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Research article

The spread of debt risk from real estate companies to banks: Evidence from China

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Abstract: The recent real estate debt crisis in China has dealt a huge blow to the banking sector. To address this challenge, we construct a dynamic game model that considers the interaction of the government, banks and real estate companies. The model is used to analyze the default behavior of real estate companies and loan losses for banks when facing information asymmetry. In addition, we empirically demonstrate the contagion effect of debt risk of real estate companies to banks, using a sample of 119 listed real estate companies and 42 listed banks in China from 2001 to 2020. The results show the following. (1) The debt risk associated with non-state-owned real estate companies is more likely to be contagious to banks compared to state-owned real estate companies. (2) The contagion effect of debt risk of real estate companies to banks is more significant among small and medium-sized banks. (3) The debt risk of non-state-owned real estate companies is most contagious for rural banks, followed by urban banks. Further tests show that the rising debt risk of non-state-owned real estate companies significantly increases the asset risk of small and medium-sized banks. This effect is reinforced through the liquidity channel. This implies that controlling the contagion of debt risk of non-state-owned real estate companies to small and medium-sized banks is an effective way to prevent the occurrence of banking crises.

Keywords: debt default; risk contagion; real estate companies; banks; game model

JEL Codes: B41, G33, M21

1. Introduction

In the second half of 2021, several of China's top real estate companies experienced a liquidity crisis and a series of debt defaults under the pressure of sales and financing. This led to a cooling of China's real estate market and a rise in a "wait-and-see" sentiment in the land market. It also generated operational difficulties for real estate companies and associated upstream and downstream companies. Several Chinese listed banks have released annual reports for 2021 showing a decline in the quality of real estate loans. In addition, the frequent discontinuation of mortgage payments by owners of unfinished buildings in 2022 may also further threaten the asset quality of banks. Real estate loans are an important source of funding for China's real estate industry and an important profitable asset for banks. China's real estate "golden age" generated high returns, so banks sometimes underestimate the risk of lending and have relaxed loan terms (Zhang et al., 2016). As a result, real estate-related loans account for 40% of China's banking sector loans. The asymmetry in risk-reward between lenders and borrowers has somewhat encouraged opportunistic behavior by real estate development enterprises to operate at high levels of leverage, shifting the risk of business failure to banks. Financing policies in the real estate industry have been positive since 2022. However, the policy intervention failed to fully restore the confidence of home buyers, and the stability of the banking system may continue to be tested in the future. Therefore, given the high concentration of bank credit funds in the real estate industry, it is important to conduct a micro-level examination of the contagion effect of debt risk of China's real estate companies to banks. This may help clarify the spillover effects of debt risk in the real estate industry, prevent the spread of debt risk in the real estate industry and improve the efficiency of policy regulation.

In China, approximately one third of financial resources are invested in the real estate sector, indicating that financial institutions are highly dependent on real estate. Table 1 shows the shares of real estate development loans and housing mortgage loans for 42 listed banks in China in 2021. It indicates that banks invest significant credit resources (approximately one third) in real estate; this does not include resources such as subprime mortgage. Overall, large banks have the highest share of all real estate loans, at an average of 35.48%. However, five small and medium-sized banks have a real estate development loan ratio of more than 10%, which is significantly higher than the industry average. Some of China's small and medium-sized banks are taking advantage of the withdrawal of large banks to compete for real estate loan market share. This reliance on the real estate industry also closely links the operational safety of small and medium-sized banks to the debt risk of real estate companies. The website of the China Banking and Insurance Supervisory Commission indicated that, as of December 2021, there were more than 4,000 small and medium-sized banking financial institutions in China, with combined assets of about one fourth of the entire banking system. These small and medium-sized banks have lower thresholds for bankruptcy and are more prone to joint failures. This has important implications for economic and social development and stability (Foglia et al., 2022).

Real estate financial risk is a significant source of systemic financial risk in China (Deng et al., 2018; Liu et al., 2020). The debt risk associated with real estate companies can be directly contagious to banks through credit linkages (Cuñat et al., 2018; Jiménez et al., 2020; Glancy, 2021) and can be bi-directionally contagious to upstream and downstream firms through the industrial chain. This eventually spreads to more banks (Han et al., 2021). However, previous studies on the contagion of China's real estate debt risk to banks have been mostly industry-level analyses as a whole, highlighting the need to research more specific contagion characteristics. Which real estate companies are more

prone to debt risk contagion? For which banks in China is the contagion effect of real estate companies' debt risk more pronounced? To assess these questions more accurately, this study examines a sample of 119 listed real estate companies and 42 listed banks from 2001 to 2020 to analyze the contagion effect of debt risk of listed real estate companies on banks in China. The insights from the study may help improve the efficiency of debt risk disposal by real estate companies and provide policy guidance to support the goal of minimizing systemic financial risk.

Table 1. Shares of real estate development loans and personal housing mortgage loans in China, 2021.

Bank name	Real estate development loans /Total loans	Bank name	Residential mortgage loan /Total loan	Bank names	All real estate loans /Total loans
Shanghai Rural Commercial Bank	17.83	China Construction Bank	34.04	Bank of China	38.52
Qingdao Rural Commercial Bank	13.00	Postal Savings Bank of China	33.61	China Construction Bank	38.50
Bank of Shanghai	12.75	Bank of China	30.79	Shanghai Rural Commercial Bank	36.99
China Zheshang Bank	12.56	Industrial and Commercial Bank of China	30.79	Postal Savings Bank of China	35.76
Bank of Zhengzhou	11.92	Agricultural Bank of China	30.59	Agricultural Bank of China	35.71
Ping An Bank	9.43	Industrial Bank	25.32	Industrial and Commercial Bank of China	35.30
Bank of Lanzhou	9.00	China Merchants Bank	24.68	Industrial Bank	32.93
China Minsheng Banking	8.91	Bank of Communications	22.70	China Merchants Bank	31.89
Bank of Qingdao	8.70	Bank of Chengdu	21.88	Bank of Communications	29.10
Bank of China	7.73	Bank of Beijing	20.90	Bank of Beijing	28.18
6 large banks	5.06	6 large banks	30.42	6 large banks	35.48
9 joint-stock banks	7.80	9 joint-stock banks	16.71	9 joint-stock banks	24.51
17 urban banks	6.43	17 urban commercial banks	14.82	17 urban commercial banks	21.25
10 rural banks	4.10	10 rural commercial banks	13.91	10 rural commercial banks	17.90
42 banks	5.97	42 banks	17.32	42 banks	23.31

This paper makes three key contributions to the literature. First, it expands previous research on the risk contagion relationship between non-state-owned real estate companies and small and medium-sized banks in China. Previous studies have focused on the overall contagion effect of real estate market risk on banks (Koetter and Poghosyan, 2010; Davis and Zhu, 2011; Deng et al., 2019), but the findings may not apply to all real estate companies and banks. This paper fills this research gap by distinguishing the contagion effect of real estate debt risk to banks based on different equity properties and theoretically and empirically analyzes the contagion characteristics. Second, the study quantifies the contagion effect of China's real estate debt risk on banks at the firm level. In this paper, we use the least absolute shrinkage and selection operator vector autoregression (LASSO-VAR) model to construct a high-dimensional risk contagion network between China's real estate industry and the banking sector. We explore each real estate firm's risk spillover and each bank's risk inflow. This identifies key real estate companies and vulnerable small and medium-sized banks. Third, the study finds that the rising debt risk of non-state-owned real estate companies significantly increases the asset risk of small and medium-sized banks and reinforces this effect through the liquidity channel. This demonstrates that non-state-owned real estate companies in China may be more prone to debt risk contagion, while small and medium-sized banks are more vulnerable to risk shocks.

2. Theoretical analysis

2.1. Debt risk linkage of government, banks and real estate

Banks and real estate form a complex credit network through loans. This network is a channel for real estate financing and bank profitability and for the rapid formation and transmission of debt default risk (Liu et al., 2016). During the rapid expansion of China's real estate market, real estate companies had high profit margins and recovered capital rapidly. As a result, local government financing companies, financial institutions, social capital and others flooded the real estate industry. Real estate tends to experience overheating in investment, increasing its attributes as a virtual part of the economy and making the speculative tendency of the market increasingly prominent (Glaeser, 2013; Van Loon et al., 2017). The debt size and leverage levels of real estate companies have been rising, and their financialization and the bubbles continue to be amplified. However, rising financial risks tend to spill over and amplify real estate risks. As the asset quality of financial institutions' housing-related loans declines, there is a decrease in the risk-taking of financial institutions in the real estate sector. In addition, as the financing cost of real estate companies increases, the risk of capital chain breakage of small and medium-sized real estate companies increases, further increasing real estate risks (Lin et al., 2021).

Local government debt risk is closely related to real estate enterprise debt risk. Real estate-related taxes and fiscal revenues from local government land sales account for a significant proportion of China's fiscal revenues, which can trigger the spread of debt risk between the government and real estate (Pan et al., 2015; Wang and Hou, 2021). During the previous real estate upturn cycle, it was easier for local government financing platforms to finance with land, and the scale of financing expanded rapidly as the land appreciated. This indirectly increased local governments' hidden debt. However, once the ability and willingness of real estate companies to acquire land decreases, and housing prices trend downward, land auctions narrow the government's space for further debt financing. When the government is unable to borrow new money to repay old debts, it exposes the risk

of high hidden debt (Ang et al., 2018). When facing higher fiscal pressure, local governments increase land concessions to state-owned enterprises (SOEs) at lower prices. This is particularly true when economic growth declines and when local governments use fiscal policies as an economic stimulus. Therefore, when a real estate company is an SOE, creditors assume that the government has certain obligations to the enterprise (Borisova and Megginson, 2011; Zhang and Wang, 2020; Walker et al., 2021), and the government is more likely to bail out the enterprise if it cannot repay the loan. This makes it easier for SOEs to obtain external financing. Compared to non-state-owned real estate companies, which do not have government backing and are subject to "credit discrimination" by banks, state-owned real estate companies in China have a high degree of soft budget constraints and are prioritized with respect to credit rationing (Wang, 2021).

The link between government debt risk and financial market risk is stronger today than in the past; as such, risk can spread between the two and can expand to systemic risk if not handled properly. An increase in financial risk can exacerbate the risk associated with government debt (Beirne and Fratzscher, 2013; Battistini et al., 2014). Banks are important investors and holders of local government bonds in China. At the end of 2020, the balance of local government bond stock was 25.49 trillion RMB. Of this total, banks held about 22.05 trillion RMB, or 86.5%. The overall risk of China's financial institutions is currently manageable, with a low risk of a financial crisis. However, the People's Bank of China's 2021 stress test of banking financial institutions found that small and medium-sized banks are less resilient to a deterioration in overall credit asset quality. In recent years, some local financial institutions have been in crisis due to serious credit risks. These have deteriorated the local financing environment and damaged the overall financial environment. Significant asset losses and financial risks generated by these high-risk financial institutions are, in turn, transmitted to local finances. This further exacerbates local government debt risks. However, a significant increase in government debt risk further affects and triggers financial risk (Pagano and Sedunov, 2016). Most government financing platform companies lack a clear separation between government and enterprises, have unclear responsibilities and powers and have irregular and non-transparent operations. If the government financing platform loses its solvency, and the hidden debt risk of local governments is not resolved in a timely manner, the balance sheet of financial institutions can significantly deteriorate, triggering financial risks.

2.2. Dynamic game model of government, banks and real estate

This study constructs a three-party dynamic game model involving the government, banks and real estate to analyze the debt default of real estate companies and the loss of real estate loans of banks in the face of information asymmetry. The three-party model of government, banks and real estate is a dynamic game with asymmetric information about the debt risk linkage. In this game model, participant actions by the government, banks and real estate companies are sequential. Later actors can observe the actions of the first actor but not the first actor's type.

The theory of dynamic games with incomplete information holds that game participant actions are type-dependent. Each participant's action conveys information about its own type, and the later actor can infer its type or correct the prior probability distribution of its type by observing the actions taken by the first actor and choosing the optimal action. Predicting that their actions will be used by the later actor, the first actor will choose to convey favorable information and avoid conveying unfavorable information.

This study included proposing the general assumptions of a three-party dynamic game model that includes the triad of government, banks and real estate.

i. The game participants, who include the government, banks and real estate companies, are rational and are trying to maximize their own interests.

ii. There is information asymmetry with real estate companies, which are well informed about their business management status, financial status, profitability, solvency and willingness. However, it is difficult for the government and banks to get real information of real estate companies. Therefore, in the game's process, real estate companies have an information advantage.

iii. The game is a three-party dynamic game, in which game participants act sequentially. Later actors can infer the probability distribution by observing the behaviors of the previous actors before their own actions.

iv. The game is a non-cooperative game; this means there is no collusion or conspiracy between the three game parties.

Based on these assumptions, the game model variables are defined as follows. The loan principal is C, the loan interest rate is i, and the operating rate of return of real estate companies after obtaining the loan is r. In the correlation network of real estate loans, the government's gain from supporting real estate companies' financing is E, the integrity gain of real estate companies' performance in repaying the loan is R, and the integrity loss of default in not repaying the loan is L. The following is the three-party game analysis of real estate loans.

The theory of a dynamic game with incomplete information is used to derive a three-party dynamic game function, involving the triad of government, banks and real estate. This is used to construct the game model.

i. If the government provides guaranteed support, the bank chooses to issue the loan, and the real estate firm's strategy is to fulfill the contract. In this case, the benefits to the government, the bank and the real estate firm are E, iC, and $C(r-i)+R$, respectively.

ii. If the government provides guaranteed support, the bank chooses to issue the loan, and the real estate company strategy is to default. In this case, the government makes a partial substitution hC for the loan, and the substitution ratio is h. The government recovers kC from the real estate company. The recovery ratio is k, where $h \geq 0, k \geq 0$. This is because when an enterprise is a state-owned enterprise, creditors assume the government will back the enterprise, and the government will help if the enterprise cannot repay the loan. The benefits for the government, banks and real estate companies are $E-hC+kC$, $hC-C(1+i)$ and $C(1+r)-kC-L$, respectively.

iii. If the government provides guaranteed support, and the bank adopts the strategy of not issuing loans, there are no (zero) benefits for all three parties, including the government, the bank and the real estate company.

iv. If the government does not provide guaranteed support, and the bank issues a loan to the housing firm, the housing firm must increase the loan fee a, $a \geq 0$. In this case, if the housing firm complies in repaying the loan, then the benefits to the government, the bank and the housing firm are E, $iC+a$ and $C(r-i)-a+R$, respectively. If the housing firm defaults and does not repay the loan, then the benefits are E, $a-C(1+i)$ and $C(1+r)-a-L$, respectively.

v. In the case that the government does not provide a guarantee, and the bank chooses not to lend, the three parties do not receive any gains (zero).

Given these assumptions, Figure 1 shows a three-way dynamic game tree of government, banks and real estate companies.

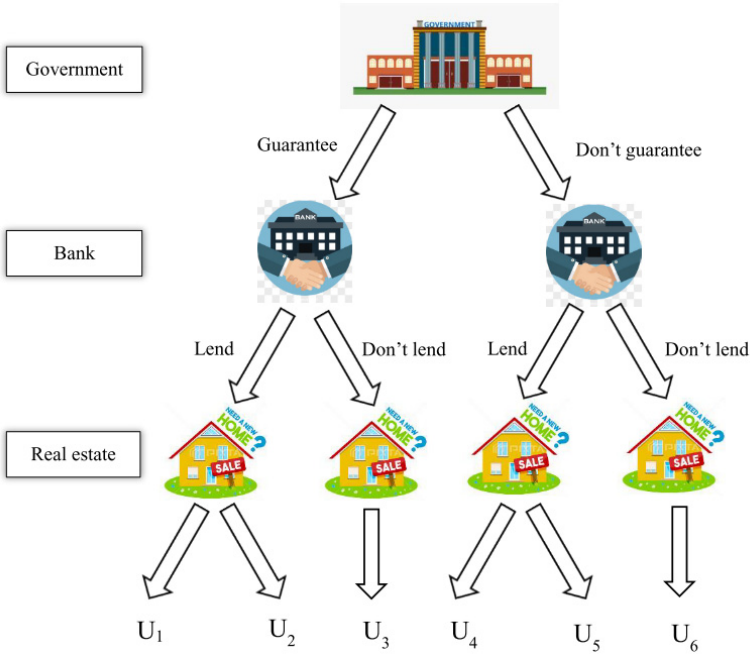

Figure 1. Dynamic game tree of government, banks and real estate companies.

Given this game tree, analyzing the game payoffs of the three parties yields the following six payoff functions.

$$U_1 = [E, iC, C(r-i)+R] \tag{1}$$

$$U_2 = [E - hC + kC, hC - C(1+i), C(1+r) - kC - L] \tag{2}$$

$$U_3 = [0,0,0] \tag{3}$$

$$U_4 = [E, iC + a, C(r-i) - a + R] \tag{4}$$

$$U_5 = [E, a - C(1+i), C(1+r) - a - L] \tag{5}$$

$$U_6 = [0,0,0] \tag{6}$$

When the benefits of a real estate company choosing to default exceed the benefits of complying with the contract, the real estate company does not meet its repayment responsibility. The default probability (DP_{SOE}) by a state-owned real estate company with a government guarantee is expressed as

$$DP_{SOE} = P[C(1+r) - kC - L > C(r-i) + R] = P\left(C > \frac{L+R}{1+i-R}\right) \tag{7}$$

Similarly, the default probability (DP_{nonSOE}) of a non-state-owned real estate company without a government guarantee is expressed as

$$DP_{nonSOE} = P[C(1+r) - a - L > C(r-i) - a + R] = P\left(C > \frac{L+R}{1+i}\right) \tag{8}$$

Because $\frac{L+R}{1+i-R} > \frac{L+R}{1+i} > 0$, $P\left(C > \frac{L+R}{1+i}\right) > P\left(C > \frac{L+R}{1+i-R}\right)$. In other words, $DP_{nonSOE} > DP_{SOE}$. The study's first hypothesis is derived from the above three-party game theory model of government, banks and real estate companies.

Hypothesis 1: *Non-state-owned real estate companies without government guarantees are more likely to experience the spread of debt risk than state-owned real estate companies with government guarantees.*

When a state-owned real estate enterprise with a government guarantee defaults on a bank loan, the bank's loan loss is expressed as

$$LOSS_{SOE} = (1-h)C \tag{9}$$

Similarly, when a non-state-owned real estate company without government guarantee defaults on a bank loan, the bank's loan loss is expressed as

$$LOSS_{nonSOE} = C \tag{10}$$

Assume the proportion of state-owned real estate companies among the bank's real estate loan customers is φ, and the proportion of non-state-owned real estate companies is $(1-\varphi)$. In this case, the bank's average loss of real estate loans is

$$\overline{LOSS} = \varphi(1-h)C + (1-\varphi)C \tag{11}$$

Among the real estate loan customers of large banks, the proportion of state-owned real estate companies is φ_1, and the proportion of non-state-owned real estate companies is $(1-\varphi_1)$. Among the real estate loan customers of small and medium-sized banks, the proportion of state-owned real estate companies is φ_2, and the proportion of non-state-owned real estate companies is $(1-\varphi_2)$. Small and medium-sized banks do not have a dominant position in the credit market, lack customer resources and lack a high-quality customer base for public business. Given that state-owned real estate companies have implicit government guarantees, we hypothesize that state-owned real estate companies are high-quality customers compared with non-state-owned real estate companies. Therefore, $\varphi_1 > \varphi_2$.

Given this, the average loss of real estate loans of large state-owned banks under the impact of debt risk of real estate companies is

$$\overline{LOSS_1} = \varphi_1(1-h)C + (1-\varphi_1)C = (1-h\varphi_1)C \tag{12}$$

The average loss on real estate loans of small and medium-sized banks is

$$\overline{LOSS_2} = \varphi_2(1-h)C + (1-\varphi_2)C = (1-h\varphi_2)C \tag{13}$$

Because $\varphi_1 > \varphi_2$, $\overline{LOSS_1} < \overline{LOSS_2}$. The above derivation leads to the second hypothesis of this paper.

Hypothesis 2: *When a real estate company defaults on its debt, small and medium-sized banks bear a larger loss on real estate loans.*

3. Empirical framework

3.1. LASSO-VAR model

The LASSO-VAR model is used to empirically demonstrate the contagion effect of debt risk of Chinese real estate firms to banks. The principle driving the model is the use of a variance decomposition matrix to represent the risk contagion. The model then explains whether the same risk depends on the endogenous contagion effect from a cross-sectional view of the data. The model can provide a clear picture of the direction, magnitude and intensity of the contagion, and it can measure the correlation of a characteristic across multiple individuals at different levels.

In the classical VAR model, the number of parameters to be estimated increases exponentially in a high-dimensional network. This makes the variable matrix inverse impossible, and there is significant covariance among the variables. Therefore, to quantify the scale and direction of the risk contagion of real estate companies' debt risk to banks, we estimate a high-dimensional VAR model based on generalized variance decomposition, using the LASSO algorithm to shrink and reduce the number of parameters. The final variance decomposition matrix represents the scale and direction of risk contagion among different individuals.

This study uses a spillover index proposed by Diebold and Yilmaz (2012) to determine the contagion effect of real estate firms' debt risk on bank risk. Based on Li and Zhong (2020) for the DY spillover index setting, the debt risk of real estate firms and bank asset risk align with the VAR model, given as

$$Y_t = \sum_{k=1}^{p} \Phi_k Y_{t-k} + \varepsilon_t \tag{14}$$

where Y_t is the matrix of real estate enterprise debt risk and bank asset risk, and p represents the lag order in the VAR model. The parameter ε_t is a random error vector with zero mean, normal and independent homogeneous distribution. The variance matrix is denoted by Σ. The moving average expression of Equation (14) is $Y_t = \sum_{i=1}^{\infty} A_i \varepsilon_{t-i}$, where A_i is the coefficient matrix, and it is constrained by Equation (15).

$$A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \cdots + \Phi_p A_{i-p} \tag{15}$$

where A_0 represents the unit matrix, and when $i < 0$, $A_i = 0$. Equation (15) and the moving average expression are used to estimate the impulse response function and to predict the error variance decomposition.

The variance decomposition is based on the generalized VAR framework with the H-step-ahead forecast error variance. For more detail about the generalized VAR framework, refer to Diebold and Yilmaz (2012). It is defined as follows:

$$\theta_{ij}^{\mathrm{g}}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_h \Sigma e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Sigma A_h' e_i\right)^2} \tag{16}$$

where σ_{jj} is the element of the j-th row and j-th column of Σ. e_i and e_j denote the vectors where the i-th and j-th elements are 1, and the other elements are 0, respectively. $\theta_{ij}^{\mathrm{g}}(H)$ is the risk contagion effect of individual j on individual i. The risk contagion effect is further normalized and expressed as

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{17}$$

The correlation network between the debt risk of real estate firms and bank asset risk is constructed according to $\tilde{\theta}_{ij}^{g}(H)$. The network is given as

$$\begin{array}{c} \\ NP_{m_1} \\ \vdots \\ NP_{m_i} \end{array} \begin{array}{c} \begin{array}{ccc} DEBT_{n_1} & \cdots & DEBT_{n_j} \end{array} \\ \begin{bmatrix} \tilde{\theta}_{m_1 n_1}^{g}(H) & \cdots & \tilde{\theta}_{m_1 n_j}^{g}(H) \\ \vdots & \ddots & \vdots \\ \tilde{\theta}_{m_i n_1}^{g}(H) & \cdots & \tilde{\theta}_{m_i n_j}^{g}(H) \end{bmatrix} \end{array} \tag{18}$$

where $DEBT_{n_j}$ represents the debt risk of the n_j-th real estate firm, and NP_{m_i} represents the asset risk of the m_i-th bank.

The VAR models constructed from real estate firm debt risk and bank asset risk need to be estimated at a very high level of dimensionality. To avoid the challenges of dimensionality, it is important to reduce the number of parameters to be estimated. This study estimates the VAR model using LASSO, with reference to the method used by Demirer et al. (2018).

The least squares estimation for solving a high-dimensional VAR model using LASSO is expressed as

$$\hat{\beta} = \arg\min_{\beta} [\sum_{t=1}^{T} (y_t - \sum_i \beta_i x_{it})^2 + \lambda \sum_{i=1}^{K} |\beta_i|] \tag{19}$$

where $\lambda \sum_{i=1}^{K} |\beta_i|$ denotes the LASSO penalty term, and λ is the penalty parameter controlling the size of the degree of compression. Cross validation is used to determine the optimal penalty parameter.

3.2. Data sources and descriptive statistics

The 2012 industry classification guidelines of listed companies by the China Securities Regulatory Commission (CSRC) were used to select 119 A-share listed real estate companies and 42 A-share listed banks. These samples were used to analyze the contagion effect associated with the debt risk of real estate companies on bank asset risk. The real estate companies include 62 state-owned real estate companies and 57 non-state-owned real estate companies. The banks include 6 large banks, 9 joint-stock banks, 17 urban banks and 10 rural banks. The data include annual data from 2001 to 2020, and the financial data used to monitor the debt risk of listed real estate companies are mainly from the Wind database.

With respect to bank asset risk, we borrow the natural logarithm of listed banks' non-performing loan (NPL) balances as a proxy for bank asset risk. The average NPL ratio of the 42 listed banks has decreased each year since 2016. However, the average NPL balance from 2016-2021 increased from 29.635 to 41.644 billion RMB, an increase of 40.52%. The NPL balance is more effective in representing the default losses experienced by banks. The banks' financial statements do not disclose the specific customers of NPLs, and most of the banks' loans are property mortgages. Therefore, we use NPL balances to study the spread of real estate debt risk on banks.

Based on previous research literature on the debt risk of real estate firms, we classify the collected financial statements and firm characteristics into three indicators: solvency, cash flow level and

operating characteristics. We use the XGBoost model (Chen and Guestrin, 2016) to measure the debt risk of real estate companies in China.

Table 2 reports the descriptive statistics of debt risk of real estate firms and NPL balances of banks for 2001–2020. For the sample period, the mean values of debt risk for non-state-owned real estate firms and state-owned real estate firms are 0.1073 and 0.0750, respectively. This indicates that non-state-owned real estate firms have a higher risk of debt default compared to state-owned real estate firms. In 2021, several Chinese listed real estate firms reported debt problems, and 91 real estate firms defaulted on their bonds; 78% of these were private firms. The average value of the NPL balances is highest for large banks and is lowest among rural banks compared to other bank types. In addition, the Industrial and Commercial Bank of China (ICBC) had the highest NPL balance (825 billion RMB) in 2003.

Table 2. Descriptive statistics.

Variable	Category	Mean	Median	Max.	Min.	Std. err.	Obs.
Debt risk	State-owned real estate companies	0.0750	0.0007	0.9994	0	0.2485	1240
	Non-state real estate companies	0.1073	0.0008	0.9996	0	0.2925	1140
	Real estate companies	0.0905	0.0007	0.9996	0	0.2709	2380
NPL balance	Large banks	1590	977	8250	44.3	1790	101
	Joint-stock banks	189	102	814	0	192	168
	Urban banks	24.2	13.1	246	0.9186	32.9	265
	Rural banks	17.9	10.7	170	1.28	21.8	104
	Banks	314	33.8	8250	0	907	638

Note: The unit of NPL balance is billion RMB.

4. Empirical results

4.1. Empirical results of LASSO-VAR model

Table 3 shows the top 10 real estate firms with debt risk spillover values and the top 10 banks with debt risk reception values. The table's first ten rows are the rankings obtained by summing the correlation network between listed real estate firms' debt risk and banks' asset risk (Equation 18) by row. The last 10 rows are the rankings obtained by adding the values in each column.

First, with respect to the spread of debt risk, the top 10 real estate companies included 6 non-state-owned real estate companies and 4 state-owned real estate companies. This indicates that the debt risk of non-state-owned real estate firms is more likely to be transmitted to banks compared to state-owned real estate firms. When measuring risk spillover, the real estate firms ranked 1st, 2nd, 3rd, 4th, 7th and 8th are non-state-owned real estate firms. In addition, when measuring risk acceptance, the real estate firms ranked 5th, 6th, 9th and 10th are state-owned real estate firms. These data verify this study's Hypothesis 1.

Wind data indicate that 91 real estate companies defaulted on their bonds in China in 2021; 78% of these are private companies. This may be because non-state-owned real estate companies have increasing financing costs and a single financing structure, making them vulnerable to the risk of capital chain breakage. China has an underdeveloped corporate bond market, with a low proportion of direct financing for enterprises. Private enterprises have more short-term liabilities, and they mainly

rely on bank loans, commercial credit, and other social funds such as informal private finance. In 2020, the ratio of short-term liabilities to long-term liabilities was 1.04 for the DongGuan Winnerway Industry Zone and 3.65 for 5I5J Holding. In recent years, 5I5J Holding has invested significant money to capture market share, and the percentage of short-term borrowings has increased each year. In addition, the net profit of 5I5J Holding declined from 2019 to 2021, with its semi-annual report in 2022 showing a net profit of -416 million RMB, with a net profit margin of −6.84%. In the case of the expanding operation risk associated with 5I5J Holding, once an enterprise's capital supply is insufficient, with fewer fixed assets that can be collateralized, the debt risk emerging from a broken capital chain will significantly impact banks. Non-state-owned real estate companies are unbalanced with respect to short-term and long-term borrowing, with a strong emphasis on short-term borrowing. This reflects an ineffective financing structure.

Table 3. Top 10 rankings of the contagion of debt risk of real estate companies to bank asset risk.

Rank	Name	Spillover values
1	Zhejiang Xinhu Venture Investment	0.5484
2	Wolong Real Estate Group	0.5076
3	Deluxe Family	0.4584
4	5I5J Holding	0.4477
5	Chongqing Yukaifa	0.4288
6	Everbright Jiabao	0.4280
7	DongGuan Winnerway Industry Zone	0.4184
8	Lvjing Holding	0.4158
9	Beijing Capital Development	0.4090
10	China Merchants Property Operation & Service	0.3873
Rank	Name	Reception values
1	Jiangsu Changshu Rural Commercial Bank	0.7186
2	Jiangsu Zhangjiagang Rural Commercial Bank	0.7013
3	Shanghai Rural Commercial Bank	0.6863
4	Bank of Chengdu	0.6774
5	Bank of Guiyang	0.6745
6	Xiamen Bank	0.6739
7	Qingdao Rural Commercial Bank	0.6647
8	Wuxi Rural Commercial Bank	0.6647
9	Bank of Beijing	0.6637
10	Bank of Zhengzhou	0.6541

Second, rural banks and urban banks each have five of the top ten risk receivers. This indicates that the contagion effect of real estate enterprise debt risk to banks is more significant in small and medium-sized banks. The 1st, 2nd, 3rd, 7th and 8th risk acceptance rankings are associated with rural banks. The 4th, 5th, 6th, 9th and 10th are associated with urban banks. This verifies Hypothesis 2.

The more significant contagion effect of real estate enterprise debt risk to small and medium-sized banks may be from their high concentration of real estate development loans. There are clear differences in the real estate loan business and scale formed by large banks and small and medium-sized banks, based on their underwriting capacities and business characteristics. The structure of bank

loans shown in Table 1 shows that large banks have the highest proportion of real estate loans. This is mainly because state-owned banks hold a high proportion of housing loans. In contrast, state-owned banks hold a low share of real estate development loans. This reflects the more conservative business style of state-owned banks compared to other bank types. Some small and medium-sized banks have a high level of real estate development loans, mainly with small and medium-sized real estate development enterprises. These loans are mainly concentrated in China's third and fourth tier cities (tiers of Chinese cities refer to the website https://multimedia.scmp.com/2016/cities/). If real estate market exposure increases, and there is an increase in bankruptcy levels for small and medium-sized developers in third- and fourth-tier cities, it can lead to a downward spiral in the quality of real estate loans of small and medium-sized banks, expanding their risk exposure.

In addition, Figure 2 demonstrates the contagion effect of debt risk of non-state-owned real estate firms with respect to bank asset risk.

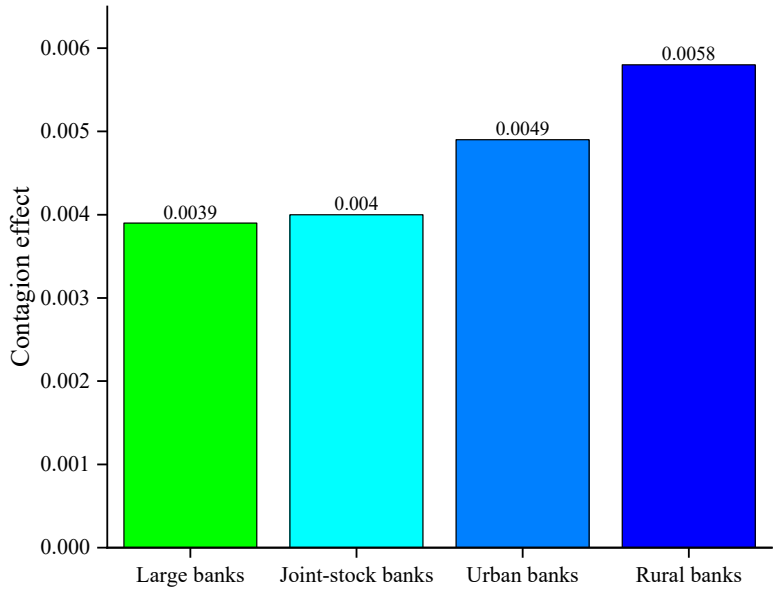

Figure 2. Contagion effect of debt risk of non-state-owned real estate companies on bank asset risk.

Figure 2 shows that the debt risk of non-state-owned real estate companies is most contagious to rural banks, with an average contagion effect of 0.0058; the spread of debt risk to urban banks has an average contagion effect of 0.0049. In China, state-owned enterprises enjoy preferential treatment in bank financing and support from government industrial policies. In contrast, non-state-owned enterprises face ownership challenges and financing constraints. Some small and medium-sized banks rely heavily on and have a high proportion of credit investment in the real estate industry; this level is significantly higher than the average level of the banking sector. In addition, China has long had a tacit financing agreement under which large banks favor lending to large enterprises and small and medium-sized banks favor lending to small and medium-sized enterprises. If a non-state-owned real estate enterprise defaults on its debt, the impact of the default is concentrated at the level of small and medium-sized banks.

4.2. Additional tests

To provide more direct empirical evidence related to the study findings, we further test the impact of debt risk of state-owned and non-state-owned real estate companies on the asset risk of small and medium-sized banks. Four unbalanced panel regression models are established as follows:

$$NP_{it} = \beta_0 + \beta_1 Risk_{State_t} + \Gamma Controls_{Micro_{ijt}} + \Pi Controls\_Macro_{kt} + \varepsilon_{it} \quad (20)$$

$$NP_{it} = \beta_0 + \beta_1 Risk_{State_t} + \Gamma Controls_{Micro_{ijt}} + \Pi Controls\_Macro_{kt} + \delta_i + \varepsilon_{it} \quad (21)$$

$$NP_{it} = \beta_0 + \beta_1 Risk_{NonState_t} + \Gamma Controls_{Micro_{ijt}} + \Pi Controls\_Macro_{kt} + \varepsilon_{it} \quad (22)$$

$$NP_{it} = \beta_0 + \beta_1 Risk_{NonState_t} + \Gamma Controls_{Micro_{ijt}} + \Pi Controls_{Macro_{kt}} + \delta_i + \varepsilon_{it} \quad (23)$$

where NP_{it} represents the asset risk of small and medium-sized banks, $Risk\_State_t$ represents the annual average value of the debt risk associated with state-owned real estate companies, $Risk\_NonState_t$ represents the annual average value of the debt risk of non-state-owned real estate companies, $Controls\_Micro_{ijt}$ represents the micro-control variables at the bank level, $Controls\_Macro_{kt}$ represents the macro control variables at the national macroeconomic level, and Γ and Π represent the matrices of influence coefficients of macro- and micro-control variables, respectively. Based on Brunnermeier et al. (2020), time fixed effects are not included in the regression model, because these would absorb part of the variation of interest. The symbol δ_i represents an individual fixed effect, and ε_{it} is an unobservable disturbance term.

A series of macro and micro control variables are introduced in the model to mitigate the endogenous problem caused by omitted variables. Micro-control variables at the bank level include (i) bank size, expressed as the natural logarithm of total bank assets; (ii) bank profitability, expressed as net profit ratio of total bank assets; (iii) NPL provision coverage ratio; and (iv) deposit to loan ratio. Macro-control variables at the national macroeconomic level include (v) economic development, expressed as the natural log of GDP, and (vi) monetary policy, expressed as the natural log of the broad money supply.

Table 4 shows the regression results of the four panel models. Model (1) shows the effect of debt risk of state-owned real estate companies on the asset risk of small and medium-sized banks without individual fixed effects. The effect of this debt risk is not significant during the sample period. Model (2) results also show that this same effect is not significant after adding the individual fixed effects. Model (3) shows the effect of debt risk of non-state-owned real estate companies on the asset risk of small and medium-sized banks, without individual fixed effects. The coefficient of the impact of this debt risk during the sample period is 1.0630, which is significant at the 5% level. Model (4) results show that the coefficient of the impact of this debt risk after the inclusion of individual fixed effects is 0.8433 and is significant at the 5% level. This indicates that the rising debt risk of non-state-owned real estate companies significantly increases the asset risk of small and medium-sized banks, while there is no significant effect for state-owned real estate companies. This further demonstrates that controlling the spread of debt risk from non-state-owned real estate companies to small and medium-sized banks is an effective way to prevent risks in the banking sector.

Table 4. The results of panel regression.

Variable	Asset risk of small and medium-sized banks			
	(1)	(2)	(3)	(4)
Risk_State	−0.3934	−0.6394		
	(0.6831)	(0.5615)		
Risk_NonState			1.0630**	0.8433**
			(0.4282)	(0.3715)
Bank size	0.8874***	0.9658***	0.8873***	0.9385***
	(0.0236)	(0.0931)	(0.0234)	(0.0929)
Bank profitability	−0.3435***	−0.5121***	−0.2815***	−0.4518***
	(0.0765)	(0.0686)	(0.0794)	(0.0723)
NPL provision coverage ratio	−0.0039***	−0.0036***	−0.0039***	−0.0036***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Deposit to loan ratio	0.0159***	0.0176***	0.0140***	0.0143***
	(0.0022)	(0.0025)	(0.0022)	(0.0027)
Economic development	0.2002	0.0355	−0.8753	−0.9007*
	(0.6196)	(0.5066)	(0.6185)	(0.5131)
Monetary policy	−0.2406	−0.3204	0.7298	0.5828
	(0.5092)	(0.4183)	(0.5030)	(0.4259)
Constant	−1.2453	−0.0129	−0.1562	0.9380
	(1.6352)	(1.4036)	(1.6485)	(1.4244)
Individual	No	Yes	No	Yes
Adjusted R^2	0.8744	0.9198	0.8765	0.9207
Observations	362	362	362	362

Note: Standard errors are in parentheses. *, **, *** represent 10%, 5% and 1% significance levels, respectively.

4.3. Liquidity channel for the contagion of debt risk to bank asset risk

When a housing firm defaults, the risk first spreads to the guarantor firms and creditor banks directly associated with the defaulting housing firm through the liquidity channel (Acemoglu et al., 2015). Subsequently, there is a spillover of the real estate enterprise debt risk to banks and firms that are not directly associated with the defaulted enterprise; the directly associated firms and banks are the media of these effects. Figure 3 shows the contagion mechanism associated with the debt risk of real estate companies under the liquidity channel.

The debt risk of real estate companies spreads to the guaranteeing companies directly associated with the defaulted real estate companies. Bond defaults at the corporate level affect counterparties throughout the guarantee chain. This means that a bond default of one counterparty creates direct capital losses for other counterparties associated with the guarantee. At this point, the liquidity of the guaranteeing enterprise decreases and impacts normal business activities. This may lead to a decline in the prices and credit ratings of the enterprise's related assets and financial products, inducing price volatility in the related assets and financial products. This may worsen the balance sheet of the enterprises holding these assets and products.

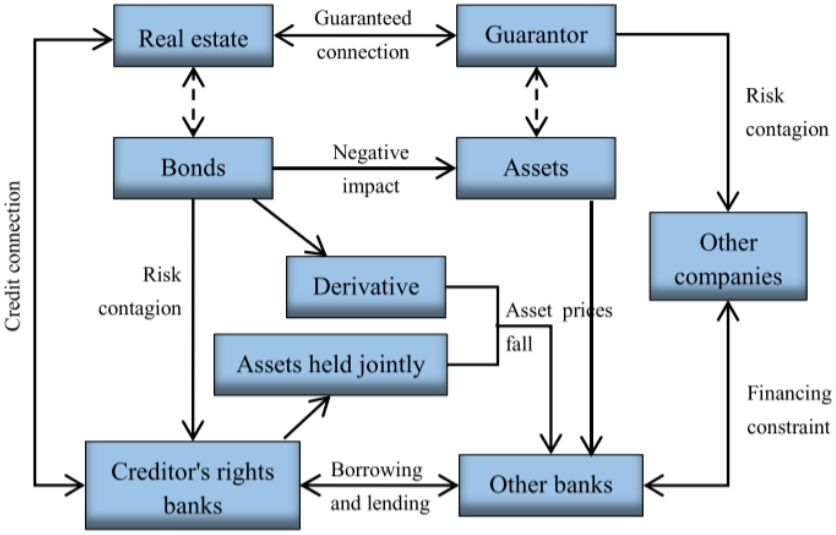

Figure 3. Contagion mechanism of debt risk of real estate companies under liquidity linkage.

Therefore, we use liquidity as a moderating variable to test the effect of the liquidity of small and medium-sized banks on the relationship between banks and firms. The model to test the liquidity channel is as follows:

$$NP_{it} = \beta_0 + \beta_1 LIQ_{it} + \Pi Controls_{kt} + \delta_i + \varepsilon_{it} \tag{24}$$

$$NP_{it} = \beta_0 + \beta_1 Risk_{NonState_t} + \beta_2 LIQ_{it} + \beta_3 Risk_{NonState_t} \times LIQ_{it} + \Pi Controls_{kt} + \delta_i + \varepsilon_{it} \tag{25}$$

where LIQ_{it} is bank liquidity, given as

$$LIQ_{it} = 1 - \frac{Loans_{it}}{Deposits_{it}} \tag{26}$$

where $Loans_{it}$ represents bank loans, and $Deposits_{it}$ represents bank deposits. A larger LIQ_{it} indicates a higher level of bank liquidity.

Table 5 shows the regression results of the panel model with the liquidity channel included. In particular, Model (5) shows the effect of the liquidity of small and medium-sized banks on the asset risk of those banks. The coefficient of the effect is −0.0169, which is significant at the 1% level. This indicates that a higher level of liquidity is associated with a lower asset risk for small and medium-sized banks. Model (6) shows the effect of non-state-owned real estate companies on the asset risk of small and medium-sized banks after adding the liquidity channel. The influence coefficient of the interaction term is 0.0831, which is significant at the 1% level. This implies that the liquidity channel enhances the positive effect of the debt risk of non-state-owned real estate companies on the asset risk associated with small and medium-sized banks.

Table 5. Panel regression results for adding the liquidity channel.

Variable	Asset risk of small and medium-sized banks		
	(4)	(5)	(6)
Risk_NonState	0.8433**		−2.1371**
	(0.3715)		(0.9610)
LIQ		−0.0169***	−0.0241***
		(0.0024)	(0.0039)
Interaction			0.0831***
			(0.0248)
Control variables	YES	YES	YES
Individual	YES	YES	YES
Adjust R^2	0.9207	0.8460	0.8525
Observations	362	362	362

Note: Standard errors are in parentheses. *, **, *** represent 10%, 5% and 1% significance levels, respectively.

5. Conclusions and policy implications

This study constructed and analyzed a dynamic game model involving the government, banks and real estate firms. The model was then used to analyze the default behavior of real estate firms and loan losses of banks in the face of information asymmetry. In addition, we empirically demonstrated the spread of debt risk from real estate firms to banks, using a sample of 119 listed real estate firms and 42 listed banks in China from 2001 to 2020. The key findings were as follows. First, the debt risk of non-state-owned real estate companies is more likely to spread to banks than state-owned real estate companies. This is illustrated by the fact that 6 of the top 10 real estate companies experiencing the spread of debt risk were non-state-owned real estate companies. Second, the spread of debt risk from real estate companies to banks is more significant for small and medium-sized banks. Urban and rural banks each account for five of the top ten real estate enterprise debt risk receivers. Third, the debt risk of non-state-owned real estate companies is most contagious to rural banks, followed by urban banks. Further tests show that an increase in the debt risk of non-state-owned real estate companies significantly increases the asset risk of small and medium-sized banks. In contrast, the debt risk of state-owned real estate companies has no significant effect on the asset risk of small and medium-sized banks.

The findings of this paper highlight two key policy implications for preventing and controlling systemic financial risks. First, local governments should actively stay connected with financial institutions. This can prevent financial institutions from being too sensitive to policies that reduce the reasonable financing needs of non-state-owned real estate companies. Further, local governments should help bankrupt real estate companies conduct co-benefit debt financing to avoid unfinished properties.

Second, the government should strengthen its risk-based oversight of small and medium-sized banks, and local governments should be held responsible for the improper handling of financial risks. In response to the competition for real estate loan market share among small and medium-sized banks in some regions, oversight should be strengthened for banks with high new real estate development loans. Regulators should require banks to use multiple channels to replenish their capital to enhance their risk absorption capacity. In addition, local governments should maintain

local financial stability by meeting their responsibilities for oversight, management and risk disposal of local financial organizations.

Use of AI tools declaration

No artificial intelligence (AI) tools were used in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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