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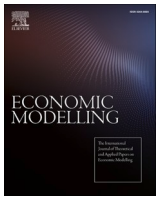

Countercyclical central government transfers incentivize local government overborrowing: Theory and evidence☆

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ABSTRACT

Local governments in China have strong incentives to overborrow, leading to unsustainable local debt. Recent research suggests that higher central government transfers serve as a key incentive for local governments to overborrow. This paper constructs a theoretical model and shows that it is the countercyclicality of central government transfers, that is, the negative correlation between transfers and local revenues, that act as the main incentive for local governments to overborrow. We test the model predictions using hand-collected provincial data on local government debt and budgets. The empirical evidence strongly supports the prediction that the negative correlation—not the magnitude—of central government transfers is the main driver of the incentive for local governments to borrow excessively. The countercyclical nature of central government transfers provides insurance against local government debt service, thereby increasing the incentive for local governments to borrow. The findings suggest the need to change the central government transfer policy framework.

1. Introduction

China's expansionary fiscal stimulus policy in response to the global financial crisis in 2008 has led to a rapid accumulation of local government debt,[1] raising widespread concerns about debt sustainability. In addition, local government debt, mainly in the form of debt issued by local government investment and financing platform companies,[2] poses a threat to financial system stability and is an important source of systemic financial risk.[3] To effectively address the problem of excessive local government indebtedness, it is imperative to gain a comprehensive understanding of the underlying reasons that lead local governments to accumulate such high levels of debt. A prevailing perspective in contemporary research is that when local governments receive higher transfer payments from the central government, they are incentivized to

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[1] In 2012, the balance of debt that local governments are responsible for repaying was 9.6 trillion, exceeding central government debt for the first time. During 2013–14, the balance of local government debt continued to rise, from 10.9 to 15.4 trillion; the debt to gross domestic product (GDP) ratio peaked at 24% in 2014. Across 2015–17, the balance of local government debt was 14.8 trillion, 15.3 trillion and 16.5 trillion, respectively, with the debt to GDP ratio stabilizing at around 22% and the ratio to total local government financial resources at around 90%.

[2] Bai et al. (2016) provide a systematic overview of government fiscal expansion and its financing characteristics during this period. An important feature of local government debt in China is the use of government investment and financing platforms, which we also call Chengtou, as the main vehicle for indirect debt financing. Until the amendment to the Budget Law in August 2014, which allowed direct debt financing by local governments, local governments mainly relied on platform companies for debt financing.

[3] In March 2016, Moody's downgraded China's sovereign rating outlook from stable to negative, and in May and September 2017, Moody's and S&P downgraded China's sovereign ratings in quick succession, which continued to cause high concern in domestic and international financial markets.

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overborrow (Potrafke and Reischmann, 2015; Lu and Zhong, 2018; Dovis and Kirpalani, 2020). In other words, higher levels of transfer payments act as a catalyst for local governments to become overindebted.[4]

The solution proposed in the literature to reduce the incentive for excessive borrowing due to higher transfers is to tighten budget constraints on local governments, mainly through the imposition of debt ceilings (Chari and Kehoe, 2007; Chari and Kehoe, 2008; Aguiar et al., 2015). In reaction to the swift increase in local government debt, the Chinese administration implemented measures to constrain borrowing akin to debt ceilings. Nevertheless, the introduction of fiscal regulations may precipitate negating consequences (Sanguinetti and Tommasi, 2004; Besfamille and Lockwood, 2008; Halac and Yared, 2014; Halac and Yared, 2018). One critical instance of this inefficiency is the underinvestment of local authorities resulting from insufficient financing resources, curtailing the growth of local economies. Strict debt limits have curbed the growth of local government debt in China, but the long-term efficiency costs of this management are high, and the incentive for excessive borrowing by local governments has not been fundamentally removed. As a result, local governments continue to borrow in various hidden ways.

Current research into local government overindebtedness incentives and the proposed debt ceiling solution have not successfully addressed the local government debt issue. In this paper, we present an alternative perspective and propose a novel solution based on this perspective. We begin with a simple intuitive analysis. The overindebtedness of local governments is based on the expectation that there will be sufficient revenues to meet the debt obligations. The greater the expected resources that local governments expect to allocate to debt service, and the lower the uncertainty about the amount of debt service, the greater the incentive for local governments to accumulate excessive debt. In addition, transfers from the central government form part of the resources allocated to debt servicing, while local governments also rely on their own revenues to meet their debt obligations. If local governments make borrowing decisions with the expectation that the central government will increase transfer payments if their own revenues fall and are insufficient to service their debt (i.e., that transfers are countercyclical), then local governments will borrow more because they have sufficient debt service coverage. In this paper, we argue that this countercyclical nature of transfers, that is, the negative correlation between local own revenues and central transfers, is a source of incentives for excessive borrowing.

To this end, we first construct a tractable model in which the funds for local government debt service come from two sources: local government revenues and central government transfers. Implicitly, we focus on the part of the transfer that is discretionary; that is, the transfer is not predetermined by a formula and the final value is uncertain ex ante. This allows us to consider the problem of the local government's choice of fiscal structure, that, how much it will rely on its own revenues versus central transfers (as an ex ante promise), and simultaneously, its borrowing decision subject to a given debt risk constraint. The crucial element of the model is the dynamic relationship between the local government revenue and the central government transfer that materializes ex post. Both are stochastic and the correlation can take any sign. We show that the correlation plays a crucial role in the local government's choice of fiscal structure and borrowing decisions. A negative correlation induces the local government to rely more on central transfer for debt service, thus strengthening its incentive to overborrow. Moreover, the greater the degree of negative correlation, the more debt the local government is willing to take on. In effect, a negatively correlated central transfer provides insurance for the local government's budget: if the local government's revenues are low in the future, it is more likely that central transfers will be high, so the local government can more easily maintain sufficient funds for debt service by trying to obtain more central transfers at the beginning.

The essence of the local government's excessive borrowing is its reliance on central transfer payments as a source of debt service. If the local government only uses its own revenues for debt service, there would be no excessive borrowing. Moreover, due to the nature of the discretionary central transfer system, there is ample room for the local government to bargain with the central government to raise the magnitude of the transfer payments at the very beginning. This choice of fiscal structure, coupled with the negative correlation between local government revenues and central transfers, inevitably creates an incentive for local governments to borrow excessively. To curb this incentive, the central government can either avoid countercyclical transfer payments relative to the local government's own revenues or establish a transfer policy rule to limit the local government's discretionary choice of relying too much on central transfer for future debt service.

We empirically test the results of the above theoretical analysis using hand-collected Chinese provincial-level local government data on debt and fiscal information. To be consistent with the theoretical model, we make considerable efforts in variable construction and data collection. First, we focus on the sample period before 2016, when a new set of local government debt limit policies were implemented in China. Second, we manually collect total debt data along with detailed fiscal budget information for each province in China from 2010 to 2015. To accurately measure a province's total government debt, we rely on debt data provided by the National Audit Office and the Ministry of Finance, which only began collecting such data in 2010. Based on the data, we calibrate the excessive debt of each province in the sample according to the theoretical model, which serves as the main dependent variable in the regression analysis. Excessive debt is defined as the difference between the actual level of debt and the theoretical maximum level of debt (i.e., the maximum level of debt that can be incurred by relying solely on the local government's own revenues to finance debt service). Finally, we equate discretionary central transfers in the theoretical model to earmarked transfers.[5]

Our empirical results strongly support the theoretical predictions. A negative correlation between central transfers and local revenues not only increases the likelihood of excessive borrowing but also leads to more excessive borrowing. The empirical results are also robust to the calibration methods for excessive debt. Moreover, while the existing literature emphasizes the role played by the magnitude of central transfers, we show that a more important factor driving excessive borrowing is the negative correlation between central transfers and local revenues. In particular, once we control for the correlation, the magnitude of transfer payments no longer has a significant impact on excessive local government borrowing.

[4] This higher level of transfer payments can be seen as a tangible manifestation of the soft budget constraint within the fiscal federation. See Kornai (1986) for an early discussion of the soft budget constraint. The central-local fiscal relationship in China is very similar to that in common fiscal federations such as Germany, Brazil, Argentina, and so forth. Soft budget constraints in fiscal federations and excessive local debt are common problems.

[5] In China, transfers can be divided into two different types: general transfers and earmarked transfers. General transfers are predetermined and fixed in advance, while earmarked transfers are uncertain and subject to the discretion of the central government. It is important to note that only earmarked transfers are directly related to bailouts and the concept of soft budget constraints.

The contributions of this paper are threefold. First, we combine the local government's choice of (discretionary) central transfers, and hence its fiscal structure, and the borrowing decision in a simple and unified framework, so that we can easily examine the incentive to overborrow in the context of the features of the transfer system. Second, in contrast to the existing literature, we highlight the crucial role of the dynamic relationship between the central transfer and local revenues in determining the incentive of local governments to overborrow. Third, we use the theory to provide a better understanding of the recent local government debt problems in China, and the empirical tests provide strong support for the main implications of the theoretical model. The analysis also provides practical policy recommendations to curb the incentive for local governments to borrow excessively. It is not necessary to completely abandon the current transfer system, which is essential for local development tasks, to control local government debt risk. Instead, the policy focus should be on either controlling the countercyclicality of central transfers relative to local revenues or designing transfer policy rules to limit the discretionary use of central transfers by local governments.

The paper is organized as follows. Section 2 provides a literature review. Section 3 lays out the theoretical framework and presents the derivation of the main theoretical results. Section 4 contains the empirical analysis. Then further policy discussion and conclusions are given in Section 5. The appendix includes the proofs and additional details for the empirical analysis.

2. Literature review

This paper examines the problem of overborrowing by local governments in China. Local government debt in China has reached alarming levels, with significant negative economic consequences and fiscal risks.[6] The problem of overborrowing by local governments is not unique to China and also exists in other countries with fiscal decentralization systems, such as Germany, Brazil, and Argentina.[7] In general, fiscal decentralization systems face the same problem: vertical fiscal imbalances that lead to significant local government debt (Rodden, 2002; Seiferling and Aldasoro, 2014). As vertical fiscal imbalances increase, local governments become more dependent on central transfers, leading to higher bailout expectations (Cooper et al., 2008; Sorribas-Navarro, 2011; Bordo et al., 2013; Gourinchas et al., 2020). As a result, as Kornai (1986) notes, fiscal discipline breaks down and debt levels increase, leading to a soft budget constraint.[8] Although our study examines the local government debt in China, our findings have broader implications.

Current research suggests that the soft budget constraint in the context of fiscal decentralization is the underlying reason for local government overborrowing. Fiscal transfers, as described in the literature, are a specific form of soft budget constraint and a driver of local government debt accumulation. This is particularly true for discretionary transfers, which are equivalent to earmarked transfers in China since local governments are motivated to seek additional financing resources by bargaining with the central government over the amount of earmarked transfers. Potrafke and Reischmann (2015) suggest that fiscal transfers are positively related to local government debt. Moreover, Lu and Zhong (2018) find that earmarked transfers, that is, transfers over which the central government has discretion, contribute to local government debt accumulation in China. In addition, Dovis and Kirpalani (2020) argue that the expectation of central government transfers creates an incentive for local governments to overborrow. Guo et al. (2022) develop a dynamic model and show that expectations of transfer payments can lead to ex ante excessive borrowing. Recent research on central transfers has also focused on their relationship with local fiscal behavior, suggesting that central transfers have a significant impact on local fiscal revenues and expenditures.[9] For example, Liu and Ma (2016) find that additional transfers to county governments in China increase local public spending.

The literature suggests that central government transfers, particularly discretionary transfers, have a significant impact on local government fiscal behavior and debt. However, the existing literature has mainly focused on a static scale perspective. In our study, we analyze central transfers from a dynamic perspective, taking into account the correlation between earmarked transfers and local own fiscal revenues. This approach distinguishes our research from the current literature. In addition, we conduct a comprehensive theoretical analysis using a model, which distinguishes our study from existing empirical research.

Our paper is related to studies on how to limit ex ante overborrowing due to soft budget constraints. According to the existing literature, the recommended policy approach is to implement fiscal rules that limit debt accumulation (Chari and Kehoe, 2007; Chari and Kehoe, 2008; Halac and Yared, 2014; Aguiar et al., 2015; Azzimonti et al., 2016; Alfaro and Kanczuk, 2017; Halac and Yared, 2018; Halac and Yared, 2022). A more detailed review of fiscal rules can be found in Yared (2019). In essence, fiscal rules serve to harden the soft budget constraint. However, some studies suggest that they may generate underinvestment inefficiencies (Besfamille and Lockwood, 2008) and may not always prevent excessive spending by local governments (Akai and Sato, 2011). Indeed, Dovis and Kirpalani (2020) find that fiscal rules are only effective in limiting debt when the central government has high credibility. While fiscal rules can help remove distorted incentives to overspend and borrow, they also limit flexibility in responding to shocks, leading to efficiency losses (Halac and Yared, 2014; Halac and Yared, 2018).

In contrast to the debt-limiting fiscal rule proposed in the above-mentioned literature, our study takes a dynamic linkage perspective on transfer payments and offers a novel solution to tackle the incentive for ex ante overborrowing resulting from the soft budget constraint. We propose an automatic countercyclical adjustment rule for transfer payments that not only guarantees the flexibility of transfer payments but also curbs the temptation of ex ante overborrowing.

3. Theoretical analysis

3.1. Basic settings

Consider the choice of fiscal structure and the borrowing decision of a single local government in period $t = [0, 1]$. The local government borrows a total amount of debt B_0 at time 0, and the amount to be repaid at time 1 is $B_1 = B_0(1 + r) > 0$ where r is the interest rate on the debt.[10] $S_t = L_t + C_t > 0$ denotes the total funds for debt service held by the

[6] See empirical evidence in Liang et al. (2017), Cuestas and Regis (2018), Cong et al. (2019), Chen et al. (2020), Huang et al. (2020), Gao et al. (2021), and Fan et al. (2022).

[7] See Yared (2019) for more discussion.

[8] For a comprehensive overview of the literature on soft budget constraints in fiscal federations, see Goodspeed (2017).

[9] For further discussion on the economic impact of central transfers, see Churchill and Yew (2017), Chiades et al. (2019), and Kim (2021).

[10] The interest rate on the debt in the model is given exogenously. The reason for this is that the risk characteristics of the debt in the model do not vary with the size of the debt.

government at time t, which consists of two parts: $L_t > 0$ denotes the local government's own revenues, and C_t denotes the central government's discretionary transfers, which are determined by bargaining between the local government and the central government.[11]

In our model, discretionary transfers correspond to earmarked transfers within the Chinese fiscal system. In China, the decision-making process for earmarked transfer payments is implemented through a declaration and approval system. In other words, local governments are required to submit transfer payment applications for specific construction projects, including the amount of funding required, to the central government. The central government then decides whether to approve these projects for transfer payments and determines the final allocation of funds. Within this decision-making process, two key factors influence the final decision on earmarked transfer payments: the initial transfer payment amount requested by local governments and the final payment amount negotiated between local and central governments through bargaining. It is against this background that we have developed our model. Given that local governments determine the initial transfer payment amount, we assume that local governments determine the initial discretionary transfers. In addition, since the final amount of the earmarked transfer payment depends on bargaining between local and central governments, the final transfer payment is subject to uncertainty and is affected by the initial amount.

Given the characteristics of the discretionary transfers C_t, we later map them to the earmarked transfers in China as a part of the empirical analysis.[12] To simplify the analysis, S_t is rewritten as follows:

$$S_t = L_t + C_t = L_t \cdot c_t,$$

where $c_t = 1 + C_t/L_t > 0$ denotes the ratio of central discretionary transfers to local own revenues, that is, the local government's fiscal structure.

Following the classical KMV model of debt default risk (Crosbie and Bohn, 2003), L_t and c_t are assumed to follow geometric Brownian motion:

$$\frac{dL_t}{L_t} = g_l dt + \sigma_l dW_{lt}, \frac{dc_t}{c_t} = g_c dt + \sigma_c dW_{ct},$$

where W_{xt} denotes the standard Brownian motion, g_x denotes the growth rate, σ_x denotes the volatility, and $x \in \{l,c\}$. We further assume that dW_{lt} and dW_{ct} can be correlated and that their instantaneous covariance matrix is denoted by

$$\begin{bmatrix} \sigma_l^2 & \rho\sigma_l\sigma_c \\ \rho\sigma_l\sigma_c & \sigma_c^2 \end{bmatrix},$$

where ρ denotes the instantaneous correlation coefficients of dW_{lt} and dW_{ct}. The initial values of the two components of the debt service funds are denoted as L_0 and c_0.

Since both L_t and c_t are geometric Brownian motions, the total funds for debt service S_t also follows a geometric Brownian motion,[13] and the initial value of $S_0 = L_0 c_0$. In particular, we have $\ln S_1 = \ln L_1 + \ln c_1$, so its distribution at time 1 is given by

$$\ln S_1 \sim N\left(\mu_s, \sigma_s^2\right),$$

where $\mu_s = \ln L_0 c_0 + g_l + g_c - \sigma_l^2/2 - \sigma_c^2/2$, and $\sigma_s^2 = (\sigma_l^2 + \sigma_c^2 + 2\rho\sigma_l\sigma_c)$.[14]

The probability, P, that a local government will default on its debt at time 1 can be expressed as follows

$$P = \Pr(S_1 < B_1) = \Pr(\ln S_1 < \ln B_1).$$

Given the distribution of S_1, the probability of default can be expressed as a function of the initial amount of debt B_0:

$$P(B_0) = \Phi\left(\frac{\ln B_1 - \mu_s}{\sigma_s}\right) = \Phi\left(\frac{\ln(1+r)B_0 - \mu_s}{\sigma_s}\right),$$

where $\Phi(\cdot)$ denotes the standard normal distribution function. In the following section, we examine the endogenous constraint on government liabilities B_0 to endogenize the choice of the fiscal structure of local governments and to analyze the impact of discretionary transfers on local government debt.

3.1.1. Local government debt constraints

Local governments typically borrow for local construction and prefer to borrow as much as possible for this purpose. However, constrained by their own debt service funds and discretionary transfers from the central government, local governments cannot borrow infinitely. In particular, we assume that the default risk $P(Z)$ of local government debt at debt level Z must be below a certain critical level p^*, and then the upper limit of local government debt takes the following form:[15]

$$\max Z \text{ s.t. } P(Z) = \Phi\left(\frac{\ln(1+r)Z - \mu_S}{\sigma_S}\right) \le p^*.$$

Since the standard normal distribution function, Φ is strictly monotonically increasing, the solution to the above optimization problem can be written directly as

$$\ln B_0 = \mu_S + \Phi^{-1}(p^*)\sigma_S - \ln(1+r),$$

where $\Phi^{-1}(\cdot)$ denotes the inverse function of $\Phi(\cdot)$. Let $q = -\Phi^{-1}(p^*)$, and we always consider the case where the critical value of debt default risk $p^* \ll 1/2$,[16] so that $\Phi^{-1}(p^*) < 0$, and $q > 0$. Then we combine μ_s and σ_s^2 into the expressions of $\ln B_0$ and obtain

$$\ln B_0 = \ln L_0 c_0 + g_l + g_c - \sigma_l^2\Big/2 - \sigma_c^2\Big/2 - q\sqrt{\sigma_l^2 + \sigma_c^2 + 2\rho\sigma_l\sigma_c} - \ln(1+r). \quad (1)$$

It follows that the debt limit of local governments is directly related to their own debt service funds L_0 at the beginning of the period and to the central discretionary transfer c_0.

So far, we have considered the case where the values of the L_t and c_t process parameters $g_x, \sigma_x, x \in \{l,c\}$ are given. Under this assumption, for any critical value of debt risk p^* (or its equivalent q), the higher the initial value of discretionary transfers c_0 that the local government can

[11] $S_t > 0$ and $L_t > 0$ imply that $C_t > -L_t$ Here we do not assume that the central discretionary transfer C_t must be positive; it can also be negative, but it cannot be less than $-L_t$.

[12] Although C_t corresponds to earmarked transfers in the real world, we assume that local governments do not intend to use all the earmarked transfers possible to repay debt, but only a certain percentage of them. For simplicity, we omit this additional coefficient and all derivations below hold subject to the addition of this ratio coefficient.

[13] We can write the stochastic differential equation satisfied by S_t, but the analysis below only requires the distribution of S_1.

[14] For the calculation of μ_s and σ_s, it is sufficient to note that $\ln L_1 \sim N(\ln L_0 + g_l - \sigma_l^2/2, \sigma_l^2)$, $\ln c_1 \sim N(\ln c_0 + g_c - \sigma_c^2/2, \sigma_c^2)$, and $\text{cov}(\ln L_1, \ln c_1) = \rho\sigma_l\sigma_c$.

[15] The debt constraint examined here is an ex ante constraint: the initial amount c_0 of central discretionary transfers received by local governments affects their ex ante debt choices, but c_0 does not fully determine the actual discretionary transfers received by local governments ex post $C_1 = L_1 c_1$, because c_1 is stochastic in nature.

[16] In the empirical analysis in Section 4, we estimate the default risk of provincial local government debt using bond market data, and the results show that p^* is less than 5%.

obtain from the central government, the higher the local government's debt B_0 will be. However, a key feature of central transfers (i.e., the corresponding discretionary transfers in our model) is the uncertainty in the amount of funding, and the final amount of transfers depends on repeated bargaining between central and local governments.[17] This uncertainty is partly reflected by letting σ_c take a fixed positive value. However, given the limited revenues of the central government itself, a more suitable hypothesis is that the uncertainty of central discretionary transfers is related to the initial commitment c_0 sought by local governments. In other words, both g_c and σ_c can be viewed as functions of c_0 rather than fixed values. Indeed, the above hypothesis can also be interpreted in terms of the vulnerability of the local fiscal structure: the higher the initial dependence on central discretionary transfers, that is, the higher c_0, the higher the fiscal uncertainty faced by local governments ex post, that is, the higher g_c and σ_c.

3.1.2. Endogenous choice of local fiscal structure

To examine the endogenous choice of a local government to seek central discretionary transfers, we assume that $g_c = G(c_0)$, $\sigma_c = H(c_0)$, and $G(\cdot)$ and $H(\cdot)$ are second-order continuous differentiable functions of c_0. We make the following assumptions about the analytic properties of these two functions, which are progressively more stringent

A1:	$G(1) = 0, H(1) = 0$
A2:	$G'(c_0) \le 0, H'(c_0) \ge 0, \forall c_0 \ge 1$
A3:	$G''(c_0) \le 0, H''(c_0) \ge 0, \forall c_0 \ge 1$

A1 shows that $g_c = 0$ and $\sigma_c = 0$ when $c_0 = 1$, that is, the initial value of the central discretionary transfer $C_0 = (c_0 - 1)L_0 = 0$. Therefore, $c_t \equiv 1$ and $C_t \equiv 0$, both of which are constants. This is a very natural assumption. The first part of A2 shows the rate of increase of the central discretionary transfer $g_c = G(c_0)$ as a decreasing function of its initial value; the second part of A2 shows the volatility of the central discretionary transfer $\sigma_c = H(c_0)$ as an increasing function of its initial value. This feature can be explained by the fact that the larger the initial value of the discretionary transfer, c_0, the greater the uncertainty that the local government may face about the actual amount disbursed at time 1.[18] The first part of A3 indicates that an increase in the initial value of discretionary transfers leads to a marginal decrease in the instantaneous growth rate; while the second part indicates that an increase in the initial value of discretionary transfers leads to a marginal increase in volatility.[19] In the appendix, we empirically test whether the data on local fiscal structure are consistent with the above hypotheses.

Substituting $g_c = G(c_0)$ and $\sigma_c = H(c_0)$ into the expression for the initial debt $\ln B_0$ in equation (1), we can express $\ln B_0$ as a function of c_0, $F(c_0)$. Then the problem of maximizing debt achieved by a local government choosing central discretionary transfers is expressed as

$$\max_{c_0 \ge 1} F(c_0) \equiv \ln B_0 = \ln L_0 c_0 + G(c_0) + g_l - \sigma_l^2 \Big/ 2 - H(c_0)^2 \Big/ 2 - q\sqrt{H^2(c_0) + 2\rho\sigma_l H(c_0) + \sigma_l^2} - \ln(1+r), \quad (2)$$

where the discretionary transfers take a range of values $c_0 \ge 1$; that is, $C_0 \ge 0$.

Under assumptions A1-A3, we can directly analyze the solution of the above optimization problem c_0^*, which is the optimal central discretionary transfer, and the corresponding optimal level of debt $\ln B_0^*$. However, from a theoretical and practical point of view, a more important concept is the excessive debt of local governments. To analyze the problem of excessive debt, the first thing that needs to be clarified is the level of nonexcessive debt, that is, the benchmark debt level. We interpret the benchmark debt of local governments as the maximum amount of debt that a local government can take on within its own repayment capacity if the local government does not need external support to ensure that the risk level of the debt is under control. According to the theoretical model in this paper, the logarithm of the benchmark debt level $\ln \overline{B}_0$ corresponds to $F(1)$, which is the level of local government debt when the central discretionary transfer is zero. We consider the optimal debt level $\ln B_0^*$, which is obtained by solving the optimization problem equation (2), to be the actual (i.e., the logarithmic value of the) debt level of the local government, and hence the difference between $\ln B_0^*$ and $\ln \overline{B}_0$ is as follows:

$$\ln B_0^* - \ln \overline{B}_0 = F(c_0^*) - F(1) = \ln c_0^* + G(c_0^*) - \frac{H(c_0^*)}{2} - q\left(\sqrt{H^2(c_0^*) + 2\rho\sigma_l H(c_0^*) + \sigma_l^2} - \sigma_l\right). \quad (3)$$

It can be defined as the level of local government excessive debt.[20]

3.2. Excessive debt: a local analysis

We first analyze whether there is excessive local government debt. According to the discussion in the previous subsection, this is equivalent to judging the relative size of $F(c_0^*)$ and $F(1)$. We first perform a local analysis of the local government's excessive debt around $c_0 = 1$, under the assumptions A1 and A2. We then add a stronger hypothesis A3 to carry out a global analysis of the problem of excessive local government debt.

The advantages of focusing on the case around $c_0 = 1$ are twofold: first, in reality, local governments have limited access to the central government's earmarked transfers (which correspond to the discretionary transfers in the model), and the size of these transfers is generally not large relative to the size of their own debt service funds; second, for the model in this paper, the local analysis only needs to be carried out under the weaker assumption A2.

To determine whether local governments have an incentive to borrow excessive debt near $c_0 = 1$, it is sufficient to examine the sign of $F'(1)$: if $F'(1) > 0$, local governments have an incentive to seek more central discretionary transfers, leading to overborrowing; meanwhile

[17] First, the amount of the central transfer is not determined by institutional regulations and policies, and the ex-post financial support from the central government does not necessarily fully fulfill the prior commitment. Second, even if the total amount of ex-post financial support can be fully disbursed, the central government may impose restrictions on the use of funds afterward, raising the cost of use by local governments. Third, the relationship between the central and local governments is always in dynamic adjustment, and they may renegotiate afterward, resulting in possible changes in the timing, amount, and conditions of use of the earmarked transfers. Finally, multiple local governments need to compete with each other for earmarked transfers, and this situation is likely to exacerbate the uncertainty of the financial support that an individual local government can receive afterward.

[18] The most meaningful parts of the theoretical analysis below are based on $H'(\cdot) > 0$; the case $H'(\cdot) = 0$ is more mundane and will only be briefly described at the end of the next subsection.

[19] Hypothesis A3 is a reinforcement of A2; although the hypothesis is consistent with the commonly used practice of diminishing marginal returns and increasing marginal costs, it implies an extremely strong conclusion: as the analysis in the next subsection will show, A3 implies that local governments must overborrow. This result is probably too strong in light of the results of the empirical analysis. We therefore separate it from A2 and first consider the theoretical predictions when only A1and A2 hold.

[20] From $\ln B_0^* - \ln \overline{B}_0 = \ln B_0^*/\overline{B}_0$ it can be seen that the level of excessive debt so defined is a relative value; from the relative value it is easy to calculate the absolute level of excessive debt: $B_0^* - \overline{B}_0 = [\exp\{\ln B_0^*/\overline{B}_0\} - 1]\overline{B}_0 = [\exp\{F(c_0^*) - F(1)\} - 1]\overline{B}_0$.

when $F^{'}(1) < 0$, local governments do not seek to obtain central discretionary transfers when c_0 is close to 1, so there is no over-borrowing. In the former case, we say that local governments have an incentive to borrow excessive debt; in the latter case, we say that they have no incentive to borrow excessive debt.

Through calculations, we can get

$$F^{'}(c_0) = \underbrace{\frac{1}{c_0} + G^{'}(c_0)}_{MB(c_0)} - \underbrace{\left(H(c_0) + q\frac{H(c_0) + \rho\sigma_l}{\sqrt{H^2(c_0) + 2\rho\sigma_l H(c_0) + \sigma_l^2}} \right) H^{'}(c_0)}_{MC(c_0)}. \tag{4}$$

We refer to the first two terms in the above equation as the marginal benefit of the central discretionary transfer $MB(c_0)$,[21] and the last term is the marginal cost of the central discretionary transfer $MC(c_0)$. From A1 we know that

$$F^{'}(1) = 1 + G^{'}(1) - q\rho H^{'}(1).$$

According to the equation, we first discuss the special case where $G^{'}(\cdot) \equiv 0$ and g_c is a constant. At this point, a direct check shows that the following result holds

Proposition 1. Under assumptions A1, A2 and considering $G^{'}(\cdot) \equiv 0$, when $\rho \leq 0$, the local government must have an incentive to borrow excessive debt; meanwhile, when $\rho > 0$, the local government has no incentive to borrow excessive debt when and only when $H^{'}(1) > 1/\rho q$.

This proposition is obvious from the technical proof, but it reveals an important feature: excessive local government debt is directly related to the statistical correlation between local own revenues and central discretionary transfers. If the correlation between the two is negative, local governments will borrow excessively. The only constraint on local governments is that their risk of default cannot exceed a certain level. They prefer to raise as much money as possible to spend. The size of the initial central discretionary transfer chosen by local governments determines the eventual funding of debt service. The higher the expected debt service resources and the lower the uncertainty of the debt service resources, the larger the initial debt financing can be. The marginal benefit of choosing a larger initial transfer is that it leads to a larger possible final transfer. However, the marginal cost is that a larger initial transfer increases uncertainty about the final transfer amount and the risk of default may exceed the limit. If local revenues and central support are negatively correlated, this reduces the uncertainty of future debt service funds for local governments and reduces the risk of default. This allows for more initial borrowing by local governments and ultimately increases their incentive to borrow more. In other words, when local fiscal revenues and central support are negatively correlated, central support hedges the risk of local fiscal shortfalls. Central transfers act as a risk hedge, allowing local governments to have higher initial debt for a given default risk limit.

In contrast, when $\rho > 0$, the hedging effect of central transfers no longer exists, but local governments still have the incentive to seek them and thus to overborrow if the uncertainty of central transfers is smaller at this point ($H^{'}(1) < 1/q\rho$ and note that $H(0) = 0$) because the marginal cost of central transfers still does not offset the corresponding marginal benefit.

In general, $G^{'}(\cdot)$ is not constant at zero, and the initial value of the discretionary transfer c_0 changes the instantaneous growth rate of c_t. Similar to the previous proposition, the local government's decision to borrow excessive debt depends on the sign of $F^{'}(1)$, as shown in proposition 2.

[21] This holds where $1 + G^{'}(c_0) \leq 0$ implies that marginal returns may be negative; however, the empirical estimates below show that $G^{'}(c_0) > -1$

Proposition 2. Under assumptions A1and A2, the local government borrows excessive debt when and only when

$$1 + G^{'}(1) > \rho q H^{'}(1).$$

Further, when $\rho > 0$, the local government has an incentive to borrow excessive debt when and only when $G^{'}(1) > -1$ and $H^{'}(1) < [1 + G^{'}(1)]/(\rho q)$; meanwhile, when $\rho \leq 0$, the local government has an incentive to borrow excessive debt only when $H^{'}(1) > [1 + G^{'}(1)]/(\rho q)$.

If $1 + G^{'}(1) > 0$, the marginal benefit of obtaining discretionary transfers is positive. The conclusion that a local government borrows excessive debt at this point is essentially the same as in proposition 1: when $\rho \leq 0$, there must be excessive debt; and when $\rho > 0$, as long as the marginal cost of discretionary transfers $H^{'}(1)$ is large enough, local governments will not choose to borrow excessive debt. If $1 + G^{'}(1) \leq 0$, then the marginal benefit of obtaining discretionary transfers is negative. At this point, if $\rho > 0$, then the marginal cost of discretionary transfers is positive and local governments will not choose to borrow excessive debt; and if $\rho < 0$, the marginal cost of the discretionary transfers is negative. In fact, it becomes a marginal benefit, so the local governments may still choose to borrow excessive debt.

Combining the conclusions of propositions 1 and 2, it follows that the likelihood of local governments borrowing excessive debt when $\rho \leq 0$ is greater than that of the situation with $\rho > 0$. Intuitively, when the local government expects the central government's discretionary transfer to be negatively correlated with its own revenues, the local government can use the hedging effect of the central discretionary transfer to ensure that the sum of its own revenues and the discretionary transfer will cover its debt service as much as possible. From another perspective, when the correlation coefficient is negative, the central discretionary transfer plays the role of insurance for the local fiscal capacity.

3.3. Excessive debt: a global analysis

The above analysis addresses the question of whether local governments will choose to borrow excessive debt locally at $c_0 = 1$ (i.e., $C_0 = 0$), and all the analysis relies only on the underlying assumptions A1and A2. Below we provide a more in-depth analysis of the global optimal debt level of local governments based on the inclusion of assumption A3.

Combined with assumption A3, the marginal benefit of central discretionary transfers $MB(c_0) = 1/c_0 + G^{'}(c_0)$ is monotonically decreasing. Therefore, the analysis of the optimal discretionary transfer decision focuses on the marginal cost term. Let

$$K(c_0) = H(c_0) + q\frac{H(c_0) + \rho\sigma_l}{\sqrt{H^2(c_0) + 2\rho\sigma_l H(c_0) + \sigma_l^2}},$$

Then the marginal cost term in equation (4) can be written as $MC(c_0) = K(c_0)H^{'}(c_0)$. In Appendix A, we illustrate the nature of the marginal cost function through three lemmas. On this basis, we can inscribe the optimal solution for the local government's choice in equation (2) for the central discretionary transfer. Slightly different from the discussions concerning propositions 1 and 2, we separate the cases where discretionary transfers have a correlation greater than 0 and less than 0 with the local own revenues.

Proposition 3. *Under A1–A3, we have the following conclusions*

(i) *When* $1 + G^{'}(1) > \rho q H^{'}(1)$, *the optimal discretionary transfer* $c_0^* > 1$, *and there is excessive debt borrowing.*

(ii) *When* $1 + G^{'}(1) \leq \rho q H^{'}(1)$ *and* $\rho \geq 0$, $c_0^* = 1$ *and there is no excessive debt.*

(iii) *When* $1 + G^{'}(1) \leq \rho q H^{'}(1)$ *and* $\rho < 0$, *the conclusion is indefinite.*

The proof for this proposition is presented in Appendix A.2. The

empirical analysis below shows that $G^{'}(c_0) > -1$ so that the marginal benefit from the central discretionary transfer $MB(c_0)$ around $c_0 = 1$ is positive. At this point, if $\rho \leq 0$, case (iii) of proposition 3 does not occur, and at the same time, $1 + G^{'}(1) > 0 \geq \rho q H^{'}(1)$ must hold so that the local government must choose to borrow excessive debt. We summarize the above corollary in the following theorem.

Theorem 1. Under A1–A3, if $G^{'}(c_0) > -1$ holds, then when $\rho \leq 0$, the local government must choose to borrow excessive debt, while when $\rho > 0$, local governments do not necessarily choose to borrow excessive debt.

3.4. The amount of excessive debt

We can further reveal the impact of the correlation ρ between discretionary transfers and local governments' own debt service funds on their excessive debt. From equation (2), it can be seen that the logarithm of the optimal debt size $\ln B_0^*$ can be viewed as a function of ρ and c_0^*, which is denoted as $\Gamma(\rho, c_0^*)$. When a local government has excessive borrowing, its optimal choice of discretionary transfer c_0^* must satisfy the first-order condition $MB(c_0^*) = MC(c_0^*)$. Since the marginal benefits and costs depend on, we can therefore consider c_0^* as a function of ρ. Substituting Γ, the optimal debt size can then be viewed as a function of ρ; that is, $\Gamma(\rho, c_0^*(\rho))$. Using the envelope theorem, we can analyze how a change in ρ causes a change in excessive debt. Specifically, taking the derivative of ρ and combining it with equation (2), it can be shown that

$$\frac{d\Gamma\left(\rho, c_0^*(\rho)\right)}{d\rho} = \frac{\partial\Gamma\left(\rho, c_0^*(\rho)\right)}{\partial\rho} + \frac{\partial\Gamma\left(\rho, c_0^*(\rho)\right)}{\partial c_0^*} = \frac{\partial\Gamma\left(\rho, c_0^*(\rho)\right)}{\partial\rho} + F^{'}\left(c_0^*(\rho)\right).$$

And from equation (3) we can see that $F^{'}(c_0^*(\rho)) = MB(c_0^*(\rho)) - MC(c_0^*(\rho)) = 0$, so we have

$$\frac{d \ln B_0^*}{d\rho} = \frac{\partial\Gamma\left(\rho, c_0^*(\rho)\right)}{\partial\rho} = -\frac{\sigma_l H\left(c_0^*(\rho)\right)}{\sqrt{H^2(c_0^*(\rho)) + 2\rho\sigma_l H(c_0^*(\rho)) + \sigma_l^2}} < 0.$$

The above expression clearly shows that when local governments have excessive debt, the size of their debt is a decreasing function of the correlation between central discretionary transfers and their own debt service funds. In other words, the size of excessive debt increases as the value of ρ decreases; in particular, when $\rho < 0$, the size of the excessive debt rises as the negative correlation increases. We summarize the above findings in the following theorem.

Theorem 2. *Under A1–A3, the amount of excessive debt of local governments increases as the degree of the negative correlation between the central discretionary transfer and a local government's own debt service funds increases.*

The intuition behind theorem 2 is that the stronger the negative correlation, the stronger the risk-hedging effect of central transfers. This reduces uncertainty about the future financing of debt service and reduces the risk of default. Thus, depending on a given default risk constraint, local governments will seek to receive more transfers and issue more debt in the initial period.

4. Empirical analysis

4.1. Econometric model

In the theoretical model, the main conclusion is that local governments tend to choose to borrow excessive debt when the correlation between local own revenues and central discretionary transfers is negative and that the amount of local excessive debt increases with the degree of this negative correlation. Based on the previous discussion, excessive debt is defined as

$$EDebt_{it} = \ln B_{it} - \ln \overline{B}_{it}.$$

It should be noted that, according to the definition and characteristics of discretionary transfers, earmarked transfers are the most compatible with them in China's existing fiscal system. We use earmarked transfers as a proxy for discretionary transfers in our empirical analysis. Earmarked transfers usually have a specific purpose, and cannot be used for other purposes. We treat earmarked transfers as a source of debt service for the following reasons. First, earmarked transfers in the form of "ex post projects and ex post grants" are funds that local governments are free to spend. Second, earmarked transfers help local governments save on investment and construction expenditures, thus indirectly increasing their available resources. Overall, earmarked transfers increase the resources available for debt servicing. Therefore, although earmarked transfers may not be used directly for debt servicing, they increase the funds available to local governments.

Based on the definition of excessive debt, we then define the dummy variable of whether to borrow excessive debt *DEDebt*, and the dummy variable of whether the correlation coefficient is negative *DCorr*:

$$DEDebt_{it} = \begin{cases} 1, \text{if } EDebt_{it} > 0, \\ 0, \text{if } EDebt_{it} \leq 0, \end{cases}$$

$$DCorr_{it} = \begin{cases} 0, \text{if } Corr_{it} > 0, \\ 1, \text{if } Corr_{it} \leq 0, \end{cases}$$

where $Corr_{it}$ denotes the correlation coefficient between central earmarked transfers and local own revenues in province i at time t.

To test the first conclusion, we use a linear probability model (LPM)

$$DEDebt_{it} = \alpha + \beta DCorr_{it-1} + \sum_k Control_{k,it} + \varepsilon_{it}, \tag{5}$$

and the Logit model

$$y^* = \alpha + \beta DCorr_{it-1} + \sum_k Control_{k,it} + u_{it}\ ,$$

$$DEDebt_{it} = \begin{cases} 1, \text{if } y^* > 0, \\ 0, \text{if } y^* \leq 0. \end{cases} \tag{6}$$

Two types of models are used to estimate the effect of the sign of the correlation on the likelihood of excessive debt borrowing. $\sum Control_k$ denotes a set of control variables. Based on the results of the theoretical analysis, we expect β to be significantly positive, that is, the likelihood of a local government incurring excessive debt is higher when the correlation coefficient is negative than when the correlation coefficient is positive. In addition, to consider the time lag between government debt decisions and debt data observations, we lagged all the explanatory variables by one period in the regression model.

To test the second inference, we further develop the following regression model to observe whether the amount of local excessive debt increases with the increase of the degree of the negative correlation between local own revenues and central earmarked transfers

$$EDebt_{it} = \alpha + \beta Corr_{it-1} + \sum_k Control_{k,it} + \varepsilon_{it}\ . \tag{7}$$

According to theorem 2, we expect β to be significantly negative, that is, the higher the degree of negative correlation between local own revenues and central earmarked transfers, the larger the amount of excessive debt. Moreover, the control variables used in equations (5)–(7) are the same.

4.2. Descriptions of variables and data

Because the focus of this paper is on the impact of the dynamic relationship between local own revenues and central discretionary transfers on local governments' incentives to overborrow, the sample period in this paper is 2010–2015. Although local government debt data is publicly available from 2016 onward, debt data after 2016 does not

accurately reflect the true incentives of local governments since the Ministry of Finance's "Opinion on the Implementation of Limit Management on Local Government Debt" was implemented at the end of 2015. This policy curbed local governments' incentive to borrow by directly controlling the size of local government debt.

4.2.1. Measurement of earmarked transfers and local own revenues

Central government transfers to local governments consist of three items: tax rebates, general transfers, and earmarked transfers. Tax rebates and general transfers are calculated based on formulas according to established objective criteria, and there is little opportunity for local governments to aspire to them because there is no room for discretion. In contrast, there is no standard for the allocation of earmarked transfers, and the phenomenon of "running for money" is common. It is common for local governments to seek central fiscal support, and therefore there is uncertainty with earmarked transfers.

In particular, we consider the difference between the two forms of central government transfers in China, that is, general and earmarked transfers. While the former is formula-based and stable over time, the latter is discretionary and requires bargaining between local and central governments, leading to different incentive effects on local government borrowing.

To properly define local own debt service funds, it is first necessary to analyze the structure of local fiscal revenue and expenditure. The structure of local fiscal revenue and expenditure is as follows:

$$\begin{gathered}\text{Total local revenue} = \text{general public budget revenue} + \text{transfer payments revenue} + \\ \text{government managed fund budget revenue} + \\ \text{states capital operations budget revenue} + \\ \text{social security fund budget revenue} + \text{new debt issuance revenue} = \text{local government necessary expenditure} + \text{disposable expenditure} + \\ \text{social security fund budget expenditure} + \\ \text{states capital operations budget expenditure} = \text{total local expenditure}\end{gathered}$$

The total fiscal revenue of local governments can be decomposed into general public budget revenue, transfer payments revenue, government-managed fund budget revenue, state capital operations budget revenue, and social security fund budget revenue. Since the ratio of state capital operations budget revenue to total fiscal revenue is low[22] and the use of this fund is usually circulated within the state-owned enterprise system,[23] while the social security fund cannot be easily used by local governments due to its specific purpose, we do not consider state capital operations budget revenue and social security fund budget revenue when calculating the funds for debt service. At the same time, considering that local governments have necessary expenditures, we treat general public service expenditures in the general public fiscal expenditure items as local governments' necessary expenditures. Accordingly, we take the sum of the general public budget revenue, transfer payments revenue, and government-managed funds revenue after deducting necessary expenditures as the consolidated debt service funds of local governments. Local government own debt service L_t is measured by deducting the earmarked transfers C_t from the consolidated debt service funds.[24]

In the above definition, we include both general transfers and tax rebates in the local government's own debt service funds. As mentioned earlier, the reason for this measurement is that both of these funds are determined ex ante: on the one hand, the amounts of both funds are determined by formulas and cannot be changed by the central government on an ad hoc basis; on the other hand, local governments cannot expect to receive additional financial support for their efforts in seeking it.

The correlation coefficient between the measured own debt service funds and the central government earmarked transfers can be further calculated. We calculate the correlation coefficient, denoted as $Corr_{it}$, using the data on province i's own debt service funds (the log value) and central earmarked transfers (the log value) from period $t-2$ to period t.[25]

4.2.2. Measurement of local government excessive debt

For the measurement of government debt, although the Chengtou bond data can measure the scale of local government debt at the municipal level, it cannot fully reflect a local government's incentive to borrow because it only includes a part of the local government's actual liabilities, so we use the provincial government's debt data from the National Audit Office. The National Audit Office conducted a mapping exercise of local government debt in 2010 and 2013, respectively, and published information on local government debt in 2010 and from 2012 to 2013. Moreover, most local governments have since made their debt audit data public. In 2014, the Ministry of Finance conducted a survey on the scale of local government debt in each province according to the National Audit Office's debt standard, using debt with repayment responsibility as the measure of local government debt,[26] and some provinces have since published their debt reports on their official platforms. After 2015, data on local government debt were gradually made

[22] In our data sample, state capital revenue typically accounts for less than 0.5% of total fiscal revenue.

[23] According to the "Opinions of the State Council on the Trial Implementation of State-Owned Capital Management Budget" (Guo Fa [2007] No. 26), the expenditure of funds from the state-owned capital operation budget shall be applied by the enterprise within the approved budget, reported to the finance department for examination, and then directly allocated to the using enterprise in accordance with the relevant provisions of the treasury management system.

[24] Consistent with the footnote in the model section, we do not assume that the total debt service funds S_t and its fraction C_t and L_t can be used by local governments to repay their debt. In fact, local governments have a wide range of spending items to juggle, and the amount of funds that can be used for debt repayment is only a certain percentage of the amount measured above. However, this ratio coefficient does not affect the core explanatory variables in this paper, that is, the correlation coefficient between own debt service funds and earmarked transfers, so we ignore these ratio coefficients in the measurement.

[25] The calculation of the correlation coefficient is slightly different from the meaning of correlation coefficient ρ in the theoretical analysis in the previous section. Here we calculate the correlation coefficient between $\ln L_{it}$ and the level of earmarked transfer $\ln C_{it}$, whereas in the theoretical analysis it is the correlation coefficient between $\ln L_{it}$ and the relative value of earmarked transfer $\ln c_{it}$. Appendix B.1 explains in detail the approximate relationship between the two correlation coefficients and illustrates that the findings of the previous theoretical analysis also hold under the correlation coefficient calculated on the basis of the earmarked transfer magnitudes.

[26] According to the description of the National Audit Office's 2011 national audit report on local government debt, the specific definition of debt for which government is responsible for repayment is as follows: debt incurred by government or government departments and other entities and repaid from fiscal revenues.

public. Therefore, we collected and collated data on various types of local government debt by province from 2010 and from 2012 to 2015 through documents such as fiscal accounts, fiscal budget execution, fiscal statistics, and descriptions related to local government debt published by each province on the websites of their finance departments, people's governments, and people's congresses, and collated data on local government debt according to the standard of debt with repayment responsibilities set by the Ministry of Finance.

For the debt interest rate r and default risk constraint p^*, we use the average interest rate and average spread of 5-year bonds issued by provincial local governments in the first half of 2016 as the benchmark measure. The reason for not using the bond issuance interest rate data for 2015 is that 2015 was the first year of nationwide public issuance of local government bonds. As such, the bond pricing was not fully market-oriented, and there was a situation where the bond issuance interest rates of some provinces were lower than the interest rates of treasury bonds. In the second half of 2015, after the "Liaoning bond runoff" incident, interest rates in the local government bond market started to diverge, and bond prices gradually reflected the debt service capacity and credit risk of local governments. At the same time, we do not use Chengtou bond interest rates and spreads in our benchmark analysis because the main borrowers of Chengtou bonds are government investment platforms rather than local governments themselves, so the financing cost and credit risk of Chengtou bonds do not directly reflect the debt service capacity and debt risk of local governments. In addition, there are many types of Chengtou bonds, some of which are repayable by the government and some of which are not. Further, they are only one type of government debt. To accurately measure the risk and financing cost, we use the data on local government bond issuance in the first half of 2016, which is more market-oriented and can directly reflect the risk of local debt. The financing interest rate r_i and the default risk constraint $q_i = \Phi^{-1}(p_i^*)$ are measured for each province using the spread between the interest rate on the 5-year bond with the largest issuance amount and the interest rate on the 5-year treasury bond in the same period.[27]

Based on the above data selection, we follow the theoretical model to measure the baseline level of government debt by province and year,[28] which allows us to further measure the level of local government excessive debt. According to the previous illustration, the logarithmic value of the benchmark level of local government debt for province i in year t is

$$\ln \overline{B}_{it} = \ln L_{it} + g_{l,i} - \sigma_{l,i}^2 \Big/ 2 + q_i \sigma_{l,i} - \ln(1 + r_i)\,. \tag{8}$$

Due to the poor transparency of local fiscal data, there are missing data and inconsistent data samples across provinces. To ensure the uniformity of the calculation method of the growth rate of funds of each province, we take the continuous growth rate of own debt service funds from 2010 to 2014 in each province as the long-term growth rate of local own debt service funds $g_{l,i}$, and take the volatility from 2010 to 2014 as the long-term volatility $\sigma_{l,i}$. Then the data on own debt service funds, financing cost, and default probability are used to calculate the maximum debt size of local governments in each province $\ln \overline{B}_{it}$. Combined with the actual debt balance of each province $\ln B_{it}$, we can calculate the excessive debt $EDebt_{it} = \ln B_{it} - \ln \overline{B}_{it}$ for each province.

4.2.3. Other control variables

Since there is no empirical analysis of local government excessive debt in existing studies, we can only select control variables by referring to the existing literature that studies the factors influencing the size of local government debt. The control variables selected in this paper include the following: (1) Economic growth (*PerGDP*) is measured by taking the logarithm of regional GDP per capita. According to the existing literature, economic growth can increase the fiscal capacity of local governments, which in turn increases the likelihood of raising debt and the size of debt. (2.) The promotion incentives for government officials (*Rank*) is measured by ranking the GDP growth rate of each region. (3) Foreign trade (*External_Trade*) is expressed as the logarithm of total imports and exports.[29] (4) The level of urbanization (*Urban*) is measured by the share of urban population in the total population according to the National Bureau of Statistics. (5) The natural population growth rate (*Popgrowth*) is also considered. Among the aforementioned control variables, economic growth and the promotion incentives of government officials reflect the active factors of excessive borrowing, while the foreign trade level, the urbanization level, and the natural population growth rate reflect the passive factors of excessive borrowing by local governments.

4.2.4. Data sources

To obtain data on the debts that local governments are responsible for repaying, we manually collected and collated documents such as fiscal accounts, fiscal budget execution, fiscal statistics, and statements on local government debt published by provincial and regional governments, the People's Congress, and the Ministry of Finance.[30] Since the published provincial government debt audit results started in 2010, the starting period of the sample can only be that year. Similarly, we manually collected and collated the fiscal data published by the Fiscal Yearbook of each province, the Chinese Fiscal Yearbook, and financial departments (bureaus) to obtain detailed fiscal revenue and expenditure structure data such as various types of local government transfers, public budget revenue, the government-managed budget fund revenue, and public service expenditure data.[31] However, because detailed fiscal information on some provinces is missing, our sample contains only 21 provinces and special districts. The detailed data sources of the fiscal and debt information mentioned above are shown in Appendix C. Local debt financing costs and spreads are obtained from the "Review and Outlook of Local Debt Market in the First Half of 2016" compiled by Pengyuan Credit; the control variables of GDP per capita, GDP growth rate, total import and export, and natural population growth rate are obtained through the Guotaian database. The urbanization data are obtained from the China Statistical Yearbook.

Due to the limitation of local fiscal and debt information, we ultimately compiled a set of panel data for 21 provinces for 2010 and

[27] Appendix B.2 provides a detailed description of the measurement of q_i. In short, the default risk p_i^* is approximately equal to the credit spread of the debt.

[28] In Appendix C.2, we provide a detailed analysis of the model-measured benchmark debt limit. By comparing the actual debt balance of local governments in 2015, the actual debt limit set by the Ministry of Finance, and the debt limit measured by the model, we find that the debt limit measured by the model remains highly consistent with the actual limit.

[29] Rodrik (1998) illustrates that trade openness can create external risks for a regional economy, leading to an increase in government spending and thus the likelihood of excessive borrowing.

[30] Comprehensive local government debt statistics began with a special audit by the National Audit Office in 2010. Therefore, data on local government debt in the provinces can only be traced back to 2010 at the earliest. In addition, the National Audit Office did not audit the debt in 2011, so we only consider data samples from 2010 and from 2012 onward.

[31] Only the total amount of transfer payments by province is published in the China Fiscal Yearbook, not their composition. Since 2016, the Budget Department of the Ministry of Finance has published data on the composition of transfer payments by province. In addition, the source of local government statistics commonly used in the literature, Municipal and County Fiscal Statistics, only has a data sample up to 2009, which dose not meet the needs of our study.

Table 1
Descriptive statistics.

Variables	Mean	Standard deviation	Min	Max
EDebt	0.020	0.350	−0.670	1.100
DEDebt	0.520	0.500	0.000	1.000
Corr	0.420	0.730	−1.000	1.000
DCorr	0.270	0.450	0.000	1.000
PerGDP	10.46	0.430	9.460	11.56
External_Trade	14.92	1.580	10.98	18.51
Rank	15.45	8.620	1.000	31.00
Urban	0.510	0.100	0.340	0.820
Popgrowth	5.730	2.400	0.320	11.47

Table 2
The correlation coefficient and excessive debt.

	Whether to borrow excessive debt			Amount of excessive debt	
	(1)	(2)	(3)	(4)	(5)
	LPM	Logit	Panel Logit	OLS	FE
DCorr	0.292**	1.910**	4.327**		
	(0.116)	(0.775)	(1.993)		
Corr				−0.152***	−0.116***
				(0.0473)	(0.0322)
PerGDP	0.814***	6.262***	16.12*	0.649***	−0.326
	(0.269)	(2.083)	(8.857)	(0.179)	(0.302)
External_Trade	−0.0997***	−0.825***	−2.010*	−0.0704***	0.278
	(0.0362)	(0.291)	(1.069)	(0.0243)	(0.188)
Rank	−0.0167***	−0.106***	−0.0608	−0.0115***	−0.00179
	(0.00562)	(0.0382)	(0.0814)	(0.00372)	(0.00278)
Urban	−3.989***	−29.93***	−73.92*	−3.096***	3.225
	(1.162)	(9.327)	(39.75)	(0.781)	(1.979)
Popgrowth	−0.0554***	−0.409***	−0.970	−0.0366**	0.0388
	(0.0206)	(0.150)	(0.639)	(0.0140)	(0.0521)
Constant	−4.023*	−34.75**	−96.03	−3.726**	−2.501
	(2.318)	(15.49)	(63.43)	(1.554)	(1.705)
Observations	86	86	86	86	86
R-squared	0.347			0.385	0.499
Number of provinces	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses.

2012–2015 with a province-year sample size of 86, which meets the needs of the empirical analysis.[32] The descriptive statistics of the main variables are shown in Table 1.

4.3. Empirical results

4.3.1. The impact of the dynamic characteristics of earmarked transfers

Table 2 reports the results of the baseline regressions in this paper. Columns (1)–(3) are the regression results on whether the local government borrows excessive debt; columns (4)–(5) are the regressions on the amount of local government excessive debt. The specific estimation method is indicated below the model number, where Logit corresponds to a mixed logit regression and Panel Logit corresponds to a panel logit regression.[33] Due to the limited sample size, we only consider the statistical inference made by the ordinary standard errors and do not consider the robust standard errors or clustered standard errors.

Columns (1)–(3) show the results of estimation using the LPM model, the mixed logit model, and the panel logit model, respectively. The coefficients of *DCorr* in all three columns are positive, and all the results are significant at the 5% level. These results all indicate that the change in the correlation between central transfers and local debt service funds from positive to negative increases the likelihood of local government overborrowing. In the results in columns (4)–(5), both the OLS and fixed effects regressions indicate that the increase in the negative degree of the correlation coefficient significantly increases the amount of excessive local government debt, and all the results are significant at the 1% level. The regression result with fixed effects shows that a reduction in the correlation coefficient by 0.01 would result in a corresponding increase in the magnitude of overindebtedness by 0.116%.

The above results confirm the two main findings of the theoretical analysis, that is. that countercyclical central earmarked transfers have a risk-hedging effect on local governments' own fiscal revenues and that they increase the incentive for local governments to incur excessive debt. In addition, the regression results show that an increase in the level of economic development and a decrease in the level of foreign trade also increases the likelihood of local government overborrowing, which is consistent with our expectations and the findings of most of the

[32] Since systematic statistics on local government debt began with the 2010 debt audit, the study of total local government debt and its relationship with central transfers has faced a strong sample limitation. As far as we know from the literature, only Qu et al. (2023) have obtained debt data at the local government level by requesting information disclosure for all local governments in the country, thus overcoming the limitation of the provincial cross-sectional data sample. However, these data are subject to the use restrictions set by each prefecture-level city and thus cannot be freely used publicly; meanwhile, the detailed fiscal revenue and expenditure data of municipal-level cities are still not publicly disclosed. In summary, provincial debt and detailed fiscal revenue and expenditure data are the most comprehensive data currently available to researchers.

[33] The difference between a panel logit regression and mixed logit regression is that the former controls for individual fixed effects.

Table 3
Considering the impact of general transfers and tax rebates.

	Amount of excessive debt					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	FE	OLS	FE	OLS	FE
*Corr*_1	−0.133	0.0756				
	(0.135)	(0.0837)				
*Corr*_2			−0.185	0.0694		
			(0.127)	(0.0811)		
*Corr*_3					−0.158	0.0583
					(0.132)	(0.0825)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	86	86	86	86	86	86
R-squared	0.313	0.397	0.323	0.396	0.317	0.394
Number of province	21	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses.

Table 4
Considering the direct effect of earmarked transfers.

	Whether to borrow excessive debt			Amount of excessive debt	
	(1)	(2)	(3)	(4)	(5)
	LPM	Logit	Panel Logit	OLS	FE
DCorr	0.327***	2.482***	3.901**		
	(0.110)	(0.942)	(1.672)		
Corr				−0.162***	−0.135***
				(0.0464)	(0.0443)
Earmarked transfers per capita	0.566***	5.048***	7.393**	0.261**	0.141
	(0.171)	(1.576)	(3.254)	(0.119)	(0.225)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	86	86	86	86	86
R-squared	0.428			0.421	0.502
Number of province	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses.

Table 5
Explanatory power of central earmarked transfers (R^2)

	Amount of excessive debt	
	OLS	FE
Only control variables	0.305	0.389
Including the magnitude of transfers	0.330	0.422
Including the correlation coefficient	0.385	0.499
Including both	0.421	0.502

literature. Table 2 also shows that an increase in the ranking of economic growth is positively associated with the likelihood of local government overborrowing in that year, with a natural explanation being that the excellent performance of a local economy benefits from investment-led development and that the latter is usually accompanied by local government debt financing of public investment.[34]

In the previous analysis, we highlighted the role of the countercyclical nature of earmarked transfers in the excessive borrowing of local governments. Are general transfers and tax rebates, as part of local government fiscal revenues, also likely to have an impact on the likelihood and magnitude of excessive local government debt? To test this possibility, the correlation coefficients between the other types of transfers and own revenues are calculated in the following three ways: (1) Calculate the correlation coefficient *Corr*_1 between the sum of general transfers and tax rebates and total own debt service funds. (2) Calculate the correlation coefficient *Corr*_2 between the sum of general transfers and tax rebates and the remaining own debt service funds after deducting general transfers and tax rebates. (3) Calculate the correlation coefficient *Corr*_3 between the sum of general transfers and tax rebates and the remaining total fiscal revenues. Table 3 reports the results of the regressions using each of these three correlation coefficients instead of *Corr*.[35] The regression results show that the correlation coefficients of fiscal revenue from non-earmarked transfers and the local government's

Table 6
Robustness check: An alternative measure of the explanatory variable.

	Whether to borrow excessive debt			Amount of excessive debt	
	(1)	(2)	(3)	(4)	(5)
	LPM	Logit	Panel Logit	OLS	FE
DCorr	0.282**	1.733**	5.528***		
	(0.120)	(0.739)	(2.125)		
Corr				−0.174***	−0.126***
				(0.0458)	(0.0304)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	86	86	86	86	86
R-squared	0.301			0.400	0.584
Number of province	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses.

[34] To mitigate the endogeneity effect of GDP ranking due to reverse causality, we examine the regression results with this variable removed and find that the estimated coefficient magnitude and significance of the core explanatory variables remain almost unchanged.

[35] To save space, we report the estimation results for only one item of the correlation coefficient in the excessive debt regression, but the full results are available upon request.

Table 7
Robustness check: An alternative way of calculating the correlation coefficient.

	Whether to borrow excessive debt			Amount of excessive debt	
	(1)	(2)	(3)	(4)	(5)
	LPM	Logit	Panel Logit	OLS	FE
*DCorr*2	0.192	1.103	3.693		
	(0.127)	(0.747)	(2.397)		
*Corr*2				−0.163**	−0.185***
				(0.0656)	(0.0434)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	86	86	86	86	86
R-squared	0.315			0.355	0.533
Number of province	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses. *DCorr*2 and *Corr*2 denote the dummy variables and the correlation coefficients, which are calculated using periods *t*-2 to *t*+1, respectively.

own debt service funds have no significant effect on the magnitude of local government excessive debt regardless of the calculation method. From the regression results, it is clear that only the dynamic correlation between earmarked transfers and local own debt service funds affects local excessive debt.

4.3.2. Impact of earmarked transfer magnitudes

Previous studies have shown that the magnitude of earmarked transfers makes a significant contribution to the accumulation of local government debt in China. In the context of the previous subsection, a natural question is whether the impact of earmarked transfers on excessive debt is mainly due to their magnitude rather than their dynamic correlation with the local government's own revenues. To analyze this question, we include the value of the log of earmarked transfers per capita in the benchmark regression to examine the role of both on the local government's excessive debt. Table 4 shows the regression results. The amount of earmarked transfers can directly influence the likelihood and magnitude of local government excessive debt but does not alter the significant effect of the correlation coefficient on local government excessive debt. The inclusion of the magnitude of earmarked transfers makes the coefficient of the correlation coefficient more significant, reflecting the main role of the correlation coefficient in determining local government debt. This suggests that countercyclical earmarked transfers are an important and robust determinant of local government overborrowing.

To further sort out the relative importance of the correlation coefficient, Table 5 summarizes the explanatory power of the correlation coefficient, the magnitude of earmarked transfers, on the extent of local government overborrowing. Four regression settings are considered in turn: (1) the regression includes only the control variables in the baseline regression equation (7), (2) the regression includes the magnitude of earmarked transfers per capita and the control variables, (3) the regression includes the dynamic correlation coefficient of earmarked transfers and the control variables, and (4) the regression includes both the magnitude and the correlation coefficient. As can be seen from the R^2 of the four groups of regressions reported in Table 5, the contribution of the earmarked transfer correlation coefficient to the increase in R^2 is higher than that of the magnitude, and in the fixed effects regression, where the results are more precise, the correlation coefficient explains almost four times as much (0.499–0.389) as the magnitude (0.422–0.389). We also find that there was a very small increase in R^2 (0.502–0.499) when the magnitude was added to the regression containing the correlation coefficients. The results of the analysis here suggest that it is the countercyclical nature of transfers, rather than the magnitude of transfers, that is the main driver of local government overborrowing.

Table 8
Robustness check: Debt limit policy expectations.

	Whether to borrow excessive debt			Amount of excessive debt	
	(1)	(2)	(3)	(4)	(5)
	LPM	Logit	Panel Logit	OLS	FE
DCorr	0.346**	2.467**	3.377**		
	(0.138)	(1.082)	(1.696)		
Corr				−0.192***	−0.175***
				(0.0632)	(0.0424)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	67	67	67	67	67
R-squared	0.421			0.409	0.491
Number of province	21	21	21	21	21

Note: ****$p < 0.01$; **$p < 0.05$; and *$p < 0.1$. Standard errors are reported in parentheses.

4.3.3. Robustness check

To further test the impact of the correlation between earmarked transfers and local own revenues on local government overindebtedness, we consider several robustness checks. We remeasure local government debt default risk and financing costs using the average spread and average interest rate of Chengtou bonds across provinces from 2010 to 2015, thereby obtaining an alternative measure of local government excessive debt, and rerun the regression after replacing the existing explanatory variables. The regression results are shown in Table 6. The results still support the significant contribution of the correlation coefficient to the local government's excessive debt.

Given the possible influence of the way the correlation coefficient is calculated on the regression results, we use the sample from period *t*-2 to period *t*+1 to calculate the correlation coefficient between central earmarked transfers and own debt service funds in period *t* (denoted as *Corr*2). The results of the regressions using this correlation coefficient are presented in Table 7. In columns (1)–(3), the standard error of the estimated coefficient on the correlation coefficient dummy variable is large due to the sample loss caused by the increase in the duration of the calculation of the correlation coefficient, resulting in a low significance of the regression results, but the corresponding *p*-value is close to 10% and the sign of the estimated coefficient is consistent with the theoretical prediction. In columns (4)–(5), the estimated coefficients for the correlation coefficient are still consistent with the theoretical predictions and the baseline regressions and are highly significant, and the magnitudes of the coefficients are very close to the results of the baseline regressions in Table 2.

Despite the fact that the Ministry of Finance issued the "Opinion on the Implementation of Limit Management on Local Government Debt" at the end of 2015, local governments may have had certain expectations about the policy prior to its implementation. To mitigate this potential influence, we excluded the 2015 data and conducted a robustness check. The regression results indicate that the implementation of the local government debt limit management policy did not affect the conclusions drawn in this paper. The detailed regression results are presented in Table 8.

5. Conclusion and policy discussion

Local governments in China have a strong incentive to overborrow, leading to the accumulation of large amounts of local government debt. Although local government debt risks have been temporarily controlled by explicit debt-limit policies, the underlying incentives for local governments to overborrow may still be present and may persist for a long time. As emphasized in the existing literature, a key element underpinning the incentive to overborrow is central government transfers. This paper introduces a novel perspective that diverges from the conventional viewpoint. As the theoretical analysis and empirical evidence

in this paper show, a key factor driving the local government's incentive to overborrow is the countercyclical nature of transfers, that is, the negative correlation between the earmarked transfer and the local government's own revenues. Since a negatively correlated central transfer effectively acts as a hedge against local revenue risk, the local government has ample incentive to tilt its fiscal structure toward the central transfer and, in the meantime, to increase its current indebtedness with the expectation of relying on the central transfer as a means of future debt service.

The policy implications of the results of this paper can be summarized in two principles. First, if it is desirable to maintain the discretionary nature of central government transfers, that is, to allow the transfer to be determined by ex post bargaining rather than by an ex ante formula, then a necessary condition for preventing overborrowing by the local government is to weaken or eliminate the negative correlation between the transfer and the local government's own fiscal revenues. In other words, if the central government prefers some flexibility in the transfer system, it is crucial to avoid countercyclical transfer policies relative to local government revenues. Second, if countercyclical transfers are an indispensable policy choice for various reasons, then to curb the local government's incentive for excessive indebtedness, it is essential to change the transfer system from a discretionary to a rule-based one, with explicit predetermined policy rules governing the dynamics and size of transfer payments. Only in this way would the local government form an accurate expectation of future resources for debt service and internalize all explicit and implicit costs in its own budget. In other words, a rule-based transfer system with little or no discretion is a prerequisite for a hard budget constraint.

These two principles also apply to the most recent policy dilemma facing China. To achieve its development goals, the Chinese central government has to rely on large transfer payments to both incentivize and finance public investment by local governments. Moreover, the central government also uses countercyclical transfer policies to stimulate the local economy from contractionary shocks. However, the discretionary nature of (some) transfer payments and, in particular, the not-uncommon countercyclicality are worrying factors that increase the incentive for local governments to borrow excessively. As a result, there is a clear trade-off between central transfers as a means of local development and as an incentive for excessive local borrowing. The policy insights of this paper suggest that there is a way out of the policy dilemma: since central government transfers are essential and some countercyclicality is necessary to deal with negative shocks, it becomes crucial to impose strict limits on the discretionary nature of central transfers. To this end, the current discretionary transfer system should be replaced by a rule-based system, with explicit policy rules detailing the dynamics and size of transfers so that they are largely predetermined with little room for ex post bargaining, thereby mitigating or eliminating the negative incentive effects of overborrowing by local governments.

It should be noted that the theoretical analysis in this paper is a partial equilibrium analysis. To gain a deeper and clearer understanding of how the countercyclical nature of transfers affects local government debt decisions and their general equilibrium effects, a further dynamic general equilibrium model needs to be constructed for the study. At the same time, the implications and welfare outcomes of our proposed policy recommendations also depend on quantitative policy experiments in a dynamic general equilibrium framework. These are the plans for future research.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to improve readability and language. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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

Data will be made available on request.

Appendix

A. Proof of Proposition

A.1 Lemma

First, we establish the nature of the marginal costs that local governments face when using discretionary transfers through three lemmas.

Lemma 1. Under assumptions A1-A3, $\lim_{c_0 \to +\infty} H(c_0) = +\infty$.

Proof: Under A1-A3, $H(c_0)$ is a strictly increasing, convex function of c_0 and $H(1) = 0$. Therefore, for any $c_0 \geq 1$, there is $H(c_0) \geq H^{'}(1)(c_0 - 1)$. The conclusion holds from the fact that $H^{'}(1) > 0$. ∎.

Lemma 2. Under assumptions A1-A3,

(i) $\lim_{c_0 \to +\infty} K(c_0) = +\infty$;

(ii) $K^{'}(c_0) > 0 \; \forall \, c_0 \geq 1$;

(iii) When $\rho \geq 0$, $K(c_0) \geq 0 \; \forall c_0 \geq 1$, and when $\rho < 0$, there exists $\widehat{c} > 1$ such that $K(c_0) \geq 0 \; \forall c_0 \geq \widehat{c}$, $K(c_0) < 0 \; \forall c_0 < \widehat{c}$

Proof: First note that the second term in the expression $K(c_0)$ can be written as

$$q \frac{1 + \rho\sigma_l / H(c_0)}{\sqrt{1 + 2\rho\sigma_l / H(c_0) + \sigma_l^2 / H^2(c_0)}},$$

When $c_0 \to +\infty$, by Lemma 1, we know that $H(c_0) \to +\infty$, so the above equation converges to $q > 0$ and therefore $K(c_0) \to +\infty$. A direct calculation shows that

$$K'(c_0) = \left[1 + q\frac{(1-\rho^2)\sigma_l^2}{\left(H^2(c_0) + 2\rho\sigma_l H(c_0) + \sigma_l^2\right)^{3/2}}\right] H'(c_0)\ ,$$

Therefore, for all $c_0 \geq 1$ have $K'(c_0) > 0$. Finally, when $\rho \geq 0$, $K(1) = \rho q \geq 0$, so at this time $\widehat{c} = 1$; when $\rho < 0$, $K(1) = \rho q < 0$, and when c_0 sufficiently large, $K(c_0) > 0$, we know by the median theorem that there exists $\widehat{c} > 1$ such that $K(c_0) \geq 0$ holds for $c_0 \geq \widehat{c}$, and $K(c_0) < 0$ holds for $c_0 < \widehat{c}$. ∎.

Lemma 3. *Under A1-A3, the marginal cost of the central discretionary transfer $MC(c_0)$ has the following properties*:

(i) $MC(1) = \rho q H'(1)$;

(ii) $MC'(1) = \left[1 + \frac{q(1-\rho^2)}{\sigma_l}\right][H'(1)]^2 + \rho q H''(1)$ and there exists $\widetilde{c} \in [1, \widehat{c}]$ such that $MC'(c_0) > 0\ \forall c_0 > \widetilde{c}$, where $\widehat{c}$ is given by Lemma 2;

(iii) $\lim_{c_0 \to +\infty} MC(c_0) = +\infty$.

Proof: (i) This is obtained by direct calculation according to (3). (ii) $MC'(c_0) = K'(c_0)H'(c_0) + K(c_0)H''(c_0)$, where $K'(c_0), H'(c_0) > 0$ and $H''(c_0) \geq 0$. A simple calculation shows that the expression $MC'(1)$ holds. By Lemma 2, we know that $K(\widehat{c}) = 0$ and $(c_0) > 0\ \forall c_0 > \widehat{c}$, therefore $MC'(c_0) > 0\ \forall c_0 \geq \widehat{c}$. By the continuity of $MC(\cdot)$ knows that there exists $\widetilde{c} \in [0, \widehat{c}]$ satisfies the proven conclusion. On this basis, it follows from Lemma 2 and Assumption A3 that (iii) holds. ∎.

A. 2. Proof of Proposition 3

Proof: (i) Since the marginal benefit $MB(c_0)$ decreases while the marginal cost $MC(c_0)$ eventually tends to positive infinity, so when $MB(1) = 1 + G'(1) > \rho q H'(1) = MC(1)$, the debt financing maximization problem (2) must have an interior point solution, that is, $c_0^* > 1$, there must be excessive debt at this point. (ii) When $MB(1) = 1 + G'(1) \leq \rho q H'(1) = MC(1)$ and $\rho \geq 0$, by Lemma 3, the marginal cost $MC(c_0)$ monotonically increasing, so the optimal choice $c_0^* = 1$ and there is no excessive debt. (iii) Similar to (ii), by Lemma 3, we know that the marginal cost increases or decreases on $[1, \widehat{c}]$, so the conclusion is indefinite. ∎.

B. Variable definition and properties

B.1. Nature of correlation coefficient

In the appendix of this section, we describe in detail the relationship between $\overline{\rho}$ (the correlation coefficient of the local government's own debt service funds $\ln L_t$ and the central discretionary transfers $\ln C_t$) and ρ (the correlation coefficient of $\ln L_t$ and the relative value $\ln c_t$). For simplicity, the time subscripts are omitted.

First note that $c - 1 = C/L$, so that $\ln C = \ln L + \ln(c-1)$. From this, we know that

$$\mathrm{cov}(\ln L, \ln C) = \mathrm{cov}(\ln L, \ln L + \ln(c-1)) = \mathrm{var}(\ln L) + \mathrm{cov}(\ln L, \ln(c-1)).$$

Let $\overline{c}$ be the expectation of c. A second-order Taylor expansion of $\ln(c-1)$ around $\ln\overline{c}$ by using $\ln c$ as the variables yield

$$\ln(c-1) = \left(\frac{1}{\overline{c}-1} + \frac{\ln\overline{c}}{(\overline{c}-1)^2}\right)\ln c - \frac{1}{2(\overline{c}-1)^2}\ln^2 c + \text{const.},$$

where const. denotes the constant term. Given the above approximation and under the 3rd-order error term, $\mathrm{cov}(\ln L, \ln(c-1))$ is approximately equal to

$$\mathrm{cov}\left(\ln L, \left(\frac{1}{\overline{c}-1} + \frac{\ln\overline{c}}{(\overline{c}-1)^2}\right)\ln c - \frac{1}{2(\overline{c}-1)^2}\ln^2 c\right).$$

Note that $(\ln L, \ln c)$ obeying the multivariate normal distribution, it follows from Isserlis' theorem that $\mathrm{cov}(\ln L, \ln^2 c) = 0$. Therefore

$$\mathrm{cov}(\ln L, \ln C) \approx \mathrm{var}(\ln L) + \left(\frac{1}{\overline{c}-1} + \frac{\ln\overline{c}}{(\overline{c}-1)^2}\right)\mathrm{cov}(\ln L, \ln c),$$

and can be further rewritten equivalently as

$$\overline{\rho}\sqrt{\mathrm{var}(\ln C)} = \sigma_l + \left(\frac{1}{\overline{c}-1} + \frac{\ln\overline{c}}{(\overline{c}-1)^2}\right)\rho\sigma_c.$$

In the following, we calculate the approximate expressions of $\mathrm{var}(\ln C)$. From $\ln C = \ln L + \ln(c-1)$ we can see that

$$\begin{aligned}&\mathrm{var}(\ln C) = \mathrm{var}(\ln L + \ln(c-1))\\ &= \mathrm{var}(\ln L) + \mathrm{var}(\ln(c-1)) + 2\mathrm{cov}(\ln L + \ln(c-1))\\ &\approx \sigma_l^2 + \mathrm{var}(\ln(c-1)) + 2\left(\frac{1}{\bar{c}-1} + \frac{\ln\bar{c}}{(\bar{c}-1)^2}\right)\rho\sigma_l\sigma_c.\end{aligned}$$

Given the above equation, we have the following expression for $\bar{\rho}$:

$$\bar{\rho} = \frac{\sigma_l + \left(\frac{1}{\bar{c}-1} + \frac{\ln\bar{c}}{(\bar{c}-1)^2}\right)\rho\sigma_c}{\sqrt{\sigma_l^2 + \mathrm{var}(\ln(c-1)) + 2\left(\frac{1}{\bar{c}-1} + \frac{\ln\bar{c}}{(\bar{c}-1)^2}\right)\rho\sigma_l\sigma_c}}.$$

It is clear that when $\bar{\rho} \le 0$, ρ must be strictly less than 0. Further, a direct test shows that $\bar{\rho}$ is a strictly increasing function of ρ, so $\bar{\rho}$ decreases with the decrease of ρ.

B.2. Measurement of Local government debt default risk

We consider the simplest model of the present value of a bond at risk of default. Assume that T, p , i, F, and r_f represent bond maturity, bond default probability, coupon rate, face value, and the market risk-free rate, respectively, and whether the bond defaults per period are independent of each other. Then, the bond price (i.e., present value) is expressed as

$$P = \sum_{t=1}^{T} \frac{(1-p)^t iF}{(1+r_f)^t} + \frac{(1-p)^T F}{(1+r_f)^T}.$$

Let

$$r = \frac{1+r_f}{1-p} - 1,$$

then expression P can be rewritten as

$$P = \sum_{t=1}^{T} \frac{iF}{(1+r)^t} + \frac{F}{(1+r)^T}.$$

This means that in a risk-neutral environment, bond yields that include the default risk are equal to r. Thus, the credit spread of a bond can be expressed as

$$r - r_f = \Delta r = \frac{p}{1-p}(1+r_f),$$

where p is the probability of default and r_f is the market interest rate. When p and r_f are small, $\Delta r \approx p$. Since the probability of default on local government debt is low, we use bond spreads to calculate the default risk.

C. Data source and measurement

C.1. Detailed list of data sources

Detailed sources of debt information are shown in Table C1; detailed sources of local fiscal data are shown in Table C2.

Table C.1
Source of debt information

Province	Year	Detail Source	Website
Tianjin	2013	Tianjin government debt Audit Results	http://www.tjaudit.gov.cn/News/xxgk/2014/0124/4645.html
	2014	Tianjin 2015 Budget Execution, and 2016 Draft Budget Report Notes and Schedule	http://www.tjcs.gov.cn/art/2016/2/4/art_43_23683.html
	2015	The third batch of Tianjin government general bond information disclosure document 2016	http://www.chinabond.com.cn/resource/1472/1488/1505/18682/21000/18612/3718762/3719030/24909612/148004996477865460697 4.pdf
Hebei	2012	Hebei government debt audit results	http://www.hebaudit.gov.cn/h/c/i/266546
	2013	Hebei government debt audit results	http://www.hebaudit.gov.cn/h/c/i/266546
	2014	The Standing Committee of the Hebei Provincial People's Congress agreed for the record that the government debt limit of Hebei Province at the end of 2015	http://110.249.165.62:8080/pub/root17/zfxx/201512/t20151203_258614.html
	2015	2016 Hebei government general bonds (Thirteen borrows) issuance information disclosure document	http://www.chinabond.com.cn/resource/1472/1488/1505/18682/21000/18612/3718762/3719030/24836110/14787639407551732503015.pdf
Shanxi	2010	Shanxi 2010 audit report on the implementation of the provincial budget and other fiscal revenues and expenditures	http://www.cnki.com.cn/Article/CJFDTotal-SXBA201116015.htm
	2012	Shanxi government debt audit results	http://www.sxsj.gov.cn/gipc/gkml/2015-07-31/4522.html
	2013	Shanxi government debt audit results	http://www.sxsj.gov.cn/gipc/gkml/2015-07-31/4522.html

(continued on next page)

Table C.1 (*continued*)

Province	Year	Detail Source	Website
	2014	Explanation of Shanxi 2015 government debt limit allocation plan for the whole province and provincial government	http://www.sxscz.gov.cn/www/2015-12-08/201512081251156308.html
	2015	2016 fourth batch of Shanxi government general bond information disclosure document	http://www.chinabond.com.cn/Info/24786089
Inner Mongolia	2010	2010 Inner Mongolia budget execution audit report	http://economy.caixin.com/2011-09-28/100310301.html
	2012	Inner Mongolia government debt audit results	http://www.nmgaudit.gov.cn/doc/2014/01/24/17933.shtml
	2013	Inner Mongolia government debt audit results	http://www.nmgaudit.gov.cn/doc/2014/01/24/17933.shtml
	2014	2016 first batch of Inner Mongolia government general bond information disclosure document	http://www.chinabond.com.cn/Info/23014027
	2015	Information disclosure document for the second batch of Inner Mongolia government special bonds in 2016	http://www.chinabond.com.cn/Info/24657498
Jiangsu	2012	Jiangsu Provincial Government Debt Audit Results	http://www.jssj.gov.cn/art/2014/1/24/art_42_23065.html
	2013	Jiangsu government debt audit results	http://www.jssj.gov.cn/art/2014/1/24/art_42_23065.html
	2014	Information disclosure document for the third batch of Jiangsu government special bonds in 2016	http://www.jscz.gov.cn/pub/jscz/xxgk/gkml/201607/t20160722_99840.html
	2015	Information disclosure document for the first batch of the 2016 Jiangsu government general bond borrow	http://www.chinabond.com.cn/Info/23032036
Anhui	2010	Anhui People's Congress research report on the situation of government debt of the whole province	http://www.ahrd.gov.cn/npcweb/web/info_view.jsp?strId=1371454624770121
	2012	Anhui government debt audit results	http://www.ahsj.gov.cn/views/show/29623.htm
	2013	Anhui government debt audit results	http://www.ahsj.gov.cn/views/show/29623.htm
	2014	Disclosure document for the third batch of 2016 Anhui government general bonds	http://www.chinabond.com.cn/Info/24611565
	2015	Disclosure document for the third batch of 2016 Anhui government general bonds	http://www.chinabond.com.cn/Info/24611565
Fujian	2012	Fujian government debt audit results	http://www.fjaudit.gov.cn/show.aspx?Id=97883
	2013	Fujian government debt audit results	http://www.fjaudit.gov.cn/show.aspx?Id=97883
	2014	Information disclosure document for the first batch of general bonds borrowed by Fujian provincial government in 2016	http://www.cfen.com.cn/sjpd/sj/201606/t20160615_2326306.html
	2015	Information disclosure document for the second batch of general bonds borrowed by Fujian provincial government in 2016	http://www.chinabond.com.cn/Info/24263274
Jiangxi	2012	Jiangxi government debt audit results	http://www.jxaudit.gov.cn/gzdt_2/sjjggg/201401/t20140125_307348.htm
	2013	Jiangxi government debt audit results	http://www.jxaudit.gov.cn/gzdt_2/sjjggg/201401/t20140125_307348.htm
	2014	Statement of the People's Government of Jiangxi Province on the motion for consideration of the approval of the local government debt limit for 2015	http://www.jxf.gov.cn/JxfShowViews_pid_2c909703511d5d4d015147e3d19709cd.shtml
	2015	2016 third batch of Jiangxi government general bonds (9-12 borrows) issuance information disclosure document	http://www.chinabond.com.cn/Info/24465546
Shandong	2010	Audit report on the 2010 provincial budget execution and other fiscal revenue and expenditure of Shandong Province	http://www.cnki.com.cn/Article/CJFDTotal-SDCW201104031.htm
	2012	Shandong government debt audit results	http://www.sdaudit.gov.cn/Section/InfoDisplay.aspx?InfoId=c3f2d940-5753-4214-80db-9c8156a9af2b
	2013	Shandong government debt audit results	http://www.sdaudit.gov.cn/Section/InfoDisplay.aspx?InfoId=c3f2d940-5753-4214-80db-9c8156a9af2b
	2014	Report on the 2015 provincial budget adjustment and local government debt limit in Shandong	http://www.sdcz.gov.cn/Article/ShowInfo.jsp?aid=11316
	2015	2016 Shandong Provincial government general bonds (fourth batch) issuance information disclosure document	http://www.chinabond.com.cn/Info/24639034
Hubei	2010	Report on the audit of the 2010 provincial budget execution and other fiscal revenues and expenditures	http://www.hppc.gov.cn/2011/0927/3116.html
	2012	Hubei debt audit results	http://www.hbaudit.gov.cn/html/2014/0124/30729.shtml
	2013	Hubei debt audit results	http://www.hbaudit.gov.cn/html/2014/0124/30729.shtml
	2014	The People's Government of Hubei Province on the motion to consider the approval of the 2015 government debt limit	http://www.hubei.gov.cn/zwgk/zdlyxxgk/czzjgk/czyjs/201511/t20151127_755511.shtml
Hunan	2010	Hunan provincial audit report on the 2010 provincial budget execution and other fiscal revenues and expenditures	http://www.audit.gov.cn/n1992130/n1992150/n1992379/2790357.html
	2012	Hunan debt audit results	http://sjt.hunan.gov.cn/xxgk_71228/zdly/sjxx/201401/t20140124_2230836.html
	2013	Hunan debt audit results	http://sjt.hunan.gov.cn/xxgk_71228/zdly/sjxx/201401/t20140124_2230836.html
	2014	Report on the draft provincial accounts of Hunan province for 2015 and budget implementation in the first half of 2016	http://www.hnrd.gov.cn/Info.aspx?ModelId=1&Id=10374
	2015	The third batch of the 2016 Hunan government special bond information disclosure document	http://www.chinabond.com.cn/Info/24802588
Guangxi	2010	Audit report on budget execution and other fiscal revenues and expenditures for 2010	http://news.xinhuanet.com/2011-07/29/c_121745470.htm
	2012	Guangxi Zhuang autonomous region debt audit results	http://www.gxaudit.gov.cn/show.php?contentid=2878
	2013	Guangxi Zhuang autonomous region debt audit results	http://www.gxaudit.gov.cn/show.php?contentid=2878
	2014	Review Report on the Motion of the People's Government of Guangxi Zhuang Autonomous Region on Submitting for Consideration the Approval of the Region's Local Government Debt Limit in 2015	http://www.gxrd.gov.cn/html/art152211.html
	2015	Information disclosure document of the fifth batch of general bonds of Guangxi Zhuang autonomous region government in 2016	http://www.chinabond.com.cn/Info/24755867
Sichuan	2012	Sichuan government debt audit results	http://www.scaudit.gov.cn/10000/10002/10011/2014/01/24/10008313.shtml
	2013	Sichuan government debt audit results	http://www.scaudit.gov.cn/10000/10002/10011/2014/01/24/10008313.shtml

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Table C.1 (*continued*)

Province	Year	Detail Source	Website
	2014	Explanation of the motion for consideration of the approval of the 2015 local government debt limit	http://www.scspc.gov.cn/ysgzwyh/yjybg_625/201512/t20151221_29534.html
	2015	2016 Sichuan government special bonds (thirteen to sixteen borrows) disclosure and issuance documents	http://www.chinabond.com.cn/Info/24711669
Shaanxi	2012	Shaanxi government debt audit results	http://www.sxaudit.gov.cn/admin/pub_newsshow.asp?id=29003543&chid=100056
	2013	Shaanxi government debt audit results	http://www.sxaudit.gov.cn/admin/pub_newsshow.asp?id=29003543&chid=100056
	2014	The third batch of 2016 Shaanxi government special bond information disclosure documents	http://www.sf.gov.cn/info/1208/22656.htm
	2015	Issuance disclosure document for the first batch of 2016 public issuance of Shaanxi government general bonds (9 to 12 borrows)	http://www.chinabond.com.cn/Info/24521915
Gansu	2010	Announcement of audit results of Gansu province's 2010 provincial budget execution and other fiscal revenues and expenditures	http://epaper.gansudaily.com.cn/gsrb/html/2011-09/22/content_102554.htm
	2012	Gansu government debt audit results	http://www.gsaudit.gov.cn/articles/2014/01/24/article_1314_82348_1.html
	2013	Gansu government debt audit results	http://www.gsaudit.gov.cn/articles/2014/01/24/article_1314_82348_1.html
	2014	Gansu Province 2015 government debt limit determined	http://www.czxx.gansu.gov.cn/xinwenzhuanqu/shenting/20151215/090654377306e0.htm
	2015	2016 first batch of Gansu government general bonds (phase i-iii) issuance information disclosure document	http://www.chinabond.com.cn/Info/23222465
Qinghai	2012	Qinghai government debt audit results	http://www.qhaudit.gov.cn/info/1026/1440.htm
	2013	Qinghai government debt audit results	http://www.qhaudit.gov.cn/info/1026/1440.htm
	2014	2015 Qinghai province fiscal accounts explanation	http://www.qhcz.gov.cn/info.aspx?tid=wl_table_1.16081710130778121390
	2015	2016 third batch of Qinghai government general bond issuance information disclosure document	http://www.chinabond.com.cn/Info/24627250
Ningxia	2010	2010 governmental debt audit results for the whole region	http://news.cntv.cn/20110803/108990.shtml
	2012	Ningxia Hui Autonomous Region Governmental Debt Audit Results	http://www.nxaudit.gov.cn/zwgk/jggg/201410/t20141013_2924273.html
	2013	Ningxia Hui autonomous region governmental debt audit results	http://www.nxaudit.gov.cn/zwgk/jggg/201410/t20141013_2924273.html
	2014	Information disclosure document for the third batch of the 2016 Ningxia Hui autonomous region government general bond borrow	http://www.nxcz.gov.cn/WebSiteOut/010000/CZGG/content/13718.html
	2015	Information disclosure document for the third batch of the 2016 Ningxia Hui autonomous region government general bond borrow	http://www.nxcz.gov.cn/WebSiteOut/010000/CZGG/content/13718.html
Xinjiang	2010	2010 Xinjiang Uygur Autonomous Region governmental debt audit results	http://policy.caixin.com/2011-09-21/100307697.html
	2012	Xinjiang Uygur Autonomous Region governmental debt audit results	http://www.xjsj.gov.cn/Content.aspx?id=1128&catid=53
	2013	Xinjiang Uygur Autonomous Region governmental debt audit results	http://www.xjsj.gov.cn/Content.aspx?id=1128&catid=53
	2014	Notice on the official issuance of the 2015 government debt limits for all cities and municipalities	http://www.xjcz.gov.cn/9?p_p_id=general_articles_INSTANCE_A5eY&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&p_p_col_id=column-15&p_p_col_pos=1&p_p_col_count=2&_general_articles_INSTANCE_A5eY_struts_action=%2Fgsoft%2Fgeneral_articles%2Fview&_general_articles_INSTANCE_A5eY_articleId=d197739b-606e-4dba-987e-7d90f828e0a4&_general_articles_INSTANCE_A5eY_target=_blank
	2015	Information disclosure document for the fifth batch of Xinjiang Uygur autonomous region government special bonds in 2016	http://www.chinabond.com.cn/Info/24982832

Table C.2
Sources of local fiscal data

Province / Municipality	2010		2012		2013		2014		2015	
	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data
Beijing	B4		B1		B1		B2		B2	
Tianjin					B1	S1/S4	B8	S1/S4	B2	S1/S4
Hebei			B1	S1/S2/S4	B1	S1/S2/S4	B7	S1/S2/S4	B2	S1/S2/S4
Shanxi	B3	S1/S4	B1	S1/S4	B1	S1/S4	B9	S1/S4	B2	S1/S4
Inner Mongolia	B3	S1/S2/S4	B1	S1/S2/S4	B1	S1/S2/S4	B2	S1/S2/S4	B2	S1/S2/S4
Liaoning	B3		B1		B1		B2		B2	
Jilin	B4	S1/S3	B1	S1/S3	B1	S1/S3	B2	S1/S3	B2	S1/S3
Heilongjiang			B1		B1		B2		B2	
Shanghai			B1		B1		B2		B2	
Jiangsu			B1	S1/S4	B1	S1/S4	B2	S1/S4	B2	S1/S4
Zhejiang			B1		B1		B2		B2	
Anhui	B12		B1	S1/S4	B1	S1/S4	B2	S1/S4	B2	S1/S4
Fujian			B1	S1/S4	B1	S1/S4	B2	S1/S4	B2	S1/S4
Jiangxi			B1		B1	S1/S4	B7	S1/S4	B2	S1/S4
Shandong	B3		B1	S1/S4	B1	S1/S4	B10	S1/S4	B2	S1/S4
Henan			B1		B1		B2		B2	
Hubei	B3		B1	S3/S4	B1	S3/S4	B7	S3/S4		S3/S4
Hunan	B3		B1		B1	S1/S4	B5	S1/S4	B2	S1/S4
Guangdong			B1	S1/S3/S4	B1	S1/S3/S4	B2	S1/S3/S4		S1/S3/S4

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Table C.2 (*continued*)

Province / Municipality	2010		2012		2013		2014		2015	
	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data	Debt Data	Fiscal Data
Guangxi	B3	S1/S3	B1	S1/S3	B1	S1/S3	B11	S1/S3	B2	S1/S3
Hainan	B3		B1		B1		B2		B2	
Chongqing	B3		B1		B1		B2		B2	
Sichuan			B1	S1/S2/S4	B1	S1/S2/S4	B7	S1/S2/S4	B2	S1/S2/S4
Guizhou					B1		B2		B2	
Yunnan			B1	S1/S3	B1	S1/S3	B2	S1/S3	B2	S1/S3
Tibet										
Shaanxi			B1	S1/S2	B1	S1/S2	B2	S1/S2	B2	S1/S2
Gansu	B4	S3/S4	B1	S3/S4	B1	S3/S4	B7	S3/S4	B2	S3/S4
Qinghai			B1	S3/S4	B1	S3/S4	B5	S3/S4	B2	S3/S4
Ningxia	B4	S1/S2/S4	B1	S1/S2/S4	B1	S1/S2/S4	B2	S1/S2/S4	B2	S1/S2/S4
Xinjiang	B4	S1/S3/S4	B1	S1/S3/S4	B1	S1/S3/S4	B7	S1/S3/S4	B2	S1/S3/S4

Note: B1 is audit announcement, B2 is bond disclosure report, B3 is budget audit report, B4 is debt audit report, B6 is final account report, B7 is debt limit document, B8 is budget execution report, B9 is debt allocation program, B10 is budget adjustment report, B11 is debt review report, B12 is debt survey report; S1 is public information on the website of local finance department (bureau), S2 is information published on the websites of other government departments (central government, provincial government, provincial people's congress, audit department, etc.) that are not finance departments (bureaus); S3 is the Fiscal Yearbook of each province, autonomous region, and municipality; S4 is the Statistical Yearbook of each province, autonomous region and municipality and the China Fiscal Yearbook.

C.2. Benchmark debt level and additional analysis

This subsection adds a justification for the level of local benchmark debt, i.e. debt that can be supported by own debt service funds, as measured in the main text. For a proper comparative analysis, we use data on local debt balances (general and earmarked debt combined) and local debt limits published by the Ministry of Finance in 2015 and compare them with the local benchmark debt levels we measure using equation (6) in our model. The local benchmark debt we measure uses only data on local debt service funds, local debt financing costs, and local debt financing credit risk, and does not use data on local debt levels. Table C3 shows the actual debt levels, limits, and results of the theoretical calculations for 2015.

In the table above, we report four calculations of the theoretical debt limit. In the first two columns, we use only the local government's own debt service funds and consider two measures of local debt risk, using the local debt spreads in the first half of 2016 and the Chengtou bond spreads in 2015, respectively. In the last two columns, we combine the magnitude of earmarked transfers received by local governments with their own debt service funds to obtain a composite financial capability indicator; however, we assume that the correlation between own debt service funds and earmarked transfers is zero, and calculate the corresponding debt limit. The choice of earmarked transfers by local governments, in reality, is slightly different from the extreme case assumed by the theoretical model: in the theoretical model, local governments can choose earmarked transfers C_0 that can be arbitrarily close to 0; however, in reality, considering the importance of earmarked transfers to local financial resources, the choice of C_0 by local governments must have a lower bound $C_0 \geq \overline{C} > 0$ that is strictly greater than 0. For practical reasons, we can assume that $\overline{C}$ should also be part of the local own debt service funds, and the part exceeding $\overline{C}$ corresponds to the local excessive debt issuance. Naturally, the correlation coefficient between L_0 and $\overline{C}$ is 0.

Table C.3
Comparison of actual and theoretical debt, 2015

Province	Actual debt limit	Actual debt balance	Theoretical debt limit			
			Self-owned debt service funds		Plus earmarked transfers	
			Local bond spreads	Chengtou bond spreads	Local bond spreads	Chengtou bond spreads
			B1	B2	B3	B4
Jiangsu	10,954.30	10,556.26	12,033.72	11,610.40	12,234.56	12,184.68
Shandong	8,443.20	8,135.40	8,541.00	8,742.84	9,057.81	9,482.87
Sichuan	7,808.00	7,470.00	6,550.80	6,755.49	7,586.49	7,749.27
Yunnan	6,628.10	6,228.60	3,922.01	2,992.32	4,760.90	4,036.06
Hunan	6,780.30	6,152.22	4,600.08	4,630.93	5,471.76	5,634.70
Inner Mongolia	5,675.50	5,455.21	2,501.07	2,654.14	3,105.77	3,343.78
Hebei	5,888.00	5,309.16	4,789.59	4,506.09	5,495.43	5,271.18
Anhui	5,424.10	5,107.20	5,065.85	4,855.17	5,748.15	5,702.65
Shaanxi	5,064.80	4,681.30	3,480.74	3,260.55	4,226.25	3,873.30
Guangxi	4,464.80	4,308.85	3,395.14	3,432.71	3,709.77	3,858.96
Fujian	4,586.30	4,215.82	3,910.79	3,651.22	4,182.42	4,022.95
Jiangxi	3,905.20	3,735.86	3,918.07	3,907.37	4,444.06	4,563.10
Jilin	3,018.70	2,755.93	1,956.24	2,146.83	2,536.20	2,741.40
Xinjiang	2,836.70	2,633.40	2,301.22	2,491.57	3,168.46	3,458.04
Tianjin	2,591.50	2,380.60	3,207.20	3,295.12	3,244.32	3,357.43
Shanxi	2,122.80	2,025.21	2,635.45	2,768.53	3,016.44	3,175.68
Gansu	1,709.50	1,588.00	1,784.66	1,864.26	2,719.89	2,766.32
Qinghai	1,330.90	1,235.45	723.41	764.99	1,097.01	1,012.91
Ningxia	1,138.90	1,058.54	724.94	762.11	932.34	980.03

As can be seen from the results in Table C3, the debt limit measure is of the same order of magnitude as the actual debt balance and the debt limit, even if the (necessary) value of the earmarked transfer is disregarded and only own debt service is used. The actual debt limit correlates very well with the theoretical debt limit: the correlation coefficients with all four debt limits B1–B4 are above 0.9. Among them, if we consider the theoretical limit B4

including the earmarked transfers, the actual debt limit ratio, and the debt balance ratio have an average of 106.97% and 100.19% respectively. Fig. C.1 shows the scatter plot of the actual debt limit and the theoretical debt limit B4, which shows that they are highly consistent; the simple linear regression results show that the regression coefficient between the actual debt limit and our theoretical debt limit is 0.9971 and the R-squared reaches 0.82. This indicates that our theoretical model can quantitatively represent the actual debt limit very well.

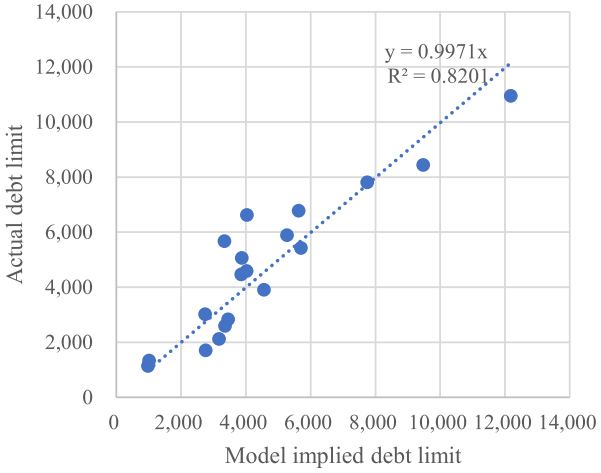

Fig. C.1. Actual and model implied debt limits (B4).

Fig. C.2 further plots the ratio of the actual debt balance of each province to the debt limit obtained from the model measurements. As can be seen from the figure, the debt balances of all provinces are in the same order of magnitude as the four debt limit measures listed in Table C3, and most of the province's debt balances vary within a small range just around the theoretical measures. This figure further illustrates that our benchmark debt measurement based on the theoretical model is highly comparable to reality.

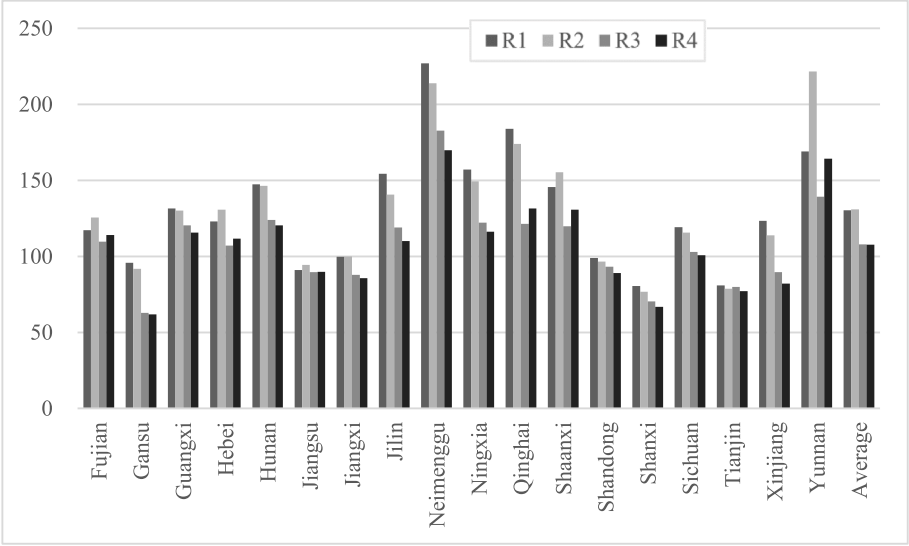

Fig. C.2. Comparison of actual debt balance with model implied limit, 2015.

Note: R1-R4 indicates the ratio of the actual debt balance of each province to the theoretical debt limit of B1–B4 presented in Table C3.

D. Validation of the main assumptions of the theoretical model

The key hypothesis to get the conclusion of the theoretical part is the endogenous selection hypothesis of local governments to central discretionary transfers in the third part of the paper, including both the growth rate and volatility of earmarked transfers. Now, we empirically test these two hypotheses separately.

D.1. Volatility assumption testing

First, we test whether the assumptions of the function of volatility $H(c_0)$ are reasonable. In the endogenous selection hypothesis for central discretionary transfers, we assume that the expected volatility of implicit financial support is strictly monotonically increasing for period 0 implicit financial support c_0. Now, we set the relationship of $H(c_0)$ with the period 0 discretionary transfers as

$$\sigma_c = H(c_0) = \exp(\alpha)\cdot(c_0 - 1)^{\beta} ,$$

then the first-order derivative of $H(c_0)$ is

$$H^{'}(c_0) = \exp(\alpha)\cdot\beta(c_0 - 1)^{\beta-1}.$$

When $\beta > 0$, assumptions A1-A2 on the $H(\cdot)$ function are supported. Now, we build the regression model to estimate the β by first taking the logarithm of $H(c_0)$ at both ends,

$$\ln\sigma_c = \alpha + \beta\ln(c_0 - 1).$$

The following panel data model is then built to allow for the estimation of β

$$\ln\sigma_{c,it} = \alpha + \beta\ln\left(c_{0,it} - 1\right) + \varepsilon_{it}.$$

We perform a regression analysis using implicit financial support in period t on volatility data from period t to $t+5$, with the following parameter estimates:

Table D1
Volatility regression results

	OLS	FE	RE
β	0.6883*** (0.0907)	0.7685*** (0.2498)	0.7462*** (0.1225)
cons	-2.5541*** (0.1547)	-2.4306*** (0.3865)	-2.4346*** (0.2119)

Note: ****$p < 0.01$; **$p < 0.05$; *$p < 0.1$; Standard errors are reported in parentheses.

From the results of the volatility regression, it can be found that the results of OLS regression, fixed effects model, and random effects model consistently indicate β significantly greater than 0,that is, the initial value of implicit financial support has a significantly positive effect on volatility, which validates the hypothesis that the expected volatility of implicit financial support is strictly monotonically increasing on the period 0 implicit financial support c_0.

D.2. Growth rate assumption testing

Next, we test whether the assumptions about $G(\cdot)$ in A1-A3 are reasonable. First, we test whether the growth rate function is monotonically decreasing for the initial value of the discretionary transfers, and we simply assume that the two obey a linear relationship,

$$g_c = G(c_0) = \alpha + \beta c_0.$$

A panel data model is developed and a regression analysis is conducted using the implicit financial support of each province in period t and the growth rate of discretionary transfers from period t to $t+5$. The empirical model is as follows

$$g_{c,it} = \alpha + \beta c_{0,it} + \varepsilon_{it}.$$

Also, to analyze simultaneously whether the first-order derivative and second-order derivative of the growth rate function comply with the assumptions of A1-A3, we assume that $G(c_0)$ is of the form

$$g_c = G(c_0) = \beta_1 c_0 + \beta_2 c_0^2.$$

Then $G^{'}(c_0)$ and $G^{''}(c_0)$ are given by

$$G^{'}(c_0) = \beta_1 + 2\beta_2 c_0, G^{''}(c_0) = 2\beta_2.$$

From this, we build the following model to test

$$g_{c,it} = \beta_1 c_{0,it} + \beta_2 c_{0,it}^2 + \varepsilon_{it}.$$

The regression results of the two models shown in Tables D2 and D3 show that the contribution of implicit financial support to the growth rate is significantly negative and the growth rate function is concave, which is also aptly illustrated by the shape of the scatter plot and the fitted curve (Figure C1). It can be seen that the regression results strongly support the hypotheses in A1-A3 regarding $G(\cdot)$.

Table D2
Growth rate regression results

	OLS	FE	RE
β	-0.1593*** (0.0315)	-0.6327*** (0.0965)	-0.1802*** (0.0389)
cons	0.1563*** (0.0403)	0.7564*** (0.1223)	0.1832*** (0.0500)

Note: ****$p < 0.01$; **$p < 0.05$; *$p < 0.1$; Standard errors are reported in parentheses.

Table D3
OLS regression results

β_1	0.0739** (0.0308)
β_2	-0.0854*** (0.0233)

Note: ****$p < 0.01$; **$p < 0.05$; *$p < 0.1$; Standard errors are reported in parentheses.

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