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Urbanization and the excess mortgage risk – an optimal mortgage model

Hongxia Zhang[1] & Heeho Kim[2]✉

This study investigates the optimal mortgage level and examines the impact of urbanization on the risk of excessive mortgage loan in China's housing markets. We propose a new model to theoretically derive and measure both the optimal mortgage level and the degree of urbanization across different regions of China. The paper tests two hypotheses: first, whether urbanization directly increases the risk of excess mortgages, and second, whether urbanization indirectly contributes to this risk through its effect on housing prices. Using a fixed-effects model for panel data analysis, the generalized method of moments (GMM), and monthly data from 25 regional provinces in China spanning from 2007 to 2019, our results provide strong evidence in support of these hypotheses. The impact of urbanization varies across regions, suggesting that distinct policy interventions may be needed for different regional housing markets.

[1] School of Economics, Shandong Normal University, 88 East Wenhua Road, Jinan, Shandong, China. [2] School of Economics and Trade, Graduate School Department of International Trade, Kyungpook National University, Daehak-Ro 80 Bukgu Daegu, South Korea. ✉email: kimhh@knu.ac.kr

Introduction

Urbanization has spatial implications for human capital by facilitating the dissemination of knowledge and technology exchange among diverse groups, resulting in the concentration of educated people in cities. It consequently will lead to a higher demand for urban housing demand, causing prices to rise (Wang et al. 2017). According to the National Bureau of Statistics of China (2023), the average housing price increased from 260.08 US dollars in 2000 to 1600.43 dollars per square meter in 2021. The urbanization rate has increased from 36.22% in 2000 to 64.72% in 2021, in tandem with the ongoing development of the Chinese economy.

The research question is whether this positive effect of urbanization on housing prices in China would rapidly increase household debt. According to the Financial Stability Report (2019) released by the People's Bank of China, total household debt increased from 23.5% of GDP in 2009 to 55.2% in 2019. This figure is significantly higher than the average of 43.1% observed in other emerging markets. The rapid increase in household debt is primarily due to a rise in housing mortgage loans (Funke et al. 2023). China's financial institutions have an excessively high concentration of credit in the real estate sector. Rapid growth in household debt may make China's real estate, credit, and financial markets unstable, thereby decelerating its economic growth.

Many studies have examined the relationship between urbanization and housing prices (e.g., Gonzalez and Ortega, 2013; Accetturo et al. 2014; Degen and Fischer, 2017; Liu et al. 2022; Garriga et al. 2023). However, few studies have focused on the effects of urbanization on the risk of excess house mortgages in China. To determine the excessiveness and risk of the household mortgage, it is crucial to determine its optimal level based on a rigorous theoretical framework and examine it using stringent evidence. To the best of our knowledge, there is a lack of comprehensive research on the optimal mortgage level and the role of urbanization in determining excess mortgage risk in the Chinese housing markets.

This study fills this research gap in the literature. To do so, the first step involves exploring a new model to theoretically derive and measure an optimal level of mortgage and the degree of urbanization across regions of China. Next, this study tests two hypotheses regarding whether urbanization directly drives an increase in the risk of excess household mortgages over the optimal level and whether urbanization indirectly increases the risk of excess mortgages through changes in housing prices. Using the fixed effect model of the panel analysis, the generalized method of moments (GMM), and monthly data from 25 regional provinces in China from 2007 to 2019, this study empirically examines the effects of urbanization on the risk of excess mortgages. The evidence strongly supports our hypothesis that the advent of urbanization increases the risk of excess household mortgages over its optimal level, both directly and indirectly, through a rise in housing prices. The effects of urbanization vary across various regions in China, implying distinct policy implications for the different regional housing markets.

The mechanism at work is straightforward: enhancing urbanization causes the population to increasingly migrate to cities, thereby increasing housing demand and prices. As housing prices rise, optimal mortgages decrease, whereas excess mortgages increase in the model. According to theory, the risk of excess mortgages increases as a result.

This study may not be unique in investigating the significance of financial risks derived from the risk of excess mortgages in Chinese housing markets (e.g., Jiang et al. 2021). This study is distinct from previous ones because it offers a theoretical background for determining the optimal level of household mortgage and its excessiveness. Moreover, it contributes to the literature by examining the impact of urbanization on the recent increase in excess mortgage risk across various regions of China. This issue is especially relevant considering the rapid growth of financial risks over time, particularly in China, along with other emerging markets, with a fast-growing economy and relatively limited financial market depth.

This study consists of six sections. Section 2 explains the short literature review. Section 3 provides research methods for developing a theoretical model of the optimal mortgage loan. This section also includes the formulated hypotheses and detailed data descriptions. Section 4 employs panel analysis and the GMM method to test the hypothesis concerning the relationship between urbanization, the risks associated with excess mortgages, and housing prices. Section 5 presents a discussion. The last section summarizes the policy implications for the stability of China's domestic and financial markets.

Literature review

Evidence from the U.S. and European countries indicates that the demographic impact of migrants would boost housing demand (Saiz, 2007; Gonzalez and Ortega, 2013; Sá, 2015). The increase in urbanization has led to a significant influx of new urban population, resulting in a growing demand for urban housing; consequently, this has caused a rise in housing prices. Many existing works of literature have focused on analyzing the relationship between urbanization and housing prices from population migration and labor mobility perspectives. For example, Degen and Fischer (2017) examined the relationship between migration flows and housing prices in 85 regions of Switzerland from 2001 to 2006. They discovered that a 1% increase in immigration to a specific area resulted in a 2.7% increase in the price of single-family houses. Gonzalez and Ortega (2013) analyzed the impact of immigration on housing prices and residential construction activity in Spain between 2000 and 2010. They demonstrated that the population inflow increased housing prices by approximately 25% and accounted for 50% of the construction of new housing units. Furthermore, Saiz (2003), Akbari and Aydede (2012), and Accetturo et al. (2014) demonstrated that population migration would cause significant changes in housing prices.

Unlike international immigration, migration in China occurs among different regions, with large or coastal cities as the primary destinations. The literature on China's housing market indicated that urbanization positively affects housing prices. Using the data of the population sampling survey in 2005 and the sixth population census in 2010, Wang et al. (2017) revealed that a 1% increase in the level of urbanization in China drove up housing prices by 0.343%. Chen et al. (2011) and Chen et al. (2019) proved that urbanization and population migration across provinces would affect significantly house prices in China. Using a general dynamic model, Garriga et al. (2023) found that the process of structural transformation and the resulting urbanization are essential drivers of housing price trends in China. Similar results were reported by Liu et al. (2022).

Many studies have examined the effect of government policies on housing prices from macroeconomic regulation, purchase restrictions, loan restrictions, and taxation. Li and Li (2024) and Li et al. (2022) showed that administrative factors among key economic and environmental factors most significantly affect housing prices in China. Du and Zhang (2015), Li et al. (2017), Sun et al. (2017), Lu et al. (2021), and Chang et al. (2024) discovered that housing purchase restrictions could reduce housing prices in China. Yan and Ouyang (2018) examined the effects of China's house-sale restriction policy and found that this policy reduces housing prices in the short term.

However, some literature argues that these government policies can curb the irrational rise in housing prices in the short run, but have little effect in the long run. For example, Deng et al. (2023) showed that real estate tax cannot be used to regulate house prices in China. Hu (2022) tested the effects of government policies on housing prices in China and found that land policy had the most significant effect on housing prices, followed by monetary policy. In contrast, fiscal policy based on loan-to-value has limited effects. Jia et al. (2018) found that the purchase restriction policy in the city of Guangzhou led to an increase in housing prices.

Several studies have discovered a significant positive relationship between house prices and mortgage debt. For example, Cloyne et al. (2019) examined the impact of house prices on household borrowing by analyzing administrative mortgage data from the United Kingdom. They established that a 10% increase in individual house prices would lead to a 2% to 3% increase in borrowing. Similarly, Basten and Koch (2015) analyzed the causal effect of housing prices on mortgage demand and supply in Switzerland by exploiting exogenous shocks to immigration and, thereby, to housing prices. They found that a 1% increase in house prices corresponds to a 0.52% increase in mortgage amounts. Kartashova and Tomlin (2017) used quantile regression analysis to find a significant positive relationship between regional housing prices and total household debt. Further, Anundsen and Jansen (2013), Mian and Sufi (2011) and Dajcman (2020) showed that house prices are positively associated with residential mortgage market activity. Meanwhile, in identifying the determinants of demand for housing mortgage loans, some empirical literature discovers that house prices, income, and interest rates are essential factors that affect residential mortgage demand (e.g., Nobili and Zollino, 2017; Dajcman, 2020).

Many researchers have found that a significant rapid expansion of household debt often precedes financial crises. For example, Reinhart and Rogoff (2011) demonstrated a consistent pattern of private debt surges preceding banking crises. Using data from 17 developed economies since 1987, Jordà et al. (2016) demonstrated that mortgage loans as a share of GDP rose significantly before the financial crisis. Mian et al. (2017) extended the sample data to 30 countries using household debt data from the Bank for International Settlements database. Their findings indicated that an increased household debt-to-GDP ratio led to a decrease in subsequent GDP growth. Similarly, Schularick and Taylor (2012), Drehmann and Juselius (2014), and Jordà et al. (2015) discovered that credit growth, especially mortgage credit growth, predicts financial crises. Adelino et al. (2016), Mian and Sufi (2011), and Mian et al. (2015) documented the relationship between U.S. household debt and the severity of the 2007–2009 crisis. Di Maggio et al. (2017), Donaldson et al. (2019), and Jones et al. (2022) demonstrated that real economic disruptions are associated with high household debt.

The credit of Chinese financial institutions is excessively concentrated in the real estate industry. Fluctuations in housing prices may result in systemic credit risks, which can destabilize the banking industry and further undermine the overall stability of the macroeconomy. However, the existing literature is limited to research on the factors influencing household debt behavior, such as demographics and household characteristics. In addition, previous literature focuses on examining the relationship between population immigration through urbanization and housing prices. Few studies have focused on the effects of rapid urbanization on the risk of excess household mortgages in China. To determine the excessiveness and risk of the household mortgage, it is necessary to determine its optimal level through both theoretical and empirical means. This study fills this research gap in the literature by exploring a new model to theoretically derive and empirically measure an optimal level of mortgage and the degree of urbanization across regions of China.

Research methods

Model of optimal mortgage loans. Based on the housing demand model by Stein (1995), we aim to present a theoretical approach to derive the optimal level for a household's mortgage loan. In this study, optimal mortgages are derived from the equilibrium of the housing market.

The model has three time periods: 0, 1, and 2. At the start of period 0, each family has one house; however, the level of outstanding mortgage debt owed by each family varies. In period 1, if the families desire to relocate to a new house closer to reputable schools, companies, and new jobs, they must sell their current house and repay all the outstanding debt. Having a substantial mortgage loan can limit the family's ability to relocate to a new house due to liquidity constraints. Subsequently, a new house will be purchased through a down payment. Housing consumption is subject to income restrictions, which vary based on the size of the initial mortgage debt.

Suppose the initial mortgage debt is minimal. In that case, there will be no liquidity constraint restricting the family from relocating, and they can purchase a new house by paying the full amount upfront. The model incorporates housing demand scenarios with and without a down payment. If there is a significant mortgage debt, the house will be purchased with a down payment to address liquidity constraints.

Within the model, each family's consumption comprises housing consumption (H) and consumption of composite goods (C) without the house. Because each family endowed with a house has a different outstanding mortgage debt after selling the old house, the family's net liquid asset is $P - K$, where P is the house price and K is the mortgage debt. Families earn labor income at a time between 1 and 2 and allocate it towards either consuming one unit of goods or repaying their mortgage debt. The model assumes that the family's utility function follows the Cobb–Douglas utility function.

$$U = U(H, C) = H^{\alpha}C^{1-\alpha} \tag{1}$$

If the family's mortgage debt is relatively low, a family's income constraint is as follows:

$$PH + C \le Y, \tag{2}$$

where P is the house price, H denotes the housing consumption, C is goods consumption, and Y denotes the total income. The price of C is normalized to 1; thus, all the variables are real terms. The demand for housing without a liquidity constraint (H^u) and goods (C) are obtained using the family's utility function and income constraint. Housing demand (H^u) increases as income increases or housing prices decrease.

$$H^u = \frac{\alpha Y}{P}, C = (1-\alpha)Y \tag{3}$$

A liquidity constraint exists when transitioning to a new house at time 1 if the mortgage debt (K) for the initial house is substantial. The family sells the existing house and repays the outstanding mortgage debt, then utilizes the remaining money to make the down payment for a new house. If the new house cost is PH, the down payment must be at least γPH, where γ denotes the down payment ratio. The down payment must be less than the family's net liquid assets following the down payment requirement. The down payment's constraint is given by

$$\gamma PH \le P - K \tag{4}$$

where γ represents the down payment ratio, with $0<\gamma<1$, and K denotes the initial mortgage loan. From Eq. (2), we can obtain the

housing demand if there is a liquidity constraint.

$$H^c = \frac{P-K}{\gamma P}. \quad (5)$$

H^c refers to the housing demand with a liquidity constraint. The larger the mortgage, the greater the liquidity constraint and the lower the housing demand. K and γ determine the relationship between housing prices and demand considering the liquidity constraint. If γ increases, the value of the down payment increases, and the demand for housing decreases.[1]

The total demand for housing is the sum of the housing demand with and without liquidity constraints; it is shown in Eq. (6) as the weighted average of the ratio of purchasing a house without a mortgage $(1-\theta)$ and the ratio of purchasing a house with a mortgage (θ).

$$H^d = (1-\theta)H^u + \theta H^c = \frac{(1-\theta)\alpha Y}{P} + \frac{\theta(P-K)}{\gamma P} \quad (6)$$

This demand is a function of the house price, mortgage, and income while assuming a constant preference for housing (α) and a specific percentage of the down payment (γ). The housing supply (H^s) is determined by the house price and the construction cost, assuming $H^s = H$. In the housing market equilibrium, $H^d = H^s = H$, and the equilibrium house price can be derived.

The optimal mortgage (K^*) at the housing market equilibrium is a function of income (Y) given the equilibrium house price (P^*).

$$K^* = \lambda\gamma\alpha Y - P^*\left(\frac{\gamma}{\theta}H - 1\right) \quad (7)$$

$\lambda = \frac{(1-\theta)}{\theta}$ is a ratio of purchasing a house without a mortgage to purchasing a house with a mortgage. By differentiating Eq. (7) for income and equilibrium housing prices, the effects of the two variables on the optimal mortgages can be obtained: $\frac{dK^*}{dY} = \lambda\gamma\alpha$ and $\frac{dK^*}{dP^*} = -\left(\frac{\gamma}{\theta}H - 1\right)$. An increase in income will lead to an increase in the optimal mortgage due to increased demand for a housing market equilibrium. At equilibrium, a high house price indicates high demand in the housing market and low liquidity constraints. The optimal mortgage level should be low. Thus, the relationship between housing prices and optimal mortgages in the market equilibrium is negative.

The optimal mortgage level in Eq. (7) is determined solely by housing prices and income at market equilibrium. Therefore, the mortgage loan will not align with the optimal level when house prices deviate from their equilibrium value. Specifically, housing prices in China are largely influenced by government policies. When these policies keep house prices below their equilibrium level, the resulting distortion accelerates the imbalance, causing mortgage levels to exceed the optimal amount.

Our model does not explicitly demonstrate the effect of interest rate on the optimal mortgage in Eq. (7). Instead, the optimal mortgage of each family is determined solely by housing prices and income at the market equilibrium condition. However, the interest rate represents the costs associated with actual mortgage loans; therefore, the relationship between the actual mortgage (K) and interest rate (i) should be negative, that is, $K = K(i)$. We denote the excess house mortgage as EK by subtracting the optimal mortgage $K^*(Y, P^*)$ from the actual loan $(K(i))$; $EK = K(i) - K^*(Y, P^*)$ is a function of interest rate, income, and house price, given the housing supply, down payment ratio, and preference. Urbanization may directly impact excess mortgages as a shifting parameter and indirectly through fluctuations in housing prices.

The effects of income and housing prices on the optimal mortgage have a leverage effect due to the down payment ratio, given a constant housing preference. As the down payment ratio increases, the income effect on optimal mortgage loans increases while the price effect decreases. The difference between housing demand with and without a down payment in the model is divided into two cases—with and without liquidity constraints—considering the initial size of mortgage loans. Thus, identifying the level of initial mortgages that causes the liquidity constraint in the model is necessary. For this purpose, mortgages that distinguish between housing demand with and without the liquidity constraint can be derived by setting a loan level to match $H^c = \frac{P-K}{\gamma P} = \frac{\alpha Y}{P} = H^u$.

Hypothesis and data. Theoretically, improving urbanization causes population and human capital to increasingly migrate to cities, thereby increasing income, housing demand, and housing prices. As housing prices increase, optimal mortgages decrease while excess mortgages increase. As a result, the risk of excess mortgages increases. This study tests two hypotheses. First, does urbanization directly drive the increase in the risk of excess mortgages? Second, does urbanization indirectly cause an increase in the risk of excess mortgages through changes in housing prices?

Equations (8)–(10) are formulated to test our hypothesis by considering the level of optimal mortgage in Eq. (7). This study utilizes house price as a mediating variable to examine the relationship between urbanization and excess mortgage risk. The degree of excess mortgages (EK) is initially measured by subtracting the estimated optimal mortgage $(\widehat{K_{it}^*})$ from the actual loan (K_{it}); $EK_{it} = K_{it} - \widehat{K_{it}^*}$.

$$\left(\frac{EK}{Y}\right)_{it} = \beta_0 + \beta_1 Urbanization_{it} + \sigma X_{it} + \delta_i + \varepsilon_{it} \quad (8)$$

$$P_{it} = \theta_0 + \theta_1 Urbanization_{it} + \eta X_{it} + \delta_i + \varepsilon_{it} \quad (9)$$

$$\left(\frac{EK}{Y}\right)_{it} = \gamma_0 + \gamma_1 Urbanization_{it} + \gamma_2 P_{it} + \varphi X_{it} + \delta_i + \varepsilon_{it} \quad (10)$$

where $\left(\frac{EK}{Y}\right)_{it}$ is the degree (risk) of excess mortgages to a city i over its income level. Subscripts i and t refer to the city and time, respectively. $Urbanization_{it}$ represents a degree of urbanization in each city; X_{it} represents a set of control variables, including housing supply (h_{it}), interest rate (i_{it}), and down payment ratio times housing price $(r * P_{it})$; P_{it} is a house price that is applied as a mediating variable for the indirect effect of urbanization on excess mortgage risk and Y_{it} refers to the gross regional domestic product (GRDP) per capita. δ_i is the individual fixed effect and ε_{it} is the error term.

By employing panel analysis and monthly data from the 25 provinces in China from January 2007 to December 2019, we aim to measure the degree of excessiveness of household mortgages. Subsequently, we seek to estimate the impact of urbanization on the risk of excess mortgage loans. The 25 provinces were selected based on data availability. The 25 provinces and cities include Beijing, Shanghai, Tianjin, Hebei, Jiangsu, Fujian, Liaoning, Zhejiang, Shandong, and Guangdong in the Eastern region; Shanxi, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan in the Central region; and Chongqing, Sichuan, Guizhou, Yunnan, Gansu, Guangxi, Shaanxi, and Ningxia in the Western region.

Urbanization is measured by the ratio of the urban population to the total population. The ratio of the built cubic meter housing sizes to those of sold houses is used as a proxy variable for housing supply. The data for regional housing prices,

Table 1 Definition of the selected variables.

Variable name	Variable notation	Measurement
Risk of excess mortgage loans	$\frac{EK}{Y}$	The risk of excessive mortgages in the city *i* over its income level at time *t*. Excess mortgages (*EK*) are measured by subtracting the estimated optimal mortgage from the actual loan
Urbanization	*Urbanization*	Proportion of urban population to total population
Housing price	*p*	The logarithm of residential house price
Housing supply	*h*	The ratio of the built cubic meter sizes of houses to the sold ones of houses
Interest rate	*i*	Interest rate
Down payment ratio	*r*	Down payment ratio

Sources: Data on regional urbanization, housing prices, GRDP per capita, and down payment ratios are obtained from the National Bureau of Statistics of China; data on regional house loans and interest rates are obtained from the People's Bank of China; and data on housing supply are obtained from the China Economic Net Statistics Database.

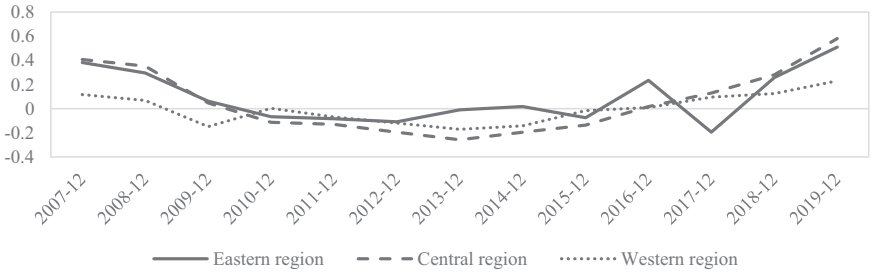

Fig. 1 Risk of excess mortgages (*EK/Y*) by regions in China.

urbanization, GRDP, and the ratio of down payments were obtained from the National Bureau of Statistics of China. The data for regional mortgages and their interest rates were obtained from the People's Bank of China. The data for the built cubic meters and sold houses were obtained from the China Economic Net Statistics Database. The selected variables are defined in Table 1.

Figure 1 shows the average trend of the risk of excess mortgages (*EK/Y*) by region. The risk of excess mortgages decreased in all three regions between 2007 and 2014 and has increased since 2014. The government began reinforcing housing market regulations in 2010. It adopted housing purchase restriction policies for major cities, which resulted in a gradual decline in housing prices. The lifting of the housing purchase restriction policy in 2014 resulted in a significant surge in housing prices and loans. China's Central Economic Work Conference in 2016 explicitly emphasized that the primary purpose of houses is for residential purposes, not for speculative investment. Additionally, several regions have intensified their regulation of real estate markets. Despite some degree of housing price control, they remained elevated and began to increase once more in 2018. Figure 1 shows that, at the end of 2019, EK/Y was 0.5103, 0.5808, and 0.2305 in the Eastern, Central, and Western regions, respectively. However, China's real estate market and real economy face economic uncertainty due to COVID-19 and economic stagnation. Identifying and quantifying the risk of the excess housing mortgage and its determinants is vital to prevent its financial risk.

Table 2 provides the descriptive statistics of the variables utilized in estimating our empirical framework. The regions in China were divided into three major regions—Eastern, Central, and Western—based on the classification standard of the National Bureau of Statistics of China. This division is based on the fact that, due to geographical advantages and first-mover advantages in policies in economic reforms, the Eastern region has enjoyed greater benefits than the Central and Western regions regarding industrial capital and factor aggregation. The economic development level and degree of urbanization in the Eastern region are significantly higher than in the Central and Western regions. According to the National Bureau of Statistics of China, the Eastern region's GDP per capita (urbanization rate) was 14,448 US dollars (74%), which is higher than 8200 US dollars (59%) in the Central region and 7584 US dollars (57%) in the Western region, respectively. Regional mortgage sizes exhibited a consistent upward trend from January 2007 to December 2019, while housing prices also experienced growth.

Table 2 Descriptive statistics of the data.

Variable	*N*	Mean	Std. Dev.	Minimum	Maximum
Panel A: Full sample					
Urbanization	3900	0.5634	0.1436	0.2825	0.8958
Y	3900	8.1055	0.5926	6.3737	9.5526
p	3900	8.5994	0.5871	5.1514	10.8554
i	3900	6.0420	0.9593	4.8834	7.9574
h	3900	0.6171	0.2931	0.0053	5.1843
Panel B: Eastern region					
Urbanization	1560	0.6813	0.1333	0.4026	0.8958
Y	1560	8.5466	0.4559	7.1565	9.5526
p	1560	9.0210	0.5989	7.6785	10.8554
h	1560	0.6800	0.3088	0.1101	3.9386
Panel C: Central region					
Urbanization	1092	0.5063	0.0707	0.3434	0.6461
Y	1092	7.8804	0.4190	6.8170	8.8370
p	1092	8.3237	0.3835	5.1514	9.2209
h	1092	0.6060	0.2769	0.0053	2.9184
Panel D: Western region					
Urbanization	1248	0.4661	0.0903	0.2825	0.6822
Y	1248	7.7510	0.5205	6.3737	8.8004
p	1248	8.3137	0.3605	7.1038	9.1996
h	1248	0.5481	0.2692	0.0384	5.1843

Sources: Data on regional urbanization, housing prices, and GDP per capita are obtained from the National Bureau of Statistics of China; data on regional house loans and interest rates are obtained from the People's Bank of China; and data on housing supply are obtained from the China Economic Net Statistics Database.
Y is the logarithm of gross regional domestic product (GRDP) per capita, *p* is the logarithm of housing prices, and *h* is the housing supply.

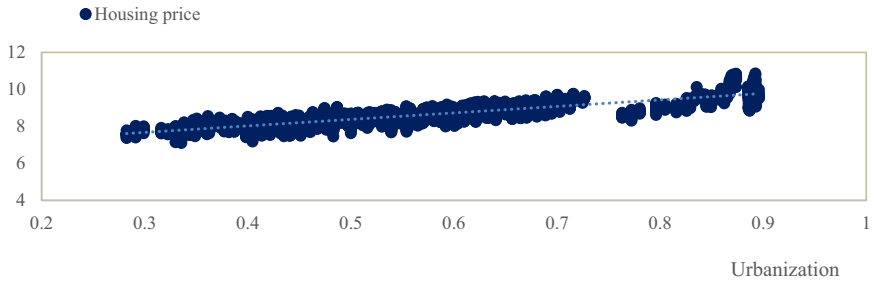

Fig. 2 Relationship between urbanization and housing prices in China. Notes: Housing prices are their logarithms; urbanization is the proportion of the urban population to the total population.

Table 3 Estimation results of the effects of urbanization on excess mortgage risk.

Variables	(1) $\left(\frac{EK}{Y}\right)_{it}$	(2) p_{it}	(3) $\left(\frac{EK}{Y}\right)_{it}$
$Urbanization_{it}$	1.2389*** (0.1607)	1.4616*** (0.0612)	0.7453*** (0.1624)
p_{it}			0.3377*** (0.0716)
i_{it}	−0.0652*** (0.0078)	−0.0873*** (0.0022)	−0.0357*** (0.0101)
h_{it}	0.0767*** (0.0223)	0.0015 (0.0052)	0.0762*** (0.0222)
rp_{it}	−0.1812*** (0.0180)	0.4989*** (0.0065)	−0.3497*** (0.0438)
Const.	0.9178*** (0.1514)	4.6728*** (0.0319)	−0.6600* (0.3663)
R^2	0.0641	0.9491	0.0707
Observations	3900	3900	3900
No. of provinces	25	25	25
Hausman Test	27.58 [0.0000]	386.37 [0.0000]	26.83 [0.0000]

Notes: Robust standard errors are in parentheses. *, **, and *** are significant at the 10%, 5%, and 1% levels, respectively. [] is the *p*-value of the Hausman test.

Increased urbanization causes multiple people to migrate to the cities, thus increasing housing demand. Figure 2 depicts a scatterplot of the relationship between urbanization and housing prices, illustrating that urbanization increases as housing prices rise.

Empirical results

This section uses panel analysis and the GMM method to empirically test our hypothesis regarding urbanization's direct and indirect effects on the risks of excess mortgages due to increasing housing prices. The Hausman test is a statistical test used to determine the most suitable model between the fixed and random effects models. If the null hypothesis is rejected, it is recommended that the fixed effects model be used for estimation. The results of the Hausman test demonstrate that the *p*-values are 0.0000, implying that the fixed effects model is the more effective and appropriate model for testing our hypothesis. Table 3 shows the estimation results of the panel analysis using the full sample data. Column (1) in Table 3 displays the estimation result of Eq. (8) without the mediating effect of housing prices. The urbanization coefficient exhibits a statistically significant and positive relationship at the conventional level. This finding supports our first hypothesis that the development of urbanization can significantly and positively influence the risk of excess mortgage loans.

Columns (2) and (3) present the test results of Eqs. (9) and (10). The regression coefficient for urbanization on housing prices is both statistically significant and positive, indicating that the advancement of urbanization has significantly impacted the increase in housing prices. This result aligns with previous works in the literature (e.g., Gonzalez and Ortega, 2013; Wang et al. 2017; Chen et al. 2019; Liu et al. 2022; Garriga et al. 2023). The regression coefficients of urbanization and housing prices on the risk of excess mortgages are statistically significant. This observation indicates that urbanization can significantly impact the risk of excess mortgages, both directly and indirectly, through changes in house prices. These results strongly support our second hypothesis.

The improvement of urbanization results in population increase and enhances human capital, resulting in higher income and increased consumption within the city. Consequently, house prices would increase (Wang et al. 2017; Garriga et al. 2023). Based on the theory, the optimal mortgage will decrease as housing prices increase and excess mortgages increase. This increases the risk of excess mortgages in the housing and financial markets. This evidence supports the empirical findings of Dajcman (2020), Cloyne et al. (2019), Jordà et al. (2016), and Mian and Sufi (2011).

Table 3 shows that the effects of the housing supply (h_{it}) and interest rate (i_{it}), and the cross-effect of the down-payment ratio (rp_{it}) are statistically significant at the conventional significance level. These results indicate that the housing supply, interest rate, and down payment ratio are essential factors in determining the level of risk associated with excess mortgages in China. The rise in interest rates increases house-building costs and, thus, reduces the housing supply. Additionally, it negatively affects the actual household mortgages borrowed. This is consistent with the findings of Dajcman (2020), that an increase in residential mortgage interest rate is negatively associated with changes in the demand for residential mortgage loans. A higher ratio of down payment will reduce housing demand and prices, which, in turn, will reduce the risk of excess mortgage loans.

The sample data can be classified into three regions to identify regional disparities. Table 4 shows the estimation results for the Eastern, Central, and Western regions. The empirical results in columns (1) and (2) show that urbanization in the Eastern region significantly positively impacts the risks of excess mortgages

Table 4 Estimation results of panel analysis among the three geographical locations.

Variables	Eastern region		Central region		Western region	
	(1)	(2)	(3)	(4)	(5)	(6)
	p_{it}	$\left(\frac{EK}{Y}\right)_{it}$	p_{it}	$\left(\frac{EK}{Y}\right)_{it}$	p_{it}	$\left(\frac{EK}{Y}\right)_{it}$
$Urbanization_{it}$	1.1917*** (0.1852)	0.3925** (0.1745)	0.7716** (0.3084)	0.5223*** (0.1501)	1.4565*** (0.3533)	0.0560 (0.3719)
p_{it}		0.4610** (0.1973)		1.5746*** (0.5280)		0.3053 (0.2105)
i_{it}	−0.0991*** (0.0072)	−0.2122*** (0.0735)	−0.0959*** (0.0112)	0.1878** (0.0772)	−0.0711*** (0.0087)	−0.0463 (0.1395)
h_{it}	0.0293* (0.0168)	0.0830 (0.0562)	−0.0504** (0.0201)	0.4539*** (0.1225)	−0.0326 (0.0261)	0.1218 (0.0892)
rp_{it}	0.5442*** (0.0278)	−0.5036*** (0.1594)	0.5862*** (0.0292)	−1.4392** (0.5855)	0.4774*** (0.0379)	−0.3823*** (0.1397)
Const.	4.5905*** (0.1525)	0.9634 (0.7978)	4.4484*** (0.1117)	−4.0669*** (1.1136)	4.7483*** (0.0877)	0.5305 (2.1795)
R^2	0.9571	0.2921	0.9442	0.6249	0.8921	0.3365
Observations	1560	1560	1092	1092	1248	1248
No. of provinces	10	10	7	7	8	8

Notes: Robust standard errors are in parentheses. *, **, and *** are significant at the 10%, 5%, and 1% levels, respectively.

directly and indirectly through changes in housing prices. Urbanization substantially increases the risk of excess mortgages in China's Eastern region. Columns (3) and (4) report the estimated results for the Central region. The dissemination of positive information from the Central region's economic planning has attracted labor force inflows and increased housing demand. This has significantly impacted excess mortgage risk.

Meanwhile, in the Western region, the effects of urbanization and housing prices are not statistically significant, as indicated in columns (5) and (6) of Table 4. This indicates that the level of urbanization in the Western region is lower than in the other two regions. Urbanization in the Western region drives up housing prices significantly. However, unlike the other two regions, it does not affect the risk of excess mortgage loans. The Western region experiences significant population outflows, with several working-age laborers migrating to the developed Eastern cities (Zhou and Hui, 2022). This indicates that excess mortgage pressure is comparatively lower in the Western region compared to the Eastern and Central regions.

The current risk of excess mortgages may be influenced by previous periods, so this paper incorporates a lagged dependent variable into the baseline model, forming a dynamic panel data structure. To address the potential estimation bias caused by the inclusion of the lagged term, we use the Generalized Method of Moments (GMM) for regression analysis. GMM includes two approaches: system GMM and difference GMM. However, difference GMM is prone to bias due to weak instrumental variables. To overcome this, Blundell and Bond (1998) introduced system GMM, which has been shown to be more efficient. Thus, we apply the system GMM method to reexamine our hypothesis and test the robustness of our prior regression results (Shao et al. 2021; Lee et al. 2020; Khan, 2019).

The estimation results of the system GMM method are shown in columns (1)–(3) of Table 5, using the urban population to total population ratio as a proxy for measuring the level of urbanization. Columns (4)–(6) show the empirical results of the GMM regarding the effects of urbanization, as measured by the ratio of urban built-up area to administrative area (Jiang et al. 2022). The empirical results of the system GMM are robust and consistent with the empirical results of the previous panel analysis, irrespective of the utilization of different urbanization proxies. The regression results obtained from the system GMM indicate that the AR(2) statistics do not provide sufficient evidence to reject the null hypothesis, and the p values of the Hansen test are all above 0.10. Therefore, the null hypothesis cannot be rejected at the 10% significance level, indicating that the model is appropriate.

Table 5 shows that the effect of the one-period lagged excess mortgages $\left(\frac{EK}{Y}\right)_{it-1}$ is significantly positive; the excess mortgages from the previous period positively influence the current risk of excess mortgages. The effects of urbanization and housing prices are statistically significant at the conventional level. This indicates that the previous panel analysis is robust and consistent with the various proxies for urbanization and different methods.

Discussions

Endogeneity problems should be considered when estimating urbanization's impact on the risk of excess house mortgage. On the one hand, a bidirectional impact relationship may exist between urbanization and excess mortgage risk. On the other hand, the model setting may have the issue of omitted variables. Therefore, we select the one-period lagged value of urbanization as the instrumental variable (IV) and employ a fixed-effect two-stage least squares method (2SLS) to examine the effect of urbanization on excess mortgage risk (Jappelli and Pagano, 1994; Liu et al. 2022).

Table 6 shows the estimated results. In these results, the Kleibergen-Paap rk Wald F statistics (the weak identification test of instrumental variables) are 230,000, 230,000, and 140,000 for the three equations, respectively. These values are greater than 16.38 at the 10% maximal IV size of the Stock-Yogo test statistics, meaning that the IVs are not weakly identified and valid. The Kleibergen-Paap rk LM statistics are 945.774, 945.774, and 738.830, respectively, all with p-values of 0.000. They suggest that IVs are not under-identified. These results indicate that the IVs utilized in the panel 2SLS regression analysis are relevant and valid. The estimation results in Table 6 align with the previous results, implying that, even after controlling for potential endogeneity problems in the model, the estimation results of the panel analysis remain robust for the hypothesis tests.

Compared to the Western region, the relationship between urbanization and the risk of excess mortgages is more pronounced in the Eastern and Central regions, which have higher income and greater urbanization. However, at the conventional level, this relationship seems statistically insignificant for the Western region, which has a lower urbanization level. The classification of the demographic into the three regions indirectly supports our hypothesis.

Urban space is the most direct and obvious characteristic of the urbanization process. The ratio of urban built-up area to administrative area can be used to test the hypothesis instead of the ratio of urban population to total population as a proxy for the level of urbanization. This finding further confirms that the

Table 5 Robustness test results of the system Generalized Method of Moments (GMM).

Variables	(1) $\left(\frac{EK}{Y}\right)_{it}$	(2) p_{it}	(3) $\left(\frac{EK}{Y}\right)_{it}$	(4) $\left(\frac{EK}{Y}\right)_{it}$	(5) p_{it}	(6) $\left(\frac{EK}{Y}\right)_{it}$
$\left(\frac{EK}{Y}\right)_{it-1}$	0.1615*** (0.0062)		0.1591*** (0.0060)	0.3081*** (0.0216)		0.3027*** (0.0218)
p_{it-1}		0.9821*** (0.0057)			0.9668*** (0.0147)	
$Urbanization_{it}$	0.2835*** (0.0486)	0.0239*** (0.0074)	0.1208* (0.0638)	1.2198** (0.5025)	0.0496** (0.0248)	0.8839** (0.3985)
p_{it}			0.1778*** (0.0341)			0.3709*** (0.0824)
i_{it}	−0.0695*** (0.0050)	−0.0016*** (0.0004)	−0.0586*** (0.0036)	−0.0170 (0.0203)	−0.0004 (0.0007)	−0.0084 (0.0208)
h_{it}	0.0919*** (0.0189)	0.0001 (0.0003)	0.0924*** (0.0196)	0.2089*** (0.0230)	0.0018 (0.0016)	0.1954*** (0.0204)
rp_{it}	−0.0802*** (0.0125)	0.0092** (0.0043)	−0.2006*** (0.0305)	0.0535 (0.0359)	0.0303** (0.0143)	−0.2830*** (0.0454)
Const.	0.7463*** (0.0851)	0.0910*** (0.0173)	0.1191 (0.0885)	−0.8313 (0.5471)	0.0579** (0.0270)	−1.5113** (0.6549)
AR(2)	0.521	0.092	0.533	0.189	0.114	0.091
Hansen test (p-value)	0.157	0.117	0.156	0.137	0.396	0.141
Observations	3875	3875	3875	3875	3875	3875
No. of provinces	25	25	25	25	25	25

Notes: Robust standard errors are in parentheses. *, **, and *** are significant at the 10%, 5%, and 1% levels, respectively. The value reported for AR(2) is the p-value for the second-order autocorrelated disturbances in the first differences equations.

Table 6 Estimation results of the 2SLS method.

Variables	(1) $\left(\frac{EK}{Y}\right)_{it}$	(2) p_{it}	(3) $\left(\frac{EK}{Y}\right)_{it}$
$Urbanization_{it}$	1.4398*** (0.1615)	1.4429*** (0.0606)	0.8564*** (0.1670)
p_{it}			0.4043*** (0.0724)
i_{it}	−0.0606*** (0.0078)	−0.0878*** (0.0022)	−0.0251** (0.0100)
h_{it}	0.0769*** (0.0225)	0.0026 (0.0052)	0.0759*** (0.0223)
rp_{it}	−0.1876*** (0.0182)	0.4959*** (0.0064)	−0.3881*** (0.0438)
R^2	0.0680	0.9499	0.0781
Observations	3875	3875	3875
No. of provinces	25	25	25

Notes: Robust standard errors are in parentheses. *, **, and *** are significant at the 10%, 5%, and 1% levels, respectively.

increase in urbanization directly increases the risk of excess mortgages and indirectly increases housing prices.

To enhance the analysis of the effects of urbanization, we have selected the four major Chinese municipalities: Beijing, Shanghai, Tianjin, and Chongqing. The regression results demonstrate that the urbanization level in Beijing, Shanghai, and Tianjin, which are primarily situated in the Eastern region, has a significant positive effect on housing prices and the excess mortgage risk. In other words, urbanization indirectly affects excess housing mortgage risk by stimulating the increase in housing prices. In Chongqing, a municipality situated in the Western region of China, the urbanization process increases housing prices. However, it does not significantly affect the risk of excess mortgage loans. These results for the four major cities are also consistent with previous results. Urbanization, directly and indirectly, affects the excess mortgage risk in major Chinese cities with higher urbanization and income levels.

Conclusions and policy implications

The rise in the risk of excess household mortgages in the Chinese housing market poses a substantial threat to the stability of its credit and financial markets, potentially impeding its economic growth. Few studies have focused on the effects of rapid urbanization on the risk of excess housing mortgages in China. This study contributes to the literature by theoretically and empirically determining the optimal mortgage level.

Using a model of optimal housing mortgages, the panel analysis, and monthly data from 25 regional provinces in China from 2007 to 2019, our findings support our hypothesis. Rapid urbanization has directly and indirectly increased the risk of excess mortgages by driving up housing prices. Urbanization has heterogeneous effects in the three regions of China—the Eastern, Central, and Western regions. Evidence reveals that urbanization has significantly increased the risk of excess mortgage loans, particularly in China's Eastern region.

Urbanization in the Western region appears to impact the increase in housing prices significantly. However, unlike in the other regions, it does not affect the risk of excess mortgage loans. This indicates significant policy implications for the stability of Chinese housing markets. The pressure of excessive mortgages is lower in the Western region compared to the Eastern and Central regions. The relationship between the level of urbanization and the risk of excess mortgages is more pronounced in the Eastern region, which has higher income and a greater degree of urbanization.

China is currently experiencing multiple pressures, including reduced demand, supply shocks, and weakening expectations, due to factors, such as increasing global economic uncertainty. The real estate market has been exposed to downside risks. Many regions gradually loosened their control over the supply of housing mortgages to curb the decline in housing prices. However, the rapid growth of household debt in recent years, primarily consisting of housing mortgages, has brought the potential risks of the household sector to the forefront. Facilitating the supply of housing mortgages may exacerbate household debt and financial system risks. Thus, enhancing the efficacy of real estate regulation policies is imperative.

Our findings provide significant policy implications in several ways. First, the policy is essential for effectively regulating household sector loans' growth rate and structural distribution. It

aims to ensure that the issuance of household sector loans is linked to household income level or repayment ability to control the hidden risks associated with housing mortgage loans. Second, income is the basic support for mortgage demand and loan repayment. However, the growth rate of disposable income per capita of Chinese residents has consistently declined in recent years, thereby undeniably amplifying the risk associated with mortgages. Therefore, measures can be taken to improve household income growth rate, particularly for low-income households, by raising the minimum wage, ensuring a reasonable augmentation in wage income, and enhancing the entrepreneurial environment.

Third, the fluctuation of housing prices significantly contributes to the pressure on excess mortgages, and a sharp increase in excess mortgages may indicate impending financial crises. Therefore, to prevent financial risks due to the increase in excess mortgage loans, policymakers should aim to maintain housing prices within a stable range. Standardized housing market development is crucial for addressing household debt issues. Meanwhile, different economic policies and regulations regarding access to mortgages and housing prices must be tailored to various regions based on their level of urbanization and income. This is due to regional variations in pressure and the risk of excessive mortgages.

The limitation of this research is that it did not evaluate whether the recent economic policies are appropriate and efficient for the stability of housing markets in China, as indicated by this study. Future research should evaluate the appropriateness and efficiency of the recent stabilization policies of Chinese houses and financial markets.

Data availability

This published article and its supplementary information files include all data generated or analyzed during this study.

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Note

1 $P^* = \frac{\lambda\gamma\alpha Y - K}{(\frac{1}{\theta}H - 1)}$. The house price based on the down payment is $P = \frac{K}{(1-\gamma H^c)} > 0$, so $H^c \leq \frac{1}{\gamma}$.

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Author contributions

Both authors contributed to the conceptualization and writing of this article. HZ: Data curation, Statistical analysis, Software, Writing-Original draft preparation, and Writing-Reviewing and Editing. HK: Methodology, Writing-Original draft preparation, Validation, and Writing-Reviewing and Editing.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

Informed consent

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Additional information

Correspondence and requests for materials should be addressed to Heeho Kim.