,t-1} + \delta LandFin_{i,t-1} + \boldsymbol{\varphi} \boldsymbol{X}_{i,t-1} + T_t + S_t + \varepsilon_{i,t}$$

where i and t are indicators of city and time, respectively. $\ln GCF_{i,t}$ is the natural-log-transformed *GCF*.[3] $LandFin_{i,t-1}$ includes the five measurements of land finance, i.e., *Land2Fis*, *Land2GDP*, *TotalRev*, *ResRev*, and *ComRev*. $\boldsymbol{X}_{i,t}$ is a matrix of variables that controls for factors likely to affect the dependent variable. It includes the change in the price index of fixed investment ($FIP_{i,t}$), capital cost (i.e., the three-year central government bond rate r_t), GDP growth rate at city level ($GDP_{i,t}$) the growth rate of residential ($redpr_{i,t}$), industrial ($indpr_{i,t}$) and commercial ($compr_{i,t}$) land prices at city level, the growth rate of house prices ($hpr_{i,t}$), and fixed effects including year effect (T_t) and seasonal effect (S_t). Descriptive statistics of these variables can be found in Table 2.

To test Hypotheses 1, we expect $\alpha_1 < 0$, $\alpha_2 < 0$, and $\alpha_3 > 0$. Subsample analysis using the third quarter of 2013 as the cut-off point is used to verify Hypothesis 2. Specifically, we expect stronger evidence to support Hypothesis 1 in the after-2013 subsample analysis. For Hypothesis 3 to be true, the coefficient estimate of $LandFin_{i,t-1}$ (δ), should be positive.

[3] Because *GCF* has negative values (i.e., cash outflows exceeded cash inflows in a given period), we added one standard deviation of *GCF* (i.e., 110.944) to the variable before taking the log transformation. This is an approach based on the suggestions in Webber (2013). The standard deviation of the natural-log-transformed *GCF* is approximately one. In other words, our approach effectively standardised the *GCF* variable, which reduced its spread without distorting the relationship near its minimum value.

Table 3
Estimation results of the first stage of the 2SLS model within the fixed-effect panel.

Dependent Variable	ln*GCF*	*Land2Fis*	*Land2GDP*	*TotalRev*	*ResRev*	*ComRev*
Model	(1)	(2)	(3)	(4)	(5)	(6)
lhp	0.078	0.685 * **	0.078 * **	19.742 * **	19.329 * **	1.618 *
	(0.071)	(0.195)	(0.019)	(4.903)	(4.823)	(0.914)
lhp ∗ *crp*	-0.379	-0.130	0.068	-12.953	-18.223	3.130
	(0.665)	(1.808)	(0.120)	(23.115)	(22.014)	(5.877)
lhp ∗ *slope*	0.010	-0.127 * *	-0.015 * *	-2.888	-2.481	-0.318
	(0.035)	(0.053)	(0.006)	(1.961)	(1.817)	(0.308)
IndTran	-0.006	0.025	0.002	0.240	-0.081	0.250 * *
	(0.007)	(0.017)	(0.002)	(0.288)	(0.326)	(0.095)
ResTran	0.003	0.043 * *	0.004 *	0.641 *	0.549	0.094
	(0.006)	(0.017)	(0.002)	(0.372)	(0.366)	(0.087)
ComTran	0.016	0.029	0.004	0.467	0.182	0.231
	(0.020)	(0.058)	(0.006)	(1.277)	(1.220)	(0.318)
FIP	0.703 * **	-0.907	-0.219 * *	-12.982	-18.317	4.931
	(0.176)	(0.936)	(0.092)	(14.859)	(12.418)	(4.275)
r	-0.024 * **	0.012	-0.001	0.072	0.055	0.085
	(0.008)	(0.045)	(0.004)	(0.840)	(0.705)	(0.203)
GDP	0.003	-0.017	-0.015	-2.127	-1.816	-0.466
	(0.027)	(0.164)	(0.012)	(1.643)	(1.582)	(0.448)
$indpr_{i,t-1}$	0.087	-0.193	-0.048	-8.388	-8.578	0.508
	(0.094)	(0.288)	(0.032)	(7.082)	(6.605)	(1.592)
$respr_{i,t-1}$	0.144 * *	0.770 * **	0.086 * *	10.505 * *	8.868 * *	1.861
	(0.065)	(0.275)	(0.034)	(3.956)	(3.868)	(1.425)
$compr_{i,t-1}$	-0.095	-0.615 * **	-0.054 * *	-7.292 * *	-4.639	-2.665 * *
	(0.060)	(0.199)	(0.022)	(2.979)	(3.114)	(1.218)
$hpr_{i,t-1}$	-0.039	0.545	0.026	12.548 *	12.292 * *	0.030
	(0.049)	(0.413)	(0.037)	(6.565)	(5.223)	(1.991)
const.	4.422 * **	-4.715 * **	-0.540 * **	-131.660 * **	-89.336 * *	-42.477
	(0.670)	(1.587)	(0.177)	(30.956)	(42.626)	(26.542)
Seasonal FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
#. obs	1155	1155	1155	1155	1155	1155
Model fitness: F-test	11.23 * **	11.20 * **	27.57 * **	74.23 * **	23.92 * **	14.19 * **
R^2	0.539	0.205	0.145	0.206	0.189	0.111

Notes: significance levels: * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. The standard errors are clustered at the city level and shown in parentheses.

6. Empirical findings

6.1. Preliminary analysis with fixed-effect panel regressions

We first estimate both fixed-effect and random-effect panel regression models with clustered standard errors at the city level. Hausman test results suggest that fixed-effect models fit the data better. Our discussions are based on the fixed-effect panel regression outputs in Table 2.

First, the coefficients of *IndTran* and some of the coefficients of *ResTran* are negative, and the coefficients of *ComTran* are positive. These three sectors, however, have weak impacts on local government debt as many of the coefficients are statistically insignificant. In other words, local governments did not consider the future development of private sectors when using debt financing. By using data from the whole sampling period, we do not find concrete evidence to support Hypothesis 1. Second, the coefficients of the three land finance measurements, i.e., *TotalRev*, *Land2Fis*, and *Land2GDP*, are positive and statistically significant at 10%. The results support Hypothesis 3, that land finance positively affects the local government debt.

We further explore the data by including the revenue from residential land leasing (*ResRev*) and commercial land leasing (*ComRev*) separately in the model. On average, residential land revenue accounts for 70% of total land revenue, while commercial land revenue takes up 20%. The industrial land lease revenue is excluded because previous studies show that Chinese local governments have controlled industrial land prices by selling lands to private sectors at low prices, sometimes even for free or at a net loss, to boost regional economic growth (Cao et al., 2008). Models 4 and 5 show that *ResRev* positively and significantly affects local government debt, while *ComRev* has a positive but insignificant effect. One possible reason for the latter is that commercial land revenue is not a major source for local governments to finance infrastructure. The findings of land revenue are similar to those of land finance reliance and support Hypothesis 3. An increase in land finance would lead to a higher level of local government debt financing for infrastructure.

6.2. Improved estimations with instrumental variables

As LGFV debt and land finance are under the control of local governments, the results presented in the previous section may be biased by endogenous variables that are calculated based on land revenue (i.e., *Land2Fis, Land2GDP*, *TotalRev*, *Land2Fis*, and *Land2GDP*). Local governments can significantly affect land prices by setting reserved prices in land auctions or offering significant discounts for industrial land leasing. This is less of a concern for land transfer volume because when there are not enough interests in the private sector, land transactions will not happen even if local governments want to lease out more land. The correlation coefficients between land revenue and land transfer variables are well below 0.5 (see the first column in Table A4). Consequently, we did not instrument the three land transfer variables (i.e., *IndTran*, *ResTran*, and *ComTran*).

To address the concern over endogeneity, the instrumental variable (IV) approach is employed to re-estimate the models. We identify two candidates as the IV for land revenue, i.e., the average slope of terrain (*slope*) as an exogenous measurement of land supply and a corruption index (*crp*) for its potential impacts on land transactions. However, these two variables are not time-varying and hence cannot be directly included in our fixed effect panel models. We follow the IV strategy in Chen and Kung (2016) by using the interaction terms between these variables and house prices (*lhp*).

The two-stage (2SLS) estimation within the fixed-effect panel model

Table 4
Estimation results of the second-stage of 2SLS models.

Model	Panel A: Sampling period 2009Q1 – 2017Q4					Panel B: Sampling period 2013Q3 – 2017Q4				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
$IndTran_{i,t-1}$	-0.005	-0.006	-0.006	-0.002	-0.010	-0.006 *	-0.005 *	-0.004	-0.003	-0.002
	(0.010)	(0.009)	(0.008)	(0.008)	(0.010)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
$ResTran_{i,t-1}$	-0.048	-0.039	-0.038 * *	-0.036 *	-0.013	-0.017 * *	-0.021 * *	-0.023 * *	-0.023 * *	-0.014
	(0.031)	(0.025)	(0.016)	(0.020)	(0.015)	(0.008)	(0.010)	(0.009)	(0.010)	(0.016)
$ComTran_{i,t-1}$	0.003	0.004	0.019	0.036	-0.104	0.013 *	0.012 *	0.020 *	0.028 * *	-0.043
	(0.033)	(0.032)	(0.028)	(0.027)	(0.110)	(0.007)	(0.007)	(0.011)	(0.013)	(0.057)
$Land2Fis_{i,t-1}$	0.207 *					0.069 *				
	(0.108)					(0.036)				
$Land2GDP_{i,t-1}$		1.695 *					0.642 * *			
		(0.886)					(0.308)			
$TotalRev_{i,t-1}$			0.008 * **					0.002 * *		
			(0.003)					(0.001)		
$ResRev_{i,t-1}$				0.009 * *					0.003 * *	
				(0.004)					(0.001)	
$ComRev_{i,t-1}$					0.061					0.019
					(0.043)					(0.020)
$FIP_{i,t-1}$	0.620 * *	0.662 * **	0.408 * *	0.471 * **	0.258	-0.168	-0.148	-0.046	-0.021	-0.223
	(0.255)	(0.176)	(0.182)	(0.167)	(0.375)	(0.168)	(0.124)	(0.071)	(0.064)	(0.296)
$r_{i,t-1}$	-0.002	-0.014	-0.019	-0.019 *	-0.026 *	0.011 * *	0.008 * *	0.002	0.002	0.008
	(0.016)	(0.011)	(0.012)	(0.011)	(0.014)	(0.005)	(0.004)	(0.002)	(0.003)	(0.006)
$GDP_{i,t-1}$	-0.002	0.048	-0.002	-0.001	-0.016	0.017	0.048	0.003	0.002	0.015
	(0.037)	(0.034)	(0.028)	(0.027)	(0.043)	(0.021)	(0.034)	(0.012)	(0.011)	(0.024)
$indpr_{i,t-1}$	0.046	0.112	0.069	0.129	0.230	0.008	0.026	0.027	0.028	0.015
	(0.112)	(0.112)	(0.090)	(0.094)	(0.175)	(0.019)	(0.022)	(0.017)	(0.018)	(0.022)
$respr_{i,t-1}$	-0.012	0.077	0.074	0.136 * *	0.067	0.043	0.028	0.003	0.007	-0.020
	(0.131)	(0.098)	(0.068)	(0.067)	(0.120)	(0.033)	(0.017)	(0.015)	(0.014)	(0.050)
$compr_{i,t-1}$	-0.011	-0.062	-0.038	-0.092	-0.054	-0.056	-0.038 *	-0.006	-0.008	0.007
	(0.105)	(0.081)	(0.058)	(0.057)	(0.103)	(0.035)	(0.021)	(0.014)	(0.013)	(0.028)
$hpr_{i,t-1}$	-0.131	-0.163	-0.159 * *	-0.178 * *	-0.096	-0.211 * **	-0.205 * **	-0.139 * *	-0.149 * *	-0.032
	(0.101)	(0.102)	(0.069)	(0.089)	(0.101)	(0.076)	(0.068)	(0.054)	(0.058)	(0.089)
const.	5.183 * **	5.264 * **	5.277 * **	5.282 * **	5.273 * **	7.528 * **	7.558 * **	7.586 * **	7.593 * **	7.540 * **
	(0.060)	(0.035)	(0.028)	(0.028)	(0.031)	(0.045)	(0.031)	(0.014)	(0.014)	(0.050)
Seasonal FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
#. obs	1155	1155	1155	1155	1155	594	594	594	594	594
R^2	0.331	0.450	0.451	0.486	0.186	0.184	0.200	0.139	0.170	0.036
Underidentification test	12.16 * **	16.60 * **	13.41 * **	8.15 * *	2.68	11.81 * *	11.58 * **	14.63 * **	12.75 * **	1.79
Overidentification test	0.55	0.67	0.83	0.96	0.65	2.85	3.27	2.04	2.14	1.60

Notes: significance levels: * ** $p < 0.01$, * * $p < 0.05$, * $p < 0.1$. The standard errors are clustered at the city level and shown in parentheses. The IV-panel regression is run with fixed effect and random effect. The table shows the results of the fixed-effect model only to keep consistent with Table 2. The instrument variables used in this table include *lhp* and *lhp*slope*.

Table A1
Correlation matrix.

	IndTran	*ResTran*	*ComTran*	*Land2Fis*	*Land2GDP*	*TotalRev*	*ResRev*
IndTran							
ResTran	0.5383						
ComTran	0.4091	0.5110					
Land2Fis	0.1310	0.4906	0.3022				
Land2GDP	0.2057	0.5884	0.4153	0.7822			
TotalRev	0.3366	0.5411	0.3285	0.4459	0.6324		
ResRev	0.2996	0.5519	0.2790	0.4758	0.6433	0.9652	
ComRev	0.1633	0.2229	0.2967	0.1755	0.3314	0.6500	0.4339

is applied for the IV regression. To confirm our identification strategy, we regress both the dependent variable and endogenous land finance on the instrumental and control variables in the first stage of the estimation. The standard errors are clustered at the city level. The results are reported in Table 3. We found an insignificant relationship between the dependent variable and IVs, while significant relationships between endogenous variables (i.e., land finance) and IVs. For example, the dependent variable in the first model in Table 3 is ln*GCF*, which is also the dependent variable in our main models in Tables 2 and 4. The coefficient estimates of the IVs are statistically insignificant in this model, which can be seen as evidence of the validity of the IVs. Meanwhile, the dependent variable in Models (2) through (6) in Table 3 is the alternative land revenue indicator in the five models investigated in Table 4. The results of these models suggest that *lhp* and $lhp * slope$ are valid IVs because their coefficient estimates are significant at the 5% level in at least one of the five alternative specifications. Subsequently, *lhp* and $lhp * slope$ are selected as instrumental variables used in the rest of the empirical analyses.

We used post-estimation tests, including under-identification and over-identification tests, to further verify the validity of IVs. Specifically, the under-identification test confirms the selected IVs are not weak and over-identification tests suggest that the IVs are exogenous. The statistics reported in Table 4 show that the IVs passed both tests in all models except for Model (5). As Model (5) is the weakest one in the fixed effect panel regression analysis (see Table 2), this model's insignificant under-identification test result should not be taken as evidence of weak IVs. On

Table A2
VIF Corresponding to Model 1–5 in Table 2.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
$IndTran_{i,t-1}$	1.56	1.56	1.51	1.50	1.50
$ResTran_{i,t-1}$	2.12	2.33	2.15	2.29	1.76
$ComTran_{i,t-1}$	1.50	1.56	1.49	1.49	1.54
$Land2Fis_{i,t-1}$	1.56				1.16
$Land2GDP_{i,t-1}$		1.77			
$TotalRev_{i,t-1}$			1.70		
$ResRev_{i,t-1}$				1.74	
$ComRev_{i,t-1}$					1.16
$FIP_{i,t-1}$	3.50	3.50	3.50	3.50	3.50
$r_{i,t-1}$	6.34	6.33	6.32	6.32	6.32
$GDP_{i,t-1}$	1.02	1.02	1.02	1.02	1.02
$indpr_{i,t-1}$	1.08	1.08	1.09	1.09	1.09
$respr_{i,t-1}$	4.27	4.26	4.29	4.28	4.29
$compr_{i,t-1}$	4.33	4.33	4.35	4.34	4.35
$hpr_{i,t-1}$	1.16	1.17	1.18	1.17	1.16
Mean VIF	3.42	3.44	3.43	3.44	3.38

the other hand, although the IVs passed the tests in most of the models, we should note that, by following the IV strategy in Chen and Kung (2016), *lhp* is included as an IV both directly on its own and indirectly as part of the other two composite IVs. It is unlikely to be strictly endogenous. Therefore, our results should be interpreted with this caveat in mind. Future studies should further explore more reliable IVs for land revenue.

In the main stage, *GCF* is regressed on the predicted values of land revenue from the first stage estimation and control variables. We report the results in Panel A in Table 4. The IV estimations show improvements over the fixed effect panel regression results in Table 2. Firstly, the point estimates (absolute value) of most key variables are larger in 2SLS estimations, which suggests that fixed effect panel estimations in Table 2 are likely to be downward biased. Secondly, the IV results are more consistent with the predictions from our analytical model. Specifically, we find a negative effect from the industrial and residential sectors and a positive effect from the commercial sector on LGFV debt issuing for infrastructure development across Models (1) to (4). The findings are consistent with Hypothesis 1. However, only the coefficients of *ResTran* are significant at the 10% level in Models (3) and (4). Overall, the support for Hypothesis 1 is weak during the whole sampling period. Finally, all instrumented land finance variables except for *ComRev* show that land finance significantly and positively affects local government debt; Hypothesis 3 is true.

6.3. Subsample analysis

To test Hypothesis 2, or the effect of central government control, we re-estimate the five models in Panel A of Table 4 by using data from the after-2013 sub-sample. As discussed in Section 2.3, the two documents issued between 2013 and 2014 may have significantly changed local government's borrowing behaviours. Therefore, if a structural break at around the year 2013 is identified, it is the evidence to support Hypothesis 2. The results are reported in Panel B in Table 4.

The patterns of the private sectors are consistent with those of the whole sample: industrial and residential sectors negatively influence while the commercial sector positively influences the local government's debt financing for infrastructure development across the five models. However, we observe significant differences in coefficient estimates between the two subsample periods. Specifically, activities in the private sector, as measured by *IndTran*, *ResTran*, and *ComTran*, had larger and more statistically significant effects on LGFV debt issuing in the after-2013 sub-sample period. Meanwhile, the effect size from the local government land finance shows an opposite trend. After 2013, the point estimate of local government land finance factors (i.e., *Land2Fis*, *Land2GDP*, *TotalRev*, *ResRev*, and *ComRev*) dropped significantly. This shows that the impact of land finance on LGFV debt issuing decisions has been reduced since 2013. The difference in these coefficients between the sub-sample and the full sample indicates that '*Document 43*' reshaped local governments' strategy in infrastructure financing. After 2013, local governments' debt financing of infrastructure projects is more responsive to activities in private sectors in their cities. The findings suggest that local governments consider the development of the commercial and residential sectors because the former would enhance debt solvency through tax revenue in the long run, and the latter would crowd out other sectors from capital markets. This is evidence to support Hypothesis 2.

The subsample results also confirmed the conclusions reached about Hypotheses 1 and 3 using the whole sample. For example, land finance significantly and positively affects local government debt in Models 1 through 4 in both periods. The results are consistent with those of the full sample. The direction and the statistical significance of the effects of land finance remain the same as in the full-sample models.

In summary, both the public and the private sectors affect local government debt issuing for infrastructure financing. For the public sector, land finance propels the debt level, but the effect was weakened by the local government debt market reform around 2013. The influence of activities in private sectors (i.e., the residential and commercial real estate markets), on the other hand, is only significant after 2013, which shows the effect of state control. Although our theoretical model implies that industrial development should restrict local governments' debt financing, data show that the industrial sector has minor, negative impacts on local government debt.

7. Policy implications

One of the government's most important tasks is providing public goods and infrastructure. This is challenging for developing countries, where local and central governments often face tight fiscal constraints. In China, local governments have used the land-value capture model to finance infrastructure projects. Although this strategy has served China's rapid urbanisation process well so far, there has been widespread concern about the potential systemic risk resulting from the land finance model. Local governments are under pressure to find alternative financing methods.

In the last decade, local government debts, particularly LGFV debts, have become an important source to finance infrastructure development in China. Technically, the use of land lease revenue can reduce the total cost of infrastructure projects as it does not involve interest payment. Meanwhile, the interest payment of local government debt can be justified by tax revenues generated from infrastructure-supported activities from the private sector. A well-balanced 'capital structure' of infrastructure projects is a good mix of land lease revenue (i.e., equity) and local government debt, such that local governments are neither heavily reliant on land leasing revenue nor overly burdened with debt interest payment.

Local government debts have grown steadily since China introduced the stimulus package in response to the 2008 financial crisis. According to the *Financial Times*, Chinese local government debts had reached 56 trillion RMB in October 2023 (Wigglesworth, 2023). LGFVs also play an increasingly important role through their financial, developmental, entrepreneurial and managerial functions in the infrastructure and transportation development (Jiang and Waley, 2022). However, these financial vehicles also increased both LGFV debts related risk and systematic financial risks. The financial viability and effectiveness of financing infrastructure through LGFV debts should be closely monitored (Wu, 2022). Our analytical model and empirical findings suggest that policymakers should be cautious with LGFV debts when land and real estate markets cool down, such as during and after the pandemic. Specifically, during market downturns, the drop in land leasing revenue will significantly dampen the level of LGFV debts. Although some funds may be shifted from the residential property market to LGFVs, as predicted by our model, the size may not be large enough to compensate for

the negative impact of the loss of land leasing revenue. If policymakers do not find alternative funding sources to stimulate the economy, infrastructure funding and development may end up in a downward spiral.

This study also has significant policy implications for the *Dual Circulation* economic development strategy, an essential part of the latest Five-Year Plan announced in May 2020. The strategy requires the funding, financing, and management of infrastructure projects to be more responsive to the domestic markets than foreign direct investment. The responsiveness of local government debt issuing to business activities in the commercial and residential sectors and the irresponsiveness of local government debt issuing to the industrial sector (which is more driven by foreign direct investment) indicate that the 2013/14 local government debt reform may have paved the way for the implementation of the Dual Circulation strategy. Policymakers should be cautious about the strong and consistent positive relationship between land lease revenue and local government debt level, particularly after the central government tightened the local government debt markets in 2013/14. The regulation of local debt markets will trigger the adjustment of other financing means, such as land lease revenue. The central government should be aware of such intriguing interrelationships among alternative financing methods.

Finally, urban development in China has entered the stage where governments work collaboratively with markets (Wang and Luo, 2022). Market and society play an increasingly important role in urban development in China. Policymakers need to consider this in decisions regarding infrastructure development. It is important to investigate whether local government debt issuing is responsive to activities in the private sector. Our empirical results suggest that local governments are working creatively to meet infrastructure development targets handed down by the central government and getting more effective by considering activities from the private sector in their debt-issuing decisions. The regulations of local government debt issuing in 2013/14 are the triggers of such responsiveness to market information and consequently allow some room, albeit limited, for private sectors to be involved in infrastructure financing decisions. Although the transformation has yet to be completed across all sectors, this suggests that the infrastructure project financing model was heading in a promising direction.

Understanding local government debt financing of infrastructure projects is important for post-pandemic economic recovery and stability in China, given the critical role infrastructure development often plays. Policymakers, analysts, and investors must closely monitor this financing vehicle to make informed decisions in the changing economic landscape. A sound understanding of LGFVs can aid in formulating prudent fiscal and land use policies and ensuring that local governments manage their debt responsibly. Our research provides both an analytical framework and empirical findings to support such policymaking.

8. Conclusions

Local government debts play an important role in financing infrastructure development in China. Over the last decade, LGFV debts have channelled a significant amount of capital into infrastructure and transportation construction. However, employing these financial vehicles has also significantly increased LGFV-related financial and systematic risks. Therefore, the operation and management of LGFV debts require scrutinisation and oversight by researchers and policymakers. Most existing LGFV studies concentrate on the financial performance of LGFV debts and the role of central and local governments in initiating and managing LGFV debts. The role of the market or the private sector has not been thoroughly explored. This study addresses this gap in the literature by developing an analytical framework to study the complex relationship between local government debt issuance for infrastructure financing, land finance, and the private sector's demand in China. On the technical front, we use LGFV's accounting data to measure LGFV debt issuing for infrastructure projects, an approach especially reliable when trustworthy official statistics are absent.

Our analysis of LGFV data between 2009 and 2017 revealed a positive association between land finance and local government debt for infrastructure. This connection weakened after the 2013–2014 local government debt regulations. Notably, post these regulations, LGFV debt issuance began to show significant reactions to private sector activities. Between 2013 and 2017, commercial sector growth positively influenced LGFV debt issuance, while residential sector development had a negative impact. The relationship between LGFV debt issuing and the industrial sector remains weaker and less clear. The empirical findings support the logic of our analytical framework: understanding the interplay of the central government, local governments, and the market is critical for the operation and management of local government debt in China.

These findings also suggest that local governments have adapted their debt issuance strategies by factoring in private sector activities. The 2013/14 debt regulations triggered this shift, carving out a space for private sector involvement in infrastructure financing. Our analysis would have been more robust had it incorporated policy shifts post-2017, such as the 2020 "Three Red Lines" policy and the 2021 residential land supply regulation. However, the effect of these new policies will take time to manifest themselves, and the data between 2020 and 2022 was muddied by the confounding effects of the COVID-19 pandemic. Consequently, we did not consider these policies in this study. Nevertheless, our analysis suggests that rules and legislation handed down by the central government can fundamentally change the landscape of infrastructure financing. Future studies can apply our analytical framework to newly available data to estimate the impacts of recent policies.

The research examines China's local government debts, touching upon three policy domains. Firstly, it highlights the role of LGFVs in infrastructure development and the associated risks. The analytical framework helps policymakers monitor LGFVs, especially when land leasing revenues face sustained declines during the post-pandemic era. Secondly, the study offers insights into the relationship between land lease revenues, real estate development activities, and local government debt. This knowledge can guide policymakers as they navigate changes in financing options in both the public and private sectors. Finally, the research suggests that, with China's shift towards collaborative urban development, the private sector's role is increasing. The study reveals that local governments have adjusted their debt-issuing decisions to better align with market information. The findings of this research contribute to a better understanding of fiscal and land use policies in China.

Our theoretical model can be extended and improved in several aspects in future studies. First, the model assumes the economic prices of commercial and residential lands to be driven by improved productivity. This is reasonable in the short run, while more factors should be considered in the long run. Second, land markets and urban development in Chinese cities are regulated by a series of policies issued by the central government. At the same time, our current model is designed to detect the combined effect of government policies by detecting structural breaks. This is a design determined by the current state of data availability, where the isolation of the net effect of each individual policy is only sometimes empirically feasible. With the advance of information technology and the advantages and opportunities offered by big data, it is possible that our analytical framework could be enhanced to pinpoint the effect of each government policy. Third, although the accounting data of LGFVs is the best measurement available for local government debt issuing, it is still a proxy or a rough estimation of the actual debt issuing for infrastructure financing. Finally, the causal chain within the private sector is long and deserves to be specified. At the time of writing, no reliable data is available to support such an in-depth investigation. This should be left to a paper that focuses on the role of the private sector in infrastructure financing, which is an under-researched yet important research direction. Our results should be

interpreted with these limitations in mind, and our future research will endeavour to address these data issues when new data and modelling techniques are made available.

CRediT authorship contribution statement

Bao Helen: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Wang Ziyou:** Writing – review & editing, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Wu Robert Liangqi:** Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

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Appendix 1. Summary of publications on LGFVs

No	Paper	Study region	Sample size	Study period	Research methods	Study focus
1	Guo et al. (2020)	National	748	2011–2016	Linear regression	LGFV financial performance (ROA, ROE, OCF)
2	Liang et al. (2017)	National	135	2005–2007 and 2011–2013	Linear regression	The crowding out effect of Chengtou bond financing
3	Luo and Chen (2019)	National	771	1999–2011	OLS, 2SLS, and ordered prohbit model	Credit rating and LGFV bond yield
4	Qian (2018)	National	2261	2010–2014	DID	Anticorruption and LFGVs' financial performance
5	Tao (2015)	National	1007	2009–2012	PCA and MDA	LGFV debt risk
6	Walker et al. (2021)	National	148,509	2010–2017	Panel regression	LGFV bond yield spread
7	Ye et al. (2022)	Jiangning	6	2015–2016	Case study	LGFV bond risk
8	Yu et al. (2022)	National	5084	2010–2017	Spatial panel data model	LGFV bond default risk
9	Feng et al. (2022b)	Jiaxing	1	2005–2017	Case study	LGFVs act as financial intermediaries in urban development
10	Han et al. (2021)	281 cities in China	2248	2009–2014	Logistic regression	New Town Development
11	Jiang and Waley (2020)	Shanghai	4	1990–2019	Case study	The role of Chengtou in city development
12	Li and Chiu (2018)	Shanghai	1	2001–2013	Case study	New Town Development
13	Feng et al. (2022a)	Zhejiang and Guizhou	2	2006–2018	Case study	Relationships between the central and local governments in LGFV management
14	Feng et al. (2023)	Shanghai	22	2019–2021	Interviews	Relationships between the central and local governments in LGFV management
15	Huang and Du (2018)	National	356,822	2007–2016	Regression	LGFVs land purchasing behaviour
16	Jiang and Waley (2018)	Shanghai	1	2011–2016	Case study	Relationships between the central and local governments in LGFV management

Note: LGFV and Chengtou are used interchangeably in these studies.

Appendix 2. A two-period model of LGFV debt issuing for infrastructure development

We develop a two-period model in which the local government aims to develop infrastructure with a target (denoted by q) while choosing optimal land allocation to maximise land revenue. Following the practice in infrastructure studies, q is measured by the area of land for infrastructure development, with the unit cost k.

In the first period, the local government aims for infrastructure development target q_1, and thus the infrastructure investment can be calculated as kq_1. Meanwhile, the local government also needs to support industrial development I_1 with unit subsidies s and repay the principal and interest of existing debts iP_1.The local government balances the fiscal expenditure by using general budgeted revenues (most constituted by taxes, and thus tY_1, where t denotes government tax rate on the total output Y_1), land finance (LF_1), and debt finance (D_1), as described in the equation below.[4]

$$eLF_1 + D_1 + tY_1 = kq_1 + sI_1 + iP_1, \quad (1)$$

[4] Although a significant proportion of local government revenues are used for debt repayment, as one of the anonymous reviewers pointed out, the determination of the value of e, P_1, and P_2 is not considered in our analytical framework. This is because our study focuses on the determinants of local government's new debt issuing for infrastructure development instead of how fiscal revenue is used for other purposes, such as debt repayment and land expropriation. Most importantly, in our empirical analysis, we used the cash flow data of LGFVs, i.e., the difference between cash outflow (expenditure) and inflow (income), to reliably identify the proportion of funds used for infrastructure development. This approach is consistent with the analytical framework developed in this section.

The land revenue mainly comes from leasing commercial and residential lands. In Eq. (1), $LF_1 = n_1C_1 + p_1R_1$, where n_1 and p_1 are the prices of commercial and residential lands, and C_1 and R_1 are the quantity of commercial and residential lands. Industrial land leasing is not included in this calculation because it doesn't generate positive revenue (e.g., the land price is equal to or less than the cost of land clearance). This is because local governments in China have been keeping industrial land prices low, sometimes even for free or at a net loss, to boost local economic growth (Cao et al., 2008). Due to the cost of land expropriation, the local government can not make full use of the land revenue. e represents the proportion of land revenue that can be invested by local government in infrastructure development, and $(1-e)LF_1$ is the compensation for land expropriation.

In the second period, the local government aims for infrastructure development q_2 so that $q_1 + q_2 = q$. The local government intends to maximise the fiscal balance that consists of the land revenue $LF_2 = n_2C_2 + p_2R_2$, general budgeted revenue tY_2, the infrastructure investment kq_2, the support to industrial development with subsidies sI_2, and the debt repayment iP_2. The final fiscal balance is

$$V_2 = eLF_2 + tY_2 - kq_2 - sI_2 - iP_2 \tag{2}$$

Following Cai and Treisman (2005), the total productivity (or total output Y) of a city is determined by public and private investments. Specifically, assume a Cobb-Douglas productivity function as follows.

$$Y_t = AQ^{\sigma}I^{\alpha}C^{\beta},$$

where Q, I, and C represent the stock of infrastructure, industrial, and commercial development at time t, respectively. $A > 0$ denotes multi-factor productivity capturing the effect of the local endowment on the output. $\alpha, \beta, \sigma > 0$, and $\alpha + \beta + \sigma < 1$ indicates decreasing return to scale. In the first period, $Y_1 = AQ^{\sigma}I^{\alpha}C^{\beta}$. With log-linear approximation, the growth rate of total productivity for each period is.

$1 + y_t \equiv \ln \frac{Y_{t+1}}{Y_t} \approx \left[1 + \sigma \frac{q_t}{Q} + \alpha \frac{I_t}{I} + \beta \frac{C_t}{C}\right]$,

where q_t, I_t, and C_t are the flow of infrastructure, industrial and commercial development at time t, respectively. In the short run, land prices grow as wages and productivity improve (Roback, 1982). In this case, land prices change at the rate of y_t in each period. For instance, the prices of commercial land from period 1 to period 2 become

$$n_2 = n_1\left[1 + \sigma \frac{q_1}{Q} + \alpha \frac{I_1}{I} + \beta \frac{C_1}{C}\right].$$

Such a pricing process captures the interaction between land price and land acquisition of private sectors. Meanwhile, land is non-renewable and limited resource. Local government faces a land budget constraint for commercial development, i.e., $C_1 + C_2 = N$. We impose this constraint on commercial land only because land parcels for commercial development are mostly located in the developed area (e.g., the city centre). Although redevelopment and regeneration projects could free up new land for commercial development, it usually takes years for the new supply to enter the market. Therefore, the supply of these commercial land parcels is limited in the short run. This is different for industrial land parcels, which are typically located in a city's peripheral or even rural areas.

Thus, according to Eq. (2), the local government in the second period has a fiscal balance of

$$V_2 = en_2C_2 + ep_2R_2 + tY_2 - kq_2 - sI_2 - iP_2$$

$$= en_1\left[1 + \sigma \frac{q_1}{Q} + \alpha \frac{I_1}{I} + \beta \frac{C_1}{C}\right](N - C_1) + ep_1\left[1 + \sigma \frac{q_1}{Q} + \alpha \frac{I_1}{I} + \beta \frac{C_1}{C}\right]R_2 + tY_1\left[1 + \sigma \frac{q_1}{Q} + \alpha \frac{I_1}{I} + \beta \frac{C_1}{C}\right] - k(q - q_1) - sI_2 - iP_2$$

Because of the pressure from the central government to keep outstanding debts and new debt issuing in check, local governments pay close attention to fiscal balance. We derive the F.O.C. accordingly as follows.

$$\frac{\partial V_2}{\partial C_1} = en_1\left[\left(\frac{\sigma n_1}{kQ} + \frac{\beta}{C}\right)(N - C_1) - \left(1 + \sigma \frac{LF_1 + D_1 - sI_1 - iP_1}{kQ} + \alpha \frac{I_1}{I} + \beta \frac{C_1}{C}\right)\right] + \frac{\beta}{C}ep_1R_2 + \frac{\beta}{C}tY_1 + en_1 = 0.$$

With some arrangements, the equation becomes

$$\frac{\beta}{C}ep_1R_2 + \frac{\beta}{C}tY_1 + \left(\frac{\sigma n_1}{kQ} + \frac{\beta}{C}\right)en_1N - en_1\frac{\sigma D_1}{kQ} = en_1\left\{\sigma \frac{LF_1}{kQ} - \left(\frac{\sigma s}{kQ} - \frac{\alpha}{I}\right)I_1 + \left(\frac{\sigma n_1}{kQ} + \frac{2\beta}{C}\right)c_1 - \sigma \frac{iP_1}{kQ}\right\} \tag{3}$$

Take derivatives (*w.r.t.* D_1, LF_1, I_1, C_1, R_1) on both sides of Eq. (3), we obtain

$$-\frac{\sigma}{kQ}dD_1 = \frac{\sigma}{kQ}dLF_1 + \left(\frac{\alpha}{I} - \frac{\sigma s}{kQ}\right)dI_1 + \left(\frac{\sigma n_1}{kQ} + \frac{2\beta}{C}\right)dC_1 - \frac{\sigma}{kQ}\frac{\partial iP_1}{\partial R_1}dR_1, \tag{4}$$

The maximum debt the local city government can raise in a given period is regulated by the provincial government with a quota system (Huang and Chan, 2018). In this two-period model, the debt quota is assumed to be D, i.e., $D_1 + D_2 \le D$. Meanwhile, the rate of central government bonds has been declining, and the money supply (M2) has been increasing in China. As a result, local government debt becomes a popular option to raise funds. Most local governments try to use up all the quota, and Eq. (4) becomes

$$\frac{\sigma}{kQ}dD_2 = \frac{\sigma}{kQ}dLF_1 + \left(\frac{\alpha}{I} - \frac{\sigma s}{kQ}\right)dI_1 + \left(\frac{\sigma n_1}{kQ} + \frac{2\beta}{C}\right)dC_1 - \frac{\sigma}{kQ}\frac{\partial P_1}{\partial R_1}dR_1 \tag{5}$$

This gives us the following propositions that capture the role of land finance and the private sector in local governments' debt financing of infrastructure development.

(i) $\frac{\partial D_2}{\partial C_1} = n_1 + \frac{2\beta}{C}\frac{kQ}{\sigma} > 0$. This suggests that commercial development in the current period positively affects local government debt issuing in the next period. Specifically, the commercial sector affects the local government debt through two channels, i.e., immediate contribution to land revenue (through n_1) and potential contribution to productivity (through $\frac{2\beta}{C}\frac{kQ}{\sigma}$).

(ii) $\frac{\partial D_2}{\partial I_1} = \frac{kQ}{\sigma}\left(\frac{\alpha}{I} - \frac{\sigma s}{kQ}\right) < 0$ when $\frac{\alpha}{I} - \frac{\sigma s}{kQ} < 0$. This condition indicates that the industrial sector affects the local debt through two channels: a positive contribution to productivity through $\frac{\alpha}{I}$ and a negative contribution to land revenue through $-\frac{\sigma}{kQ}s$.[5] The condition is equivalent to comparing $\frac{\alpha}{s}\frac{1}{I}$ and $\frac{\sigma}{k}\frac{1}{Q}$. Firstly, we have $Q < I$ as Chinese cities have promoted industrial development for the past decades. Secondly, $\frac{\alpha}{s}$ and $\frac{\sigma}{k}$ represent the ratio of productivity to cost when investing in industry and infrastructure, respectively. Infrastructure development shows a substitute effect as it brings more efficiency to boost the local economy than industrial development in China (e.g., Shi and Huang, 2014). Thus, the condition $\frac{\alpha}{I} - \frac{\sigma s}{kQ} < 0$ indicates that the industrial development in the current period has a negative total effect on the local government debt in the next period.

(iii) $\frac{\partial D_2}{\partial R_1} = -\frac{\partial P_1}{\partial R_1} < 0$. Although the development of the residential sector does not affect the production equation $Y_t = AQ^{\sigma}I^{\alpha}C^{\beta}$ in the short run, the boom in residential development in China causes resource misallocation between real estate and other sectors in the economy. Specifically, the residential sector in China has a strong crowding-out effect on non-real estate investment (Chen and Wen, 2017). Lenders favour residential investment or projects because they offer higher returns than other industries (Allen, Qian et al., 2019). Thus, residential development could stimulate the capital cost of debt in the local economy. In other words, the interest payment is positively influenced by the residential sector due to such the crowding-out effect, i.e., $\frac{\partial P_1}{\partial R_1} > 0$. We expect a negative relationship between residential land transactions and debts for infrastructure investment.

(iv) $\frac{\partial D_2}{\partial LF_1} = 1$. The positive value indicates that land finance in the current period positively affects local government debt issuing in the next period. The local government often takes an increase in land revenue as a signal of strong land demand from the private sector, which will lead to an increase in the demand for infrastructure. Meanwhile, a higher level of land revenue is also associated with optimistic anticipation of economic growth. This gives the local government the incentive and the confidence to issue new government debts to finance infrastructure projects.

The four propositions derived from Eq. (5) provide an analytical ground for the hypotheses developed in Section 4. Specifically, we derive H1a, H1b, and H1c based on propositions (i), (ii), and (iii), respectively. These three propositions also form the basis of H2. Proposition (iv) is used to develop H3.

Appendix 3. Correlations between land transfer and land revenue variables

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[5] We could consider $LF_1 - sI_1$ as the total land leasing revenue in the first period.

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