Journal of Asian Economics 86 (2023) 101608

Contents lists available at ScienceDirect

Journal of Asian Economics

journal homepage: www.elsevier.com/locate/asieco

Macroprudential policy and household wealth inequality: Evidence from China

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ARTICLE INFO

JEL classification:
C61 D63 G28 R28

Keywords:
LTV ceiling
Household wealth inequality
OLG
Gini-RIF regression

ABSTRACT

The influence of LTV ceiling on household wealth inequality is not constant. This paper finds that when the return on housing investment is higher than the return on liquid assets, the LTV ceiling generally has a negative impact on household wealth inequality; otherwise, it is more likely to be positive. Increasing the LTV ceiling can significantly alleviate household wealth inequality in China. Housing price and the number of houses purchased are important channels, and the house purchase preference (savings rate and house purchase intention) plays a key role in regulating wealth distribution through the LTV ceiling.

1. Introduction

The financial crisis of 2008 caused academic circles and policy authorities to rethink traditional regulation policies. Consequently, macroprudential policies have attracted increasing attention in the reform of financial regulatory systems. From a macro- and countercyclical perspective, macroprudential policies take measures aiming to mitigate the systemic risks caused by the procyclical volatility of financial systems and cross-sectoral contagion and to maintain the stability of financial systems. In particular, in maintaining the stability of the real estate market, emerging market countries are more likely to resort to using macroprudential policy tools, such as the LTV ceiling ratios (caps on loan-to-value ratios, the upper limit of the housing loan-to-housing value ratios, referred to as the LTV ceiling) to regulate housing prices and thus defuse systemic risks in the time dimension. However, the impact of macroprudential policies on income and wealth inequality is not neutral, and the expansion of income and wealth inequality as a potential destabilizing factor weakens the effectiveness of macroprudential policy instruments, endangers the stability of the financial system, seriously affects the sustainable development of society, and can even trigger a financial crisis (Galbraith, 2012; Bazillier & Héricourt, 2014; Monnin, 2017). Therefore, national policy authorities should pay close attention to income inequality and wealth inequality and detect signs of potential financial instability in a timely manner.

In China, since the reform of the country's housing distribution system at the end of the 20th century, the prices of commercial housing have soared as excessive credit capital has flowed into the real estate market (Guo & Huang, 2018). With the increase in housing value, the contribution rate of housing wealth to household wealth inequality reached approximately 60% in 2007 (Liang et al., 2010). By 2017, this figure had exceeded 70% (Yang & Sun, 2019). As the most important form of household wealth, housing wealth inequality determines household wealth inequality to a certain extent (Yuan & Wang, 2013).

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https://doi.org/10.1016/j.asieco.2023.101608
Received 16 August 2021; Received in revised form 11 July 2022; Accepted 9 March 2023
Available online 13 March 2023
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A large number of studies show that macroprudential policies are effective in regulating housing prices, and the research perspectives can be divided into the macro and micro levels. At the macro level, the LTV ceiling and other macroprudential policy tools can effectively control the scale of mortgage loans to curb the excessive growth of house prices and the imbalance of the mortgage market (Liang et al., 2015; Ye, 2018; Meng et al., 2018; Pan & Zhou, 2019; Akinci & Olmstead-Rumsey, 2018; Morgan et al., 2018; Cerutti et al., 2017). At the micro household level, the implementation of macroprudential policies can effectively guide residents' credit behaviour, thus reducing the abnormal fluctuations of house prices and maintaining financial stability (Xu & Chu, 2016; Hong et al., 2018; Carpantier et al., 2018).

There are few studies on the impact of macroprudential policy on inequality. Stiglitz (2015) believes that wealth or income inequality is related to rent, land value and financial systems and thus that reducing collateral requirements and bank capital adequacy ratios should not lead to higher levels of overall economic efficiency but instead to more inequality. Frost and Van Stralen (2018) used sample data for 69 countries for 2000–2013 to conduct a panel regression analysis and found that countries with countercyclical capital buffers, concentration restrictions or credit growth restrictions tend to experience more income inequality. Carpantier et al. (2018) constructed an overlapping generation (OLG) model including LTV, housing price, bequest motive and other factors to study the impact of LTV on wealth inequality. Based on the data of the 2010 Eurosystem Household Finance and Consumption Survey (HFCS), they found that LTV has a significant positive correlation with wealth inequality. All the above studies show that the impact of macroprudential policy on income and wealth inequality is nonneutral. The expansion of income inequality and wealth inequality further exacerbate credit bubbles and credit market imbalances, jeopardize financial stability and even lead to financial crises (Galbraith, 2012; Bazillier & Héricourt, 2014; Kumhof et al., 2015).

Carpantier et al. (2018) explored the relationship between macroprudential policy and household wealth inequality based on household survey data of Eurozone countries. However, there are significant differences in the real estate market and household saving behaviour between China and Eurozone countries. In China, the real estate market has been booming for a long time, and housing investment yields have remained high. There is also a "mystery of a high savings rate" in China. In light of these puzzling phenomena, it is clear that more research into the relationship between the LTV ceiling and the household wealth inequality nexus is desirable. In developing an OLG model with liquid assets (savings, for example, represent a liquid asset) based on Carpantier et al. (2018), our model complements the existing models by highlighting the important role of liquid assets in individual utility. We find that the impact of LTV ceiling on household wealth inequality in different countries may be different. When the return on housing investment is higher than the return on liquid assets, the LTV ceiling generally has a negative relationship with household wealth inequality; otherwise, the relationship is more likely to be a positive effect. This conclusion reasonably explains why raising the LTV ceiling can alleviate household wealth inequality in China, but it has an aggravating effect in Eurozone countries.

The potential marginal contributions of this paper are as follows: (1) Theoretical model design. The paper discusses the impact of macroprudential policy on household wealth inequality under the relative size of the return on housing investment and the return on liquid assets. (2) Research perspective. The research on household wealth inequality in China is still in its infancy in terms of perspectives, contents and methods. Moreover, few studies use data on China's macroprudential policy to study the distribution of household wealth, so this paper presents a new perspective. (3) Mechanism research. Carpantier et al. (2018) believe that macroprudential policy has a greater impact on the rich than on the poor, so raising the LTV ceiling will aggravate household wealth inequality. However, in China, macroprudential policy has a greater impact on the poor. Housing price and housing quantity are important channels through which macroprudential policy produces an unbalanced wealth effect. Housing purchase preference (in this paper, savings rate and purchase intention are used as proxy variables of house purchase preference) plays an important moderating role in the impact of LTV policy on household wealth inequality.

2. LTV ratios and household wealth inequality in an OLG model

2.1. OLG model construction

Because the distribution of social wealth is significantly affected by the period of an individual's life, the notable advantage of OLG model is that it considers a clear intergenerational accumulation and transmission mechanism of wealth, which can describe the impact of wealth inequality by the life cycle effect. Therefore, this paper analyses the impact of the LTV ceiling on wealth inequality by constructing an OLG model. A detailed derivation of the model is shown in the Appendix A. Due to the differences in social security system and culture, households in Eurozone countries generally hold little or no liquid assets,[1] while households in China generally maintain a sizable amount of liquid assets. The preventive motivation is an important factor leading to high savings in China (Chamon & Prasad, 2010). Sufficient savings can provide the necessary liquidity to deal with emergencies, and the liquid assets held can be accessed quickly to save time, so it has a significant effect on households. Inspired by Sidrauski's monetary model (Sidrauski, 1967), this paper introduces "liquid assets" variables into the OLG model to investigate the impact of the LTV ceiling on household wealth inequality under the condition that the rate of return on housing investment is very different from the rate of return on liquid asset investment.

It is assumed that the life cycle of a representative individual includes two periods: adulthood and old age. To simplify the analysis, it is assumed that funds for adulthood are derived only from bequests and bank loans, which are mainly used for consumption, the

[1] In this paper, liquidity assets refer to assets with no transaction costs, such as current savings, fixed deposit with term less than one year and bank financing; illiquid assets refer to assets that carry a transaction cost, such as housing, retirement accounts.

purchase of housing and the holding of liquid assets; funds for old age come from the updated value of a house and the return on liquid assets, and funds are mainly used for consumption, the repayment of housing loans and children's inheritances. It is also assumed that each elderly individual has only one child and that there is no nonblood bequest.

Suppose that bank loans taken in adulthood are repaid in full in old age. The bank lends a share θ of the house's value (1-θ is the down payment ratio).

The budget constraints for adulthood and old age are

$$b_t + H_t p_t \theta = c_{1,t} + H_t p_t + m_t, \tag{1}$$

$$H_t p_{t+1} + m_t(1+\kappa) = c_{2,t+1} + H_t p_t \theta(1+r) + b_{t+1}. \tag{2}$$

Let $c_{1,t}$ and $c_{2,t+1}$ be consumption in adulthood and old age, respectively. Similarly, b_t and $b_{t+1}$are the bequests of periods t and t + 1, respectively. m_t is the value of liquid assets. H_t denotes housing units. p_t and p_{t+1} are the price per housing unit in period t and period t + 1, respectively, and $p_{t+1}/p_t = 1 + \pi$, π are return rates on housing. θ is LTV (ceiling).[2] r is the interest rate on a bank mortgage. The return on liquid assets expressed on the cumulative basis is $m_t(1+\kappa)$, and κ is the return rates on liquid assets.

It is worth noting that the focus of this paper is to study the impact of the LTV ceiling on household wealth inequality, and the focus of model building is not to describe the impact of the savings rate, wage level or inflation on household wealth in detail. Therefore, this paper continues with a similar budget constraint to use the same method as Carpantier et al. (2018), which does no include wage level, housing rental, inflation (the bequest variables are mixed with the influence of the wage level).

It is assumed that the utility level of a representative individual's life depends on consumption in adulthood, consumption in old age, liquid assets and bequests to children. In period t, the utility function[3] takes the following form:

$$U_t = \ln(c_{1,t}) + \beta \ln(c_{2,t+1}) + \gamma \ln(b_{t+1}) + \varphi \ln(m_t). \tag{3}$$

Here, β, γ and φ respectively represent the marginal utility elasticity of consumption, bequest motives and the value of liquid assets. There are three optimal values (H_t, m_t, b_{t+1}) of the maximum effect function (3):

$$H_t = \frac{(\beta+\gamma)(1+\pi-\theta(1+r)) - (\beta+\gamma+\varphi)(1+\kappa)(1-\theta)}{p_t(1+\beta+\gamma+\varphi)(1-\theta)((\kappa-r)\theta+\pi-\kappa)} b_t \tag{4}$$

$$m_t = \frac{\varphi(1+\pi-\theta(1+r))}{(1+\beta+\gamma+\varphi)((\kappa-r)\theta+\pi-\kappa)} b_t \tag{5}$$

$$b_{t+1} = \frac{\gamma(1+\pi-\theta(1+r))}{(1+\beta+\gamma+\varphi)(1-\theta)} b_t \tag{6}$$

There is an overlap between adults and the elderly in any period in the model. The net wealth in adulthood in any period t + 1 is the housing net wealth plus liquid asset holdings:

$$W_1 = H_{t+1}P_{t+1} - H_{t+1}P_{t+1}\theta(1+r) + m_{t+1} = \alpha_1 b_t, \tag{7}$$

where

$$\alpha_1 = \frac{\gamma(1+\pi-\theta(1+r))}{(1+\beta+\gamma+\varphi)^2(1-\theta)} \left(\frac{\varphi(\kappa\theta(1+r)+\pi-\kappa)}{(\kappa-r)\theta+\pi-\kappa} - \frac{(\beta+\gamma)(\theta(1+r)-1)}{1-\theta} \right)$$

In period t + 1, the net wealth of an elderly individual is the net housing price plus the updated value of liquid asset holdings:

$$W_2 = H_t P_{t+1} - H_t P_t \theta(1+r) + m_t(1+\kappa) = \alpha_2 b_t, \tag{8}$$

where

$$\alpha_2 = \frac{(\beta+\gamma)(1+\pi-\theta(1+r))}{(1+\beta+\gamma+\varphi)(1-\theta)}.$$

This paper uses Theil entropy (half the squared coefficient of variation) to describe wealth inequality. Inter-generational inequality is significantly affected by life-cycle effects, and within-generational is not affected by inequality arising from comparing the group of adult individuals with that of old individuals. (Carpantier et al., 2018), so this paper focuses on the impact of macroprudential policy

[2] When house price increases are high and the demand for housing is greater than the supply, the public borrows as much as possible to purchase property, the maximum amount of which is acceptable to banks, and the availability of housing is constrained by macroprudential tools (caps on LTV ratios), which are central to the impact of LTV ratios on household wealth inequality (Carpantier et al., 2018).

[3] Based on the analysis paradigm of Carpantier et al. (2018), the only reason for households to have a house is capital gains. The availability of housing is very important for households. In our model, the corresponding households have mortgage loans, that is, they already have housing. Because housing is a relatively illiquid asset and many people have only one house, this paper only adds the utility of liquid assets on the basis of Carpentier et al. (2018).

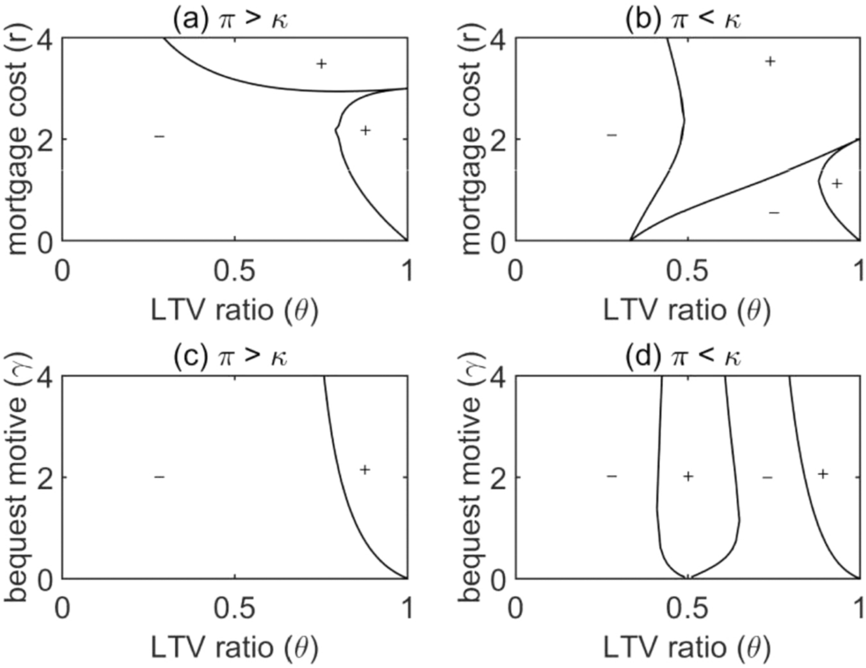

Fig. 1. Effects on within-household wealth inequality (I_W) with changes in the LTV ratio (θ).

on within-group inequality (Cowell, 1980; Bourguignon, 1979; Shorrocks, 1980). Because within-group inequality is not affected by the inequality arising from comparing the group of adult individuals with the group of old individuals, the expression of wealth inequality within a generation I_W is obtained as follows:

$$I_W = \frac{\alpha_1^2 + \alpha_2^2}{(\alpha_1 + \alpha_2)^2} A_1, \quad \text{where } A_1 > 0.$$

2.2. Comparative static analysis

This part mainly focuses on how household wealth inequality changes when LTV changes under equilibrium conditions. We calculated the following:

$$\frac{dI_W}{d\theta} = \frac{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa) - (\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi)+\gamma\theta r)}{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa) + (\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi+2\gamma)-\gamma\theta r)} 2\gamma\left(\beta+\gamma\right)\left(1+\beta+\gamma+\varphi\right)A_1$$

By virtue of $2\gamma(\beta+\gamma)(1+\beta+\gamma+\varphi)A_1 > 0$, this derives

$$Sign\left[\frac{dI_W}{d\theta}\right] = Sign\left[\frac{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa) - (\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi)+\gamma\theta r)}{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa) + (\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi+2\gamma)-\gamma\theta r)}\right]. \tag{9}$$

According to Carpentier et al. (2018), the parameters β, γ and φ are assigned as 0.9. Let $r = 1$ (which means that the principal and interest will be repaid by RMB 2 million at maturity, if the loan principal is RMB 1 million yuan). Set $\kappa = 2$ and $\pi = 3$ if $\kappa < \pi$,[4] and set $\kappa = 3$, and $\pi = 2$ if $\kappa > \pi$. A sensitivity analysis of the parameter values is also performed, and the results are still robust (as shown in the Appendix A). In Fig. 1, the positive area is represented by "+ ", and the negative region is represented by "-". The simulation analysis of Eq. (9) shows that the relative value of the return on housing investment and the return on liquid assets greatly shapes how the LTV ceiling affects wealth inequality. As shown in Fig. 1, the negative (positive) area indicates that there is a negative (positive) relationship between the LTV ceiling and household wealth inequality in this area. Fig. 1(a) - (b) shows the effect of the LTV ceiling on wealth inequality when combining the LTV ceiling with mortgage costs. When the combination of the LTV ceiling ratios and mortgage costs falls within the negative zone, this indicates that the LTV ceiling has a negative effect on wealth inequality. However, when their combination falls within the positive zone, the LTV ceiling has a positive effect on inequality. Similarly, as shown in Fig. 1(c)-(d), when

[4] In the past decade, the annual return rate of capital guaranteed bank financial products in China is generally between 2% and 5%, so the cumulative return of 30-year financial products is 80%– 322%, for example, $(1 + 3.73\%)^{30} = 1 + 200\%$, so let $\kappa = 200\%$. As shown in Fig. 2, during the period of 1998–2019, the average price of commercial housing in China has more than quadrupled; that is, the cumulative benefit is greater than the original (1 + 300%) times, so let $\pi = 3$.

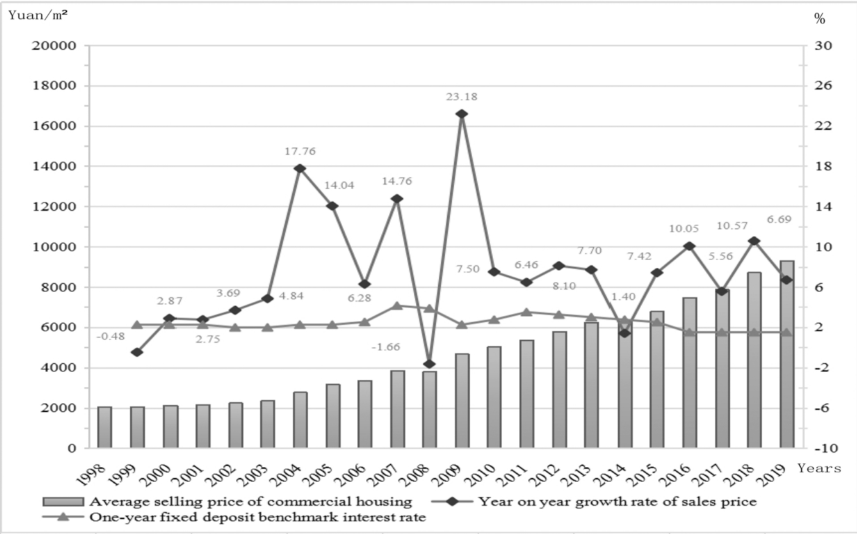

Fig. 2. Year-on-year growth of the average sales price and house price of commercial housing in China from 1998 to 2019.

the combination of the LTV ceiling and bequest motivation falls within the negative zone, the LTV ceiling has a negative effect on inequality. However, when this combination falls within the positive zone, raising the LTV ceiling aggravates household wealth inequality.

When$\pi > \kappa$, that is, the return on housing investment is greater than the return on liquid assets, Figures (a) and (c) show that the LTV ceiling has a more negative relationship with household wealth inequality, and an increase in the LTV ceiling enables households without a house or relatively poor households to buy housing. Because the proportion of housing in the total assets of households with low wealth is high, the increase in the total assets of high-wealth households is lower than that of low-wealth households, which leads to the overall decline of household asset inequality. In China, the mortgage cost is generally less than 2.16 (if the mortgage interest rate is 10% and the mortgage term is 30 years, the maximum interest to be paid is 2.16 times the principal). According to the credit policy over the years, the LTV ceiling is generally not more than 0.8. Combining Figures (a) and (c), it can be seen that the LTV ceiling has a negative relationship with household wealth inequality.

When $\pi < \kappa$, that is, the return on housing investments is less than the return on liquid assets, the probability that the LTV ceiling is positively correlated with household wealth inequality increases. Ordinary households do not have the incentive to buy housing quickly, nor do they have the means to increase wealth rapidly, while wealthier households have diversified wealth management. Under the different value ranges of mortgage costs and LTV ratios, the relationship between the LTV ceiling and household wealth inequality is uncertain, but overall, there is a positive relationship between them. The positive zone is expanding in Fig. 1(b) of the LTV ceiling and mortgage cost combination and Fig. 1(d) of the LTV ceiling and bequest motivation combination. This shows that raising the LTV ceiling is likely to exacerbate wealth inequality. This is consistent with the findings of Carpantier et al. (2018).

3. The practical application of China’s macroprudential policy in regulating the real estate market

3.1. China’s housing price trend

Since China’s real estate market reform in 1998, housing prices have continued to rise. According to the data from the National Bureau of Statistics in China, this paper sorted out the average sales price and housing price year-on-year growth rate of China’s commercial housing during 1998–2019, as shown in Fig. 2. Affected by the economy and regulated by policies, China’s housing price shows obvious stage characteristics, with negative growth in some years (such as 2008), but overall, the year-on-year growth rate of China’s housing price is relatively high. Under the influence of regulatory policies, the rise in housing prices has dropped significantly. However, according to the “survey report on the rate of return on real estate investment in China in the first half of 2018″, the average annual housing investment return rate also reached 11% in 2013–2018, which is far higher than the return rate of other assets in the same period.

In order to make a direct comparison between return on housing investment and the return on liquid assets, this paper selects the one-year fixed deposit benchmark interest rate announced by the Central Bank of China as the representative of the return on liquid assets. As shown in Fig. 2, the year-on-year growth rate of housing is basically much higher than the one-year fixed deposit benchmark interest rate.

Table 1
Summary of LTV ceiling ratios.

Date (Year)		First house (construction area/square metres)		Second house	Three or more houses
		more than 90	less than 90		
1995–1998		70%			
1999–2002		80%			
2003–2004		80%		Raise the down payment	
2005	Before Mar 17	80%		Raise the down payment	
	After Mar 18	80% in general cities; 70% in areas and cities where housing prices rise too fast			
2006	Before Jun 1	80% in general cities; 70% in areas and cities where housing prices rise too fast			
	After Jun 2	70%	80%	-	-
2007	Before Sep 27	70%	80%	-	-
	After Sep 28	70%	80%	60%	
2008		-	80%	-	
2009		80%		50%	-
2010		-		60%	
After 2011		Specific regulation varies from city to city			

Note: the data were collected by the author, and "-" means that no specific data or policies were found.

3.2. The practical application of China's LTV ceiling in regulating the real estate market

The LTV ceiling is one of the most frequently used macroprudential policy tools in China. According to the "Interim Measures for the Administration of Commercial Banks' Self-running Housing Loans" (1995), "Measures for the Administration of Personal Housing Loans" (1998), "Suggestions on Encouraging Consumer Loans" (1999), "Notice on the Adjustment of Commercial Banks' Housing Credit Policy and Interest Rates on Excess Reserve Deposits" (2005), "Notice on the Adjustment of Housing Credit Policy" (2006), "Notice on Strengthening the Management of Commercial Real Estate Credit" (2007), "Full Text of the Notice on Promoting the Steady and Healthy Development of the Real Estate Market" (2010), and other relevant policies, we summarize the specific situation of China's implementation of LTV ceiling, as shown in Table 1. From 2005–2010, China implemented as many as nine LTV ceiling regulations, and the regulation of additional purchases beyond the first home was much stricter than the regulation of first home purchases.

4. Empirical model, variable selection and descriptive statistics

To test the relationship between the LTV ceiling and wealth inequality, we conduct an empirical analysis based on data from the China Household Finance Survey (CHFS) in 2017. The CHFS is a nationwide sampling survey project carried out by the China Household Finance Survey and Research Center (The China Household Finance Survey and Research Center is a public welfare academic research institution integrating data collection and data research established by Southwest University of Finance and Economics in 2010). The sample covers 29 provinces (autonomous regions and municipalities directly controlled by the central government), 355 counties (districts and county-level cities), 1428 village (neighbourhood) committees, and 40,011 households. The CHFS provides microscale information on household demographic characteristics, assets and liabilities, income and consumption, insurance guarantees, etc., to comprehensively reflect the basic conditions of household finance (Gan et al., 2013; Yin et al., 2014).

4.1. Theoretical model setting

Recentered influence functions (*RIF*s) is used as tools to analyze the impact of the distribution change of explanatory variables on the unconditional distribution of explained variable (Firpo et al., 2009). The application of RIF regressions for Gini coefficient was studied by Firpo et al. (2018).

Denote household net wealth $Y= [y_1, y_2,., y_n]$, where each y_i is the wealth of the *i*th person. The average wealth isμ. F_Y is the cumulative distribution function of *Y*. To measure the impact a change in the distribution of household net wealth will have on the Gini index *G* (It is well known that the Gini index *G* is a functional of F_Y), we can study the change of *G* caused by the change of cumulative distribution function from the observed distribution F_Y to the ex-post distribution T_Y. This change (T_Y-F_Y) can be understood as adding a new person with random wealth to the sample and changing the ranking of everyone in the sample.

$$Set\ T_Y = (1-\varepsilon)F_Y + \varepsilon H_{y_i}$$

where $\varepsilon \in (0,1)$ and the cumulative distribution function H_{y_i}can be defined as follows

$$\begin{cases} H_{y_i}(y) = 1,\ for\ y \in [y_i, \infty) \\ H_{y_i}(y) = 0,\ for\ y \in (-\infty, y_i) \end{cases}$$

In order to measure the impact of infinitesimally small changes in *Y* (more precisely, changes of distribution function of household net wealth) on *G*, one can use the influence function (*IF*) to describe the standard change of Gini coefficient. The *IF* of the Gini coefficient is introduced as follows (Monti, 1991; Gradín, 2016),

Table 2
Distribution and statistical characteristics of net household wealth and LTV (aged 18–59).

Region	Net household wealth unit: 10,000 yuan)									LTV (%)		
	N	Mean	Median	p10/p50	p25/p50	p75/p50	p90/p50	Mea/Med	Gini	N	Mean	Median
West	5114	58.642	29.443	0.040	0.276	2.347	4.655	1.992	0.655	774	0.499	0.537
Middle	6578	59.928	27.852	0.039	0.280	2.350	4.796	2.152	0.671	664	0.513	0.542
East	12497	168.579	61.590	0.052	0.296	2.986	7.251	2.737	0.687	1773	0.531	0.567
Countrywide	24189	115.790	40.627	0.048	0.293	2.739	7.147	2.850	0.711	3211	0.520	0.556

Note: N represents observations, and mea/med refers to the ratio of the mean to the median.

Table 3
Distribution and statistical characteristics of net household wealth and LTV (over 60 years).

Region	Net household wealth (unit: 10,000 yuan)									LTV (%)		
	N	Mean	Median	p10/p50	p25/p50	p75/p50	p90/p50	Mea/Med	Gini	N	Mean	Median
West	3038	37.055	15.149	0.020	0.146	2.999	6.461	2.446	0.707	121	0.435	0.455
Middle	4299	37.243	15.100	0.022	0.146	2.836	6.115	2.466	0.716	109	0.524	0.507
East	8324	141.808	49.733	0.022	0.170	3.304	8.084	2.851	0.694	290	0.492	0.505
Countrywide	15661	92.782	26.500	0.022	0.156	3.409	9.430	3.501	0.742	520	0.485	0.500

Note: mea/med refers to the ratio of mean to median; the age range of head of household net wealth sample is 60–117 years old, and that of the LTV sample is 60–86 years old.

$$IF\left(y;G\right) = \lim_{\varepsilon\to 0}\frac{G(T_Y)-G(F_Y)}{\varepsilon} = \lim_{\varepsilon\to 0}\frac{G\left((1-\varepsilon)F_Y+\varepsilon H_{y_i}\right)-G(F_Y)}{\varepsilon} = 1-\frac{y}{\mu}-\frac{\mu+y}{\mu}G+\frac{2}{\mu}\int_0^y F_Y(x)dx$$

The influence function *IF*(*y*;*G*) is the Gâteaux or directional derivative[5] of *G*, which reflects the sensitivity of Gini coefficient to different household wealth positions.

The recentered influence function of the Gini coefficient *RIF*(*y*;*G*) is the Gini coefficient *G* plus the influence function *IF*(*y*;*G*):

$$RIF\left(y;G\right) = G+IF\left(y;G\right) = 1-\frac{Y}{\mu}-\frac{Y}{\mu}G+\frac{2}{\mu}\int_0^Y F(x)dx$$

The *IF* and the *RIF* have the following properties (Firpo et al., 2009).

$$\int IF(y;G)dF_Y = E\left[IF\left(y;G\right)\right] = 0$$

$$G = E\left[RIF\left(y;G\right)\right] = E\left[E\left[RIF\left(y;G\right)\middle|X=x\right]\right] = \int E[RIF(y;G)|X=x]dF_X(x) \tag{10}$$

Eq. (10) means that if $E[RIF(y;G)|X=x]$ can be modeled as a function of the distribution of the exogenous characteristics *X*, the result can be used to estimate how changes in the distribution of *X* may affect *G*. Following Firpo et al., (2009, 2018), Carpantier et al. (2018), we use the following RIF for the Gini index (*Gini-RIF*) regression to provide a robust assessment of the impact of *X* on *RIF*(*y*;*G*).

$$RIF(y;G) = \beta_0 + LTV'\beta_1 + B'\beta_2 + Z'\beta_3 + \varepsilon, \tag{11}$$

where *RIF*(*y;G*) is the dependent variable. *LTV* denotes the key independent variable of interest, the LTV ceiling. *B* is the variable for bequest motive, mortgage cost, or housing price variation. *Z* is a vector of covariates that mainly includes demographic characteristic variables and household characteristics. β_0 is the constant. β_1, β_2 and β_3 are the coefficients. ε is the error term with $E[\varepsilon] = 0$.

According to the fact that the expectation of the *IF* is zero and the law of iterative expectations, the Gini coefficient *G* can be expressed as the average of the conditional expectation of the *RIF* given the covariates, and the Gini-RIF regression can explore factors behind changes across unconditional distributions (Firpo et al., 2009, 2018; Gradín, 2016). We needs to obtain unconditional expectations on both sides of (11):

$$G = E[RIF(y;G)] = E[E[RIF(y;G)|X=x]] = \beta_0 + \overline{LTV}'\beta_1 + \overline{B}'\beta_2 + \overline{Z}'\beta_3, \tag{12}$$

Where $\overline{LTV}$,$\overline{B}$and $\overline{Z}$are the unconditional mean values of *LTV*, *B* and *Z*, respectively. Thus, the unconditional partial effect of $\overline{LTV}$ is β_1. The interpretation of the unconditional partial effect is that if the distribution of *LTV* changes such that its unconditional average increases by one unit, the Gini coefficient is expected to change in β_1 units.

[5] The influence function (Gâteaux or directional derivative) is a tool for statistical robustness analysis (introduced by Hampel, 1974), which is used to measure the influence that a small contamination in *Y* has on a particular statistic.

4.2. Variables

4.2.1. Household net wealth

Household net wealth (abbreviated as HHwealth) is equal to total household assets minus total household liabilities. Total household assets include nonfinancial and financial assets, of which nonfinancial assets are agricultural assets, industry and commerce assets, and vehicle and other nonfinancial assets. Financial assets include demand deposits, term deposits, stocks, bonds, funds, derivatives, financial products, non-RMB assets, gold, cash and lending. Total household liabilities correspond to formal channel loans, informal channel loans and other liabilities.

To validate the impact of the LTV ceiling on the household wealth inequality within the group in the theoretical model, the sample data were divided into two age groups: adulthood (18–59 years of age) and old age (over 60 years of age). As shown in Tables 2 and 3, across the whole country and especially in the eastern, central and western regions, the wealth inequality of adult households is lower than that of elderly households, and the wealth Gini coefficient of adult households is highest in the east, while that of elderly households is highest in the central region. On average, the LTV ratios of adult households are higher than those of elderly households. Therefore, the purchase of adult households is more vulnerable to policy regulation.

4.2.2. LTV ceiling ratios

This paper uses two methods to measure the LTV ceiling: First at the macro level, and the second is at the micro household level. (1) Macro level measurement method. If the house purchase time is before 2010 (inclusive), the LTV ceiling is determined in combination with China's housing loan policies over the years. Since the regulation of housing credit policies became no longer unified after 2010, different regions (cities) began to use different credit policy policies, resulting in different down payment ratios (i.e., different LTV ceilings). Therefore, when a house is purchased after 2010, this paper uses the mode or threshold value of the LTV of households in different cities to determine the LTV ceiling ratios. (2) Micro level measurement method. In this part, referring to the method of Carpantier et al. (2018), this paper uses the LTV of each household as the proxy variable of macroprudential policy. The LTV is obtained by dividing the total housing loan amount of a household by the housing value (that is, housing value equals the down payment plus the total loan amount). There are 531 observations with LTV = 1 (indicating that down payment data are missing). Because the amount of tax paid is relatively low, the total cost of a house purchase can be approximately equal to the total value of housing. For the 531 observations where LTV= 1, the value is calculated by dividing the total loan amount of the household by the total cost of purchasing the house (the total cost of the house includes the value of the house and taxes; because the amount of taxes is relatively small, the total cost of the house is approximately equal to the value of the house). We take into account the case of full payment for a house[6] (LTV=0). We exclude observations which loan amount data are missing and then determine the LTV according to China's housing loan policies for different years. The specific requirements imposed are as follows. The LTV ratios were less than 0.7 by 1999, less than 0.8 from 1999 to 2004, and less than 0.7 in 2005. In 2006, the LTV ratios were less than 0.7, but for housing areas of less than 90 square metres, they were less than 0.8. In 2007, for the purchase of a first house, the LTV ratios were less than 0.8 for housing areas of less than 90 square metres and less than 0.7 for housing areas of more than 90 square metres, but for additional home purchases, the LTV ratios were less than 0.6. From 2008–2009, the LTV ratios were less than 0.8. In 2010, for additional home purchases, the LTV ratios were less than 0.6. Considering the housing purchase time, samples whose LTVs do not meet the above ranges are removed. Given that the CHFS data for 2017 are identified only at the provincial level, the LTV ratios for 2011–2017 cannot be further categorized, and LTVs need to fall below a value of 0.8. For example, for a household with mortgages for two houses, if one house was purchased after 2010, the LTV is less than 0.8. If both houses were purchased before 2010, the LTV ratios must meet the upper limit according to the corresponding mortgage policy. For example, if the houses were purchased in 2000 and 2005, according to the LTV ceiling in 2000, the value is less than 0.8. We have 3201 samples with valid LTVs.

4.2.3. Mortgage cost

This paper uses two methods to measure mortgage costs. The first measure of mortgage cost (abbreviated as Cost1) is measured by the percentage of interest paid at the end of a mortgage to the principal of the mortgage (similar to r in the theoretical model). This variable combines information on the annual interest rate, principal and duration of a mortgage. A total of 1610 valid sample data were obtained. To simplify the calculation, we assume that a household's repayment of all loans involves equal principal and interest without considering cases of early repayment. For households with multiple houses, the total mortgage cost is equal to the sum of the mortgage cost per house. Based on the actual conditions in China, we exclude mortgage costs of less than 0 and more than 2.16. Considering that there are few effective samples of Cost1, this paper constructs a second index value of mortgage cost (abbreviated as Cost2) according to whether the household has outstanding housing loans. If the household has at least one outstanding loan, then Cost2 = 1; otherwise, it is 0.

4.2.4. Housing price variations

Housing price variations (abbreviated as HPvar) are average annual variations between the housing price in 2017 and the price at the time of purchase. For households with multiple houses, the variation in housing price is the weighted average of each housing price

[6] We could not directly obtain the sample of households who paid in full when buying a house. When the purchasing time was after 1991 (China's housing credit business began in 1991) and the household had no outstanding loans for all houses, we identified that these households paid in full when purchasing the houses. If the samples with LTV = 0 are excluded, all the results in this paper are still robust.

Table 4
Descriptive statistics of variables.

Variables	N	Mean	Std.Dev.	Min	Median	Max
HHwealth (ten thousand RMB yuan)	23537	117.910	242.293	-489.636	41.665	3000
HSwealth (ten thousand RMB yuan)	18654	86.053	168.669	-76.800	29.000	2100
LTV ceiling (macro)	23537	0.742	0.068	0.500	0.750	0.850
LTV ceiling (micro)	12262	0.136	0.246	0.000	0.000	0.800
BM	21185	0.096	0.308	0.000	0.000	3.000
Cost1	1610	0.379	0.334	0.000	0.328	2.117
Cost2	21110	0.144	0.351	0.000	0.000	1.000
HPvar (RMB yuan/square metre/year)	15872	6.781	22.183	-270.833	1.282	684.211
Age	23537	44.289	10.322	18.000	46.000	59.000
Health	23537	3.547	0.978	1.000	4.000	5.000
Married	23537	0.844	0.363	0.000	1.000	1.000
Education	23537	10.278	4.112	0.000	9.000	22.000
HHNI (ten thousand RMB yuan)	23537	10.587	22.679	-100.000	6.165	500.000
SHNI (Divided by 1000)	23537	0.626	7.841	0.000	0.039	250.000
Hsize	23537	4.119	1.601	1.000	4.000	18.000
PI	12248	0.224	0.417	0.000	0.000	1.000
Savings1	20096	0.132	0.606	-1.998	0.303	0.993
Savings2	19341	0.258	0.570	-1.999	0.427	1.000
Savings3	17722	-0.002	0.673	-2.000	0.119	1.000
Number of housing units	14032	1.244	0.590	0.000	1.000	3.000
Hprice1 (ten thousand RMB yuan)	13211	1.160	1.868	0.100	0.491	50.000
Hprice2 (ten thousand RMB yuan)	17193	0.901	1.704	0.000	0.322	50.000
HPP (ten thousand RMB yuan)	15304	0.281	0.632	0.000	0.108	32.000

Note: HSwealth is housing net wealth in ten thousand RMB yuan; HHNI is household net income; SHNI is square of household net income; and Hsize is the total number of people in a household.

variation.

4.2.5. Bequest motive

Following Skinner (1989), some Chinese studies have used the number of children as a proxy variable of the strength of a bequest motive. In this way, the more children there are in a household, the stronger bequest motives are. However, this seems to be unreasonable in the Chinese context. China began to implement its household planning policy in 1980, with the result that households had few children. However, Chinese household traditions surrounding inheritance and raising children for the aged are very strong, and thus, the intergenerational transfer of wealth and bequests among households is very significant. As the CHFS does not provide precise data on bequests, we construct a bequest motive index (abbreviated as BM) according to the question "Who made the down payment?" and "how was the house purchased?" as follows. When a down payment is made as a "gift" or the property is part of an "inheritance or gift", this denotes a bequest motive. The strength of a bequest motive is measured as the down payment that parents pay for their children and the number of properties inherited by children. The variable is equal to 1 (2 or 3) when parents help pay the down payment for one house (two or three houses) for their children or if their children inherit one house (two or three houses). The strength of bequest motives is determined by the number of properties for which parents pay a down payment and the number of properties inherited by children. The specific value is the sum of the two for the number of different properties; that is, if a single property is paid for by parents and inherited or given, the bequest motivation value is still 1.

4.2.6. Savings rate

Referring to the existing literature, this paper introduces three methods for calculating the savings rate. Based on the practice of Su et al. (2016), Yin and Zhang (2019), we set Savings1 = (total household income - total household consumption)/total household income; and Savings2 = [total household income - (total household consumption - (medical expenditure + education expenditure))]/total household income. Following Deaton and Paxson (1994) and Chamon and Prasad (2010), set Savings3 = ln (household gross income) - ln (household gross consumption), where ln () denotes a natural logarithmic function. We exclude data with savings rates of less than − 2 and greater than 1 (Yin & Zhang, 2019).

4.2.7. Purchase intention

The variable of purchase intention (abbreviated as PI) is measured based on the question "Does your household plan to buy or build a new house in the next five years?" in the questionnaire. If the respondents choose "have the intention to buy a new house", "have the intention to build a new house" or "have the intention to either buy or build a new house", then PI is assigned the value 1; if they choose "no", then PI= 0.

4.2.8. Housing price

The housing price variable refers to the housing price of the respondents' homes in 2017 (yuan per square metre). This variable is determined based on two survey questions: "How much is the house worth at present?" and "What is the area of this house?". The samples whose housing price is less than 1000 yuan per square metre are deleted and recorded as Hprice1; and the samples excluding

Table 5
Gini-RIF empirical results of the LTV ceiling (macro; 18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF
LTV ceiling	-0.087**	-0.082**	-0.070*	-0.081*	-0.081*	-0.069
	(0.039)	(0.040)	(0.041)	(0.045)	(0.045)	(0.045)
BM		-0.003			-0.016	-0.003
		(0.009)			(0.010)	(0.010)
Cost2			-0.051 ***			-0.056 ***
			(0.008)			(0.009)
HPvar				0.000 **	0.000 **	0.000 ***
				(0.000)	(0.000)	(0.000)
Age	-0.001 ***	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Health	-0.033 ***	-0.032 ***	-0.032 ***	-0.032 ***	-0.032 ***	-0.032 ***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Married	-0.037 ***	-0.026 ***	-0.022 ***	-0.020 **	-0.020 **	-0.015
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
Education	-0.015 ***	-0.016 ***	-0.015 ***	-0.016 ***	-0.016 ***	-0.015 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
HHNI	0.002 ***	0.003 ***	0.003 ***	0.003 ***	0.003 ***	0.003 ***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SHNI	0.007 ***	0.006 ***	0.006 ***	0.006 ***	0.006 ***	0.006 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hsize	-0.009 ***	0.000	-0.000	-0.002	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	1.139 ***	1.022 ***	1.013 ***	0.998 ***	1.003 ***	0.992 ***
	(0.036)	(0.038)	(0.038)	(0.043)	(0.043)	(0.043)
adj. R^2	0.080	0.092	0.093	0.098	0.098	0.099
Observations	23537	21185	21110	15872	15870	15828

Note: The coefficient of LTV ceiling in column 6 is significant under probability of 12%, which is close to statistical level of 10%; * $p < 0.1$; * * $p < 0.05$; * ** $p < 0.01$; standard errors are reported in brackets.

house price equal to 0 are recorded as Hprice2. In the later empirical regression analysis, Hprice1 and Hprice2 are divided by 10,000.

4.2.9. *Housing price in the year of purchase*

This variable (abbreviated as HPP) refers to the housing price paid by the respondents' households when they bought a house in that year. This variable is based on two questions: "How much did your household spend when they bought the house?" and "What is the area of this house?" We delete the samples with values equal to 0.

4.2.10. *Number of housing units*

When the household has only one house, the "number of housing units" is assigned the value 1; when the household has two houses, the value is 2; and when the household has three or more houses, the value is 3.

4.2.11. *Other control variables*

As control variables of demographic characteristics, we used the following: the age (18–59 years old) of the household head (major household income earner) and his or her level of health (measured as 1–5 denoting low to high levels of health), married (married or remarried = 1, other answers = 0), and education (The "education" variable is assigned according to the number of years of education: illiterate = 0, primary school = 6, junior high school = 9, senior high school = 12, technical secondary school or vocational high school = 13, junior college or vocational high school = 15, bachelor's degree = 16, master's degree = 19, and doctoral degree = 22). Household characteristic variables include household net income and its square and household size (i.e., the total number of people in a household). Summary statistics are given in Table 4.

5. Empirical results

5.1. *Empirical results of the LTV ceiling (macro)*

After controlling for personal variables (age, health, marital status and education) and household variables (household net income, square of household net income and household size), this paper examines the impact of the LTV ceiling and the main explanatory variables, such as bequest motivation, mortgage cost and housing price, on household net wealth inequality. The specific empirical results are shown in Table 5.

Columns (1) - (5) of Table 5 show that increasing the LTV ceiling can significantly alleviate household wealth inequality. Through the previous analysis, we can see that the different performances of housing investment returns and liquidity asset returns between China and Eurozone countries lead to opposite impacts of macroprudential policies on wealth inequality between China and Eurozone

Table 6
Gini-RIF empirical results of the LTV ceiling (micro; 18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF
LTV ceiling	-0.076***	-0.083***	-0.181***	-0.083***	-0.082***	-0.165***
	(0.015)	(0.015)	(0.049)	(0.015)	(0.015)	(0.050)
BM		-0.001			-0.004	-0.008
		(0.012)			(0.013)	(0.023)
Cost1			0.022			0.019
			(0.027)			(0.027)
HPvar				-0.000	-0.000	-0.001***
				(0.000)	(0.000)	(0.000)
Age	-0.001**	-0.001**	-0.000	-0.001*	-0.001*	-0.000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
Health	-0.030***	-0.030***	-0.029***	-0.027***	-0.027***	-0.024**
	(0.004)	(0.004)	(0.010)	(0.004)	(0.004)	(0.010)
Married	-0.013	-0.014	0.008	-0.012	-0.012	0.005
	(0.010)	(0.010)	(0.026)	(0.011)	(0.011)	(0.026)
Education	-0.015 ***	-0.015 ***	-0.017 * **	-0.014 ***	-0.014 ***	-0.016 ***
	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.003)
HHNI	0.004 ***	0.004 * **	-0.000	0.004 ***	0.004 ***	0.000
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)
SHNI	0.003 ***	0.003 ***	0.006 ***	0.002 **	0.002 **	0.005 ***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Hsize	-0.003	-0.004	-0.003	-0.004	-0.004	-0.006
	(0.002)	(0.002)	(0.006)	(0.003)	(0.003)	(0.007)
Constant	0.944 ***	0.943 ***	1.039 ***	0.901 ***	0.902 ***	1.020 ***
	(0.031)	(0.031)	(0.083)	(0.034)	(0.034)	(0.089)
adj. R^2	0.088	0.090	0.093	0.085	0.085	0.089
Observations	12262	12237	1610	10006	10005	1442

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; standard errors are reported in brackets.

countries. The coefficient of bequest motive is not significant. The coefficient of mortgage cost is significantly negative. Because the sample includes households with and without housing, the increase in mortgage costs narrows the wealth gap between households with and without housing, thus alleviating wealth inequality. Housing price variation has a significant positive effect on household wealth inequality. The rise of house prices aggravates the wealth gap between households with and households without housing and further aggravates wealth inequality.

5.2. *Empirical results of the LTV ceiling (micro)*

Taking LTV of households as the proxy variable of macroprudential policy, this paper performs Gini-RIF regression on household net wealth inequality. The regression results are shown in Table 6. The coefficient of LTV is still significantly negative, which is consistent with the regression result of macro LTV. The coefficients of bequest motive and mortgage cost are not significant. The coefficient of house price variation has a negative impact on household wealth inequality. This is contrary to the above regression results of the macro LTV ceiling. A possible reason is that the sample household for micro LTV include only households with houses, so rising house prices have reduced the wealth inequality among households with houses.

LTV ceiling ratios (micro) may have endogeneity problems. As wealthy households enjoy more investment information and channels, they may choose high LTV ratios to reduce opportunity costs. Low wealth households may also choose high LTV ratios because of a lack of funds, while middle wealth households may choose low levels of LTV to reduce interest payments. Thus, household wealth inequality affects the LTV ratio. Actually, the use of macro LTV samples solves the problem of endogeneity, but this paper also tries to use instrumental variable method to overcome the problem of endogeneity. According to our consultations with many experienced individual credit managers of commercial banks, differences in age, occupation and region significantly affect people's consumption habits, values and future plans and then determine the ratio of purchase loans. First, LTV values vary with age. Young people are more likely to buy houses to improve their competitive advantage in the marriage market (Most Chinese parents want stability for their children, and having a house, car and a stable job ensures that stability). Young people have relatively little money and generally choose a higher LTV. Whether these people can buy houses is likely to be regulated by the LTV ceiling. With increasing age and accumulated wealth, more households buy houses to improve their living conditions (LTV is low). Second, occupation determines a household's demand for funds, with self-employed or entrepreneurial households being more likely to invest funds into their main business and make a low down payment when buying a house (with a higher LTV). Borrowers employed by others or enterprises may have relatively high down payment ratios because they have fewer investment opportunities and hope to reduce interest payments. Therefore, borrowers with different levels of job stability have different expectations and future plans, which is bound to create differences in LTV ratios. Third, regional differences (These regions are divided according to the differences in economic development) entail significant differences in investment behaviour based on the level of local economic development. Therefore, we select age, type of work, and region as grouping variables. The samples are divided into two groups according to the age

Table 7
IVGini-RIF empirical results of the LTV ceiling (micro; 18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	IVGini-RIF	IVGini-RIF	IVGini-RIF	IVGini-RIF	IVGini-RIF	IVGini-RIF
LTV ceiling	-0.216 ***	-0.226 ***	-1.166 ***	-0.222 ***	-0.231 ***	-1.009 ***
	(0.053)	(0.056)	(0.369)	(0.055)	(0.059)	(0.360)
BM		0.025			0.024	0.008
		(0.016)			(0.017)	(0.024)
Cost1			0.146 ***			0.116 **
			(0.053)			(0.049)
HPvar				-0.000	-0.000	-0.001 ***
				(0.000)	(0.000)	(0.000)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.957 ***	0.949 ***	1.546 ***	0.918 ***	0.913 ***	1.470 ***
	(0.032)	(0.031)	(0.205)	(0.034)	(0.034)	(0.209)
adj. R^2	0.087	0.089	0.091	0.083	0.083	0.088
F value	256.455	288.394	27.060	190.283	225.742	17.273
t value	32.844	31.305	4.970	29.343	27.392	4.877
DWH F value	7.43	7.10	7.29	6.82	6.76	5.63
(p-value)	(0.006)	(0.008)	(0.007)	(0.009)	(0.009)	(0.018)
Observations	12259	12234	1608	10004	10003	1440

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; standard errors are reported in brackets; and F value and t value are obtained by the first stage regression. The other control variables are the same as those in Table 5.

of the household head (under 35 years of age and over 36 years of age), three groups according to working stability (Type of work 1 pertains to being employed by others or enterprises; Type of work 2 pertains to operating an individual or private enterprise (self-employment); and Type of work 3 pertains to other work), three groups for the eastern, central and western regions of China, and two groups for households based in rural and urban areas. We thus consider the following: 2 age groups $\times$ 3 occupational groups $\times$ 6 regional groups= 36 groups. We thus have 36 observation groups. Based on Zong et al. (2015), the mean LTV of other households in the group is used as the instrumental variable of LTV ceiling.

The average LTV of other households in the group is used as an instrumental variable for a two-stage regression. The empirical results are shown in Table 7. In the estimation in column (1) of Table 7, a Durbin-Wu-Hausman (DWH) test shows that LTV ratios are rejected without endogeneity at a significance level of 1%. This means that the LTV ratio is an endogenous variable. The results of a two-stage estimation conducted using the instrumental variable method (IVGini-RIF), in Table 7, show that the F values of the first-stage regression are greater than the critical value under a 10% bias value (16.38); that is, there is no weak instrumental variable (Stock & Yogo, 2005). The coefficient of LTV is still significantly negative at the 1% level, further verifying the robustness of the results. After solving endogeneity, the impact of the LTV ceiling on household net wealth becomes more elastic.

6. Robustness test

6.1. *Changing the explained variable*

According to the “2018 China urban household wealth health report”, urban households’ housing wealth accounts for 77.7% of household wealth. As the most important part of household wealth, housing wealth inequality largely determines household wealth inequality. In this paper, we replace the household net wealth variable with the housing net wealth (the current value of the household’s house minus the outstanding balance of the corresponding mortgage) and test the robustness of the LTV ceiling from macro and micro perspectives. The empirical results show that the coefficient of the LTV ceiling is still significantly negative. The specific empirical results are shown in Appendix B.1 and Appendix B.2.

6.2. *Changing the main explanatory variable*

Households often buy their first housing unit to meet the rigid housing demand, while second home purchases are often intended for improvement or investment. In China, the LTV ceiling policy is also more stringent for residents buying a second housing unit, so households are more likely to be regulated by the LTV policy when they buy a second housing unit. In this part, the LTV of households when they buy a second house is used as the proxy variable of macroprudential policy to test the robustness. The coefficient of LTV is still significantly negative. The specific empirical results are shown in Appendix B.3.

6.3. *Changing empirical regression model*

In this section, the OLS model with robust standard errors is used to replace the Gini-RIF model, and the Gini coefficient of household net wealth at district and county level is used to express household wealth inequality. Because the sample of household net wealth may be negative, the Gini coefficient may be greater than 1. This paper refers to Chen et al. (1982) and uses the adjusted Gini

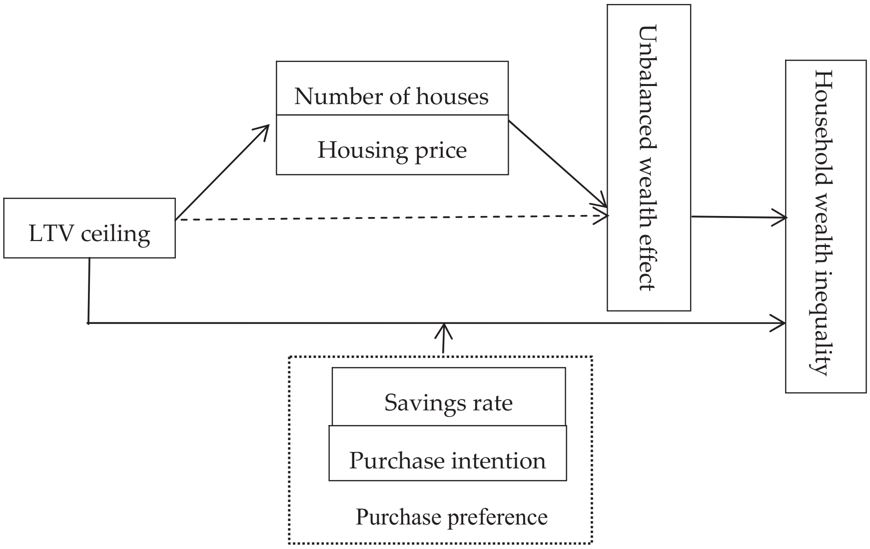

Fig. 3. Mechanism analysis.

coefficient. The specific calculation formula is as follows:

$$G* = \frac{G}{1 + \frac{2}{n}\sum_{i=1}^{J} iq_i} \tag{13}$$

where G is the Gini coefficient (before adjustment), n is the number of samples, and J meets the conditions $\sum_{i=1}^{J} q_i = 0$, where q_i is the proportion of property held by individual i in the sample. The specific empirical results are shown in Appendix B.4. The results show that increasing the LTV ceiling can still significantly alleviate household wealth inequality, which again verifies the robustness of the results.[7]

7. Mechanism analysis

Carpantier et al. (2018) think that macroprudential policy has a great impact on the rich in the model. In contrast, this paper posits that in China, macroprudential policy has a greater impact on the poor. In fact, Chinese households usually have a high level of savings, and the increase in the LTV ceiling can enable some low-wealth households to realize house purchases. The "urban large sample survey" organized by the National Bureau of Statistics shows that the savings rate of households without housing is significantly higher than that of households with housing, so housing purchases may be an important reason for young person's households to increase their savings rate. In addition, Chen and Qiu (2011) confirmed that the higher savings rate of young Chinese households is related to rising housing prices. Therefore, this paper uses "savings rate" and "purchase intention" as proxy variables of purchase preference.

This part first verifies the unbalanced wealth effect produced by the LTV ceiling and further verifies the channel role played by housing prices and the number of house purchases; moreover, this paper tests the regulatory effect of savings rates and house purchase intention when the LTV ceiling affects household wealth inequality. The specific transmission mechanism is shown in Fig. 3.

7.1. The unbalanced wealth effect of the LTV ceiling

In this part, we use the recentered influence function (RIF) regression (Firpo et al., 2009) (a kind of unconditional quantile regression) to further investigate the wealth effect of the LTV ceiling under different wealth levels and study the effect of the LTV ceiling on household wealth at different quantiles. The RIF regression model and principle are shown in formulas (14) and (15), respectively:

$$RIF(y; q_\tau) = \varphi_0 + LTV'\varphi_1 + Z'\varphi_2 + \zeta, \tag{14}$$

[7] We calculated different dependent variables (randomly combined with districts, counties, prefecture level cities and provinces according to whether the Gini coefficient is adjusted or not, in addition to the empirical results shown in the paper, there are 6 cases). All the results confirm the robustness of this conclusion. Interested readers can ask for them from the corresponding author.

Table 8
Wealth effect of the LTV ceiling (macro) under different wealth levels (18–59 years old).

	(1)	(2)	(3)	(4)	(5)
	rif_10	rif_25	rif_50	rif_75	rif_90
LTV ceiling	1.984 ***	1.552 ***	1.061 ***	1.349 ***	1.587 ***
	(0.602)	(0.312)	(0.163)	(0.151)	(0.194)
Control	Yes	Yes	Yes	Yes	Yes
Constant	0.334	4.682 ***	8.533 ***	9.991 ***	11.180 ***
	(0.573)	(0.284)	(0.149)	(0.146)	(0.195)
adj. R^2	0.069	0.142	0.224	0.227	0.182
Observations	23537	23537	23537	23537	23537

Legend: * $p < 0.1$; * * $p < 0.05$; * ** $p < 0.01$; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

Table 9
Empirical results of the LTV ceiling (macro) on housing prices (18–59 years old).

	(1)	(2)	(3)	(4)
	Hprice1	Hprice1	Hprice2	Hprice2
LTV ceiling	2.871 ***	2.009 ***	2.115 ***	1.503 ***
	(0.209)	(0.175)	(0.145)	(0.123)
HPP		1.426 ***		1.459 ***
		(0.061)		(0.061)
Control	Yes	Yes	Yes	Yes
Constant	-2.421 ***	-2.447 ***	-1.935 ***	-2.016 ***
	(0.197)	(0.178)	(0.146)	(0.133)
adj. R^2	0.121	0.389	0.153	0.418
Observations	13211	11916	17193	15304

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; robust standard errors are reported in brackets. The other control variables are the same as those in Table 5.

Table 10
Empirical results of the LTV ceiling (macro) transmission mechanism through housing quantity (18–59 years old).

	(1)	(2)	(3)	(4)
	D_1	D_2	D_3	D_4
LTV ceiling	0.663 **	0.551 *	1.140 ***	-0.269
	(0.279)	(0.308)	(0.313)	(0.335)
Control	Yes	Yes	Yes	Yes
cut1	0.302	-0.571 *	-0.468	-1.540 ***
	(0.280)	(0.315)	(0.313)	(0.330)
cut2	2.949 ***	2.387 ***	2.336 ***	0.908 ***
	(0.285)	(0.317)	(0.314)	(0.324)
cut3	4.543 ***	3.828 ***	3.820 ***	2.178 ***
	(0.317)	(0.327)	(0.318)	(0.326)
Pseudo R^2	0.031	0.030	0.019	0.019
Observations	3508	3508	3508	3508

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

$$RIF\left(y; q_\tau\right) = q_\tau + \frac{\tau - 1_{\{Y \le q_\tau\}}}{f_Y(q_\tau)}, \tag{15}$$

$RIF(y; q_\tau)$ is the RIF in quantile q_τ, and $f_Y(\cdot)$ is the density function of Y, where Y is the modified household net wealth.[8] $\zeta$is the remaining item with$E[\zeta] = 0$. $1_{\{\cdot\}}$is an indicator function, and Z are the control variables, mainly including demographic characteristics and household characteristics.

This paper divides the sample into four equal parts according to household net wealth. Households with net wealth below the 25th percentile are recorded as low-wealth households; households with net wealth between the 25th percentile and the 50th percentile are recorded as middle- and low-wealth households; households with net wealth between the 50th percentile and the 75th percentile are recorded as middle- and high-wealth households; households with net wealth above the 75th percentile are recorded as high-wealth households.

[8] Let the modified household net wealth value be ln(household net wealth + 1), if the household net wealth (RMB yuan) is greater than 0; let the modified wealth value be (−1)*ln(−1 *household net wealth + 1), if the household net wealth (RMB yuan) is less than 0.

Table 11
The moderating effect of the savings rate and purchase intention (macro; 18–59 years old).

	(1) Savings1	(2) Savings2	(3) Savings3		(4) PI
	Gini-RIF	Gini-RIF	Gini-RIF		Gini-RIF
LTV ceiling	-0.073 *	-0.060	-0.042	LTV ceiling	-0.092 **
	(0.043)	(0.044)	(0.048)		(0.039)
Savings	-0.061 ***	-0.046 ***	-0.056 ***	PI	-0.007
	(0.005)	(0.005)	(0.005)		(0.006)
LTV * Savings	0.318 *	0.770 ***	0.567 ***	LTV * PI	0.439 **
	(0.172)	(0.187)	(0.177)		(0.209)
LTV * Savings * D_1	-0.331	-0.771 ***	-0.466 **	LTV* PI * D_1	-0.553 **
	(0.204)	(0.220)	(0.207)		(0.268)
LTV * Savings * D_2	-0.345	-0.837 ***	-0.610 ***	LTV* PI * D_2	-0.546 **
	(0.218)	(0.235)	(0.218)		(0.272)
LTV * savings * D_3	-0.270	-0.701 ***	-0.552 **	LTV * PI * D_3	-0.489 *
	(0.231)	(0.251)	(0.234)		(0.287)
Control	Yes	Yes	Yes	Control	Yes
Constant	1.077 ***	1.086 ***	1.020 ***	Constant	1.146 ***
	(0.040)	(0.041)	(0.044)		(0.036)
adj. R^2	0.096	0.101	0.104	adj. R^2	0.080
Observations	20096	19341	17722	Observations	23497

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

According to the unconditional quantile regression results in Table 8, the LTV ceiling has different effects under different wealth levels. The impact of the LTV ceiling on low-wealth households and middle- and low-wealth households is relatively strong, and the impact on middle-wealth households is the lowest. Therefore, the regulatory effect of the LTV ceiling mainly reduces wealth inequality by increasing the wealth of middle- and low-wealth households, especially low-wealth households.

7.2. *Channel function based on housing price and housing quantity*

This section examines how the LTV ceiling produces an unbalanced wealth effect through housing prices and the number of houses owned. We use the OLS model with robust standard errors to verify the impact of the LTV ceiling on house prices and an ordered probit model to verify the impact of the LTV ceiling on the number of house purchases of households in different wealth quantiles.

Table 9 shows the empirical results of the LTV ceiling on house prices. Columns (1) - (2) of Table 9 are the empirical results of the LTV ceiling on Hprice1, which shows that the increase in the LTV ceiling has significantly increased the housing price. Columns (3) - (4) of Table 9 are the empirical results of the LTV ceiling on Hprice2. The impact of the LTV ceiling on Hprice2 is consistent with that on Hprice1. The positive impact of the LTV ceiling on housing prices is consistent with Kelly et al. (2018).

Table 10 shows the empirical results of the ordered probit model. The dependent variable is the number of houses owned by the household. The empirical results show that the increase in the LTV ceiling significantly increases the amount of housing units owned by low-wealth households (D_1), middle- and low-wealth households (D_2) and middle- and high-wealth households (D_3). However, the impact on the number of housing units owned by high-wealth households (D_4) is not statistically significant. Because of China's high housing yield, the increase in the LTV ceiling increases the housing wealth of relatively low-wealth households, thus reducing wealth inequality.

7.3. *The moderating effect of savings rate and purchase intention*

Compared with the rate of return on liquid assets, the rate of return on housing investment in China has long been high. When the house price is rising, residents have a strong demand for housing purchases. Some studies posit that residents maintain a high savings rate to buy houses (Chen & Qiu, 2011). This part tests the moderating effect of different wealth groups' purchase intention and savings rate on the LTV ceiling influencing household wealth inequality.

As mentioned above, the distribution of household net wealth can be divided into low-wealth households, middle- and low-wealth households, middle- and high-wealth households, and high-wealth households, and four corresponding dummy variables are set for the four household groups. We also rank household net wealth from low to high in three or five equal parts and set corresponding dummy variables. The measurement results are still robust.

The model is as follows:

$$RIF\left(y;G\right) = \eta_0 + \eta_1 LTV + \eta_2 T + \eta_3 LTV * T + \eta_{3+i}\sum_{i=1}^{3} LTV * T * D_i + \eta_7 Z + \varepsilon \tag{16}$$

where the high-wealth group is the benchmark group. T is the savings rate; ε is the remainder; and Z denotes the control variables, consistent with the previous section. As LTV and T are highly correlated with the cross-multiplication term $LTV*T$, we apply a

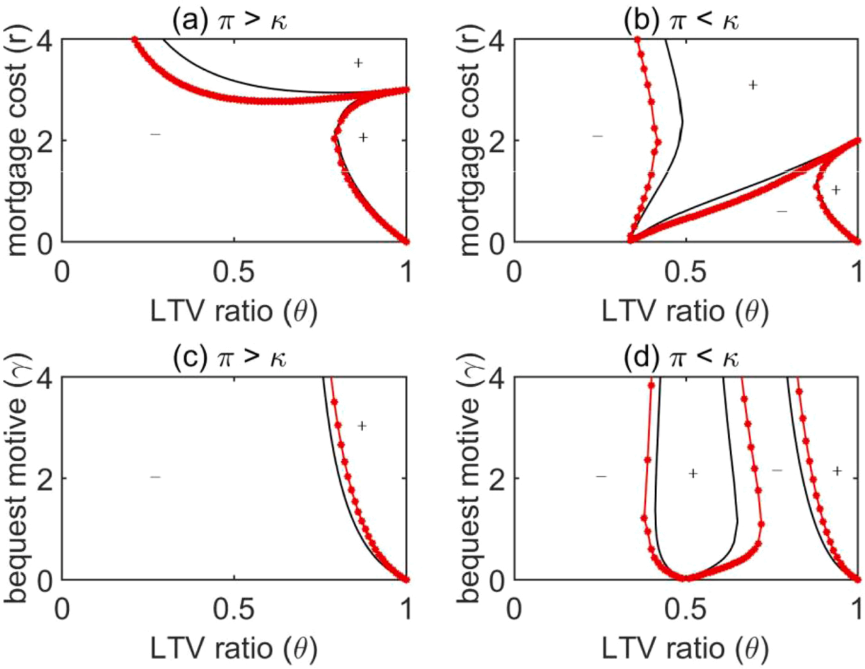

Fig. A1. Adjustment of elastic coefficientsγ andφ. The solid line in Fig. A1 is the same as that in Fig. 1, and the asterisk line represents the simulation diagram when β= 0.9, γ= 1.5, and φ= 1.5.

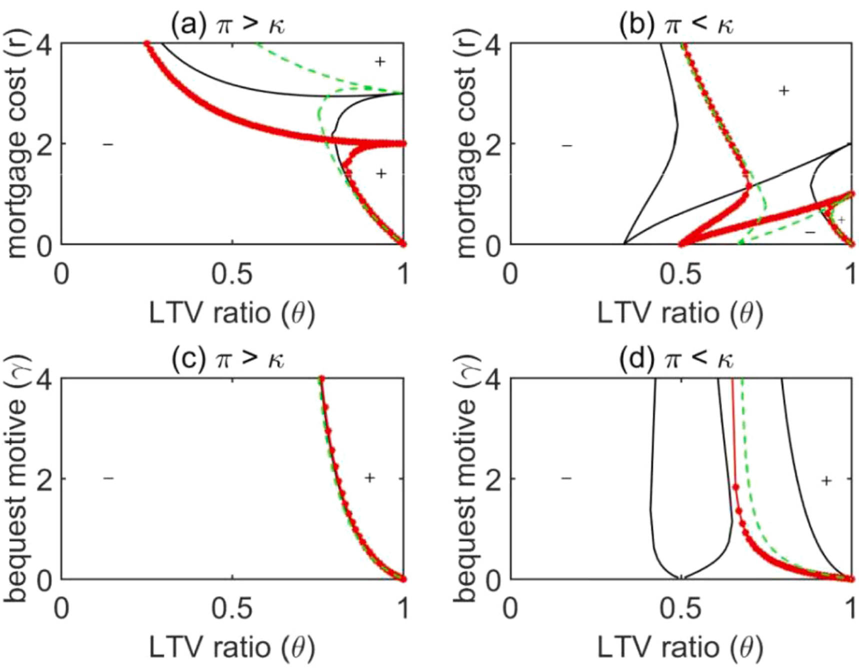

Fig. A2. Adjustment of yield coefficients πandκ. The solid line is the same as Fig. 1 (that is, the values of $\pi$and$\kappa$are 2 or 3), the asterisk line is the simulation result when$\pi$and$\kappa$are 1 or 2, and the dotted line is the effect when$\pi$and$\kappa$are 1 or 3.

centralization treatment to *LTV* and *T*.

Columns (1) - (3) in Table 11 are the empirical results with Savings1, Savings2 and Savings3 as intermediary mechanisms. The regression results show that the coefficient of the cross-multiplication term of the LTV ceiling and the savings rate is positive and significant at 10%, indicating that an improvement in the savings rate of high-wealth groups weakens the alleviating effect of the LTV

Table B1
The empirical results of the LTV ceiling (macro) on housing wealth inequality (18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF
LTV ceiling	-0.079 * *	-0.056	-0.047	-0.070 *	-0.070 *	-0.060
	(0.035)	(0.037)	(0.037)	(0.039)	(0.039)	(0.039)
BM		0.001			-0.008	0.004
		(0.009)			(0.009)	(0.009)
Cost2			-0.053 * **			-0.059 * **
			(0.008)			(0.008)
HPvar				0.001 * **	0.001 * **	0.001 * **
				(0.000)	(0.000)	(0.000)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.118 * **	0.902 * **	0.903 * **	0.903 * **	0.905 * **	0.907 * **
	(0.032)	(0.035)	(0.035)	(0.037)	(0.038)	(0.037)
adj. R^2	0.027	0.033	0.035	0.035	0.035	0.038
Observations	18654	16317	16296	14871	14869	14850

Legend: * p < 0.1; * * p < 0.05; * ** p < 0.01; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

Table B2
The empirical results of the LTV ceiling (micro) on housing wealth inequality (18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF
LTV ceiling	-0.066 * **	-0.071 * **	-0.103 * *	-0.077 * **	-0.076 * **	-0.103 * *
	(0.013)	(0.014)	(0.047)	(0.014)	(0.014)	(0.047)
BM		-0.000			-0.004	0.000
		(0.011)			(0.012)	(0.022)
Cost1			-0.003			-0.002
			(0.022)			(0.022)
HPvar				0.000	0.000	-0.001 * **
				(0.000)	(0.000)	(0.000)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.804 * **	0.805 * **	0.854 * **	0.804 * **	0.805 * **	0.861 * **
	(0.028)	(0.028)	(0.082)	(0.030)	(0.030)	(0.084)
adj. R^2	0.023	0.024	0.050	0.024	0.024	0.059
Observations	9935	9914	1358	9346	9345	1293

Legend: * p < 0.1; * * p < 0.05; * ** p < 0.01; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

Table B3
The empirical results of the micro LTV ceiling (second housing) on household wealth inequality (18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF	Gini-RIF
LTV ceiling	-0.199 * **	-0.205 * **	-0.198 * **	-0.188 * **	-0.190 * **	-0.159 * **
	(0.031)	(0.032)	(0.054)	(0.031)	(0.032)	(0.056)
BM		0.013			0.003	-0.003
		(0.015)			(0.015)	(0.034)
Cost1			0.034			0.042
			(0.035)			(0.036)
HPvar				-0.000	-0.000	-0.001 * *
				(0.000)	(0.000)	(0.001)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.943 * **	0.940 * **	0.860 * **	0.908 * **	0.907 * **	0.831 * **
	(0.034)	(0.034)	(0.140)	(0.037)	(0.037)	(0.144)
adj. R^2	0.103	0.103	0.103	0.102	0.102	0.102
Observations	10380	10374	668	8387	8386	618

Legend: * p < 0.1; * * p < 0.05; * ** p < 0.01; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

ceiling on household wealth inequality. The coefficients of "*LTV* * Savings * D_1", "*LTV* * Savings * D_2" and "*LTV* * Savings * D_3" are negative. This shows that with the increase in the savings rate of the relatively low-wealth households, the alleviation effect of the LTV ceiling on household wealth inequality is enhanced. Moreover, the increase in the savings rate of middle- and low-wealth households has the strongest effect on the mitigation of the LTV ceiling.

Column (4) of Table 11 shows that the coefficient of "*LTV* * PI" is significantly positive, which indicates that with the increase in the

Table B4
The empirical results of the macro LTV ceiling on household wealth inequality (the Gini index at district and county level; 18–59 years old).

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	OLS	OLS	OLS
LTV ceiling	-0.114 * **	-0.112 * **	-0.110 * **	-0.107 * **	-0.107 * **	-0.106 * **
	(0.010)	(0.010)	(0.010)	(0.012)	(0.012)	(0.012)
BM		0.003			0.003	0.005 *
		(0.002)			(0.003)	(0.003)
Cost2			-0.010 * **			-0.008 * **
			(0.002)			(0.002)
HPvar				-0.000 * **	-0.000 * **	-0.000 * **
				(0.000)	(0.000)	(0.000)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.748 * **	0.734 * **	0.735 * **	0.724 * **	0.723 * **	0.724 * **
	(0.009)	(0.010)	(0.010)	(0.011)	(0.011)	(0.011)
adj. R^2	0.047	0.050	0.051	0.052	0.052	0.053
Observations	19911	17861	17798	13225	13225	13194

Legend: * p < 0.1; * * p < 0.05; * ** p < 0.01; robust standard errors are reported in brackets. The other control variables are the same as those in Table 5.

Table B5
The moderating effect of the savings rate and purchase intention (micro; 18–59 years old).

	(1) Savings1	(2) Savings2	(3) Savings3		(4) PI
	Gini-RIF	Gini-RIF	Gini-RIF		Gini-RIF
LTV ceiling	-0.073 * **	-0.078 * **	-0.058 * **	LTV ceiling	-0.083 * **
	(0.015)	(0.015)	(0.018)		(0.015)
Savings	-0.071 * **	-0.050 * **	-0.055 * **	PI	-0.020 * *
	(0.007)	(0.007)	(0.007)		(0.009)
LTV * Savings	-0.120 * *	-0.126 * *	-0.009	LTV * PI	0.102 *
	(0.052)	(0.057)	(0.052)		(0.059)
LTV * Savings * D_1	0.108	0.100	-0.036	LTV * PI * D_1	-0.360 * **
	(0.077)	(0.084)	(0.079)		(0.112)
LTV * Savings * D_2	0.107	0.102	-0.011	LTV* PI * D_2	-0.136
	(0.074)	(0.079)	(0.078)		(0.095)
LTV * savings * D_3	-0.093	-0.083	-0.130 *	LTV* PI * D_3	0.019
	(0.072)	(0.079)	(0.073)		(0.086)
Control	Yes	Yes	Yes	Control	Yes
Constant	0.9280 * **	0.9386 * **	0.8631 * **	Constant	0.9521 * **
	(0.0331)	(0.0333)	(0.0375)		(0.0316)
adj. R^2	0.1111	0.1152	0.1324	adj. R^2	0.0882
Observations	10976	10571	9340	Observations	12248

Legend: * p < 0.1; * * p < 0.05; * ** p < 0.01; standard errors are reported in brackets. The other control variables are the same as those in Table 5.

purchase intention of high-wealth households, the alleviation effect of the LTV ceiling on household wealth inequality is weakened. However, in low-wealth households, middle- and low-wealth households and middle- and high-wealth households, the coefficients of "*LTV* * PI" are all significantly negative, which indicates that with the increase in the purchase intention of relatively low-wealth households, the effect of the LTV ceiling on alleviating household wealth inequality is enhanced. we also added the empirical results of micro LTV samples (p30, see B.5 in the Appendix B).

8. Conclusion

In this paper, we employ the OLG model to demonstrate the trade-offs between the financial market, housing market and household wealth inequality. It is found that the relative value of returns on housing investment and liquid assets regulates the direction of the impact of the LTV ratio on household wealth inequality. When the rate of return on housing investment is higher than the rate of return on liquid assets, the LTV ceiling generally has a negative relationship with household wealth inequality; otherwise, the two have a more positive relationship. Given that China's housing yield continues to be higher than the return on liquid assets, this paper uses the data of the China Household Finance Survey (CHFS) in 2017 to conduct an empirical test and carries out Gini-RIF regression on the LTV ceiling measured from the macro and micro perspectives. The empirical results show that there is a significant negative relationship between the LTV ceiling and household wealth inequality. Considering that at the micro level, the LTV ceiling may have endogeneity problems, the conclusion is still robust after the treatment of instrumental variables. China's high housing yield leads Chinese residents to have a strong preference for buying houses. Raising the LTV ceiling can enable some households without houses or with low- and middle-levels of wealth to buy houses. Therefore, in China, macroprudential policy has a greater impact on relatively low-wealth households. This paper uses unconditional quantile regression to verify the unbalanced wealth effect of the LTV ceiling and finds that the LTV ceiling has the greatest wealth effect on low-wealth households through housing prices and housing quantity. Furthermore, this paper uses the savings rate and purchase intention as proxy variables of purchase preference and finds that the purchase preference of low-wealth households and low- and middle-wealth households can strengthen the alleviation effect of the LTV ceiling on wealth inequality.

The LTV ceiling is one of the most frequently used macroprudential policy tools in China and plays a positive role in restraining the rapid expansion of credit and the rapid rise of housing prices. However, the impact of macroprudential policy on the distribution of household wealth is not neutral, as it aggravates household wealth inequality while regulating housing prices. Therefore, it is necessary to coordinate macroprudential policy and monetary policy to regulate the real estate market, highlight the guiding role of the monetary policy benchmark loan interest rate, and reduce the negative effects of macroprudential policy. In addition, the strong purchase preferences of low-wealth and middle- and low-wealth households are the reasons macroprudential policy can reduce wealth inequality. The government should properly solve the living difficulties and housing problems of these people, which can further strengthen the mitigation effect of the LTV ceiling.

Based on China's national conditions, this paper addresses the issue of household wealth inequality under the framework of macroprudential policy and links national policies, financial markets and real estate markets to explore a meaningful research direction. With the widespread use of household financial micro data, new findings about macroprudential policies and household wealth inequality can be obtained.

Funding

This work was supported by the National Natural Science Foundation of China [grant number 71871129], by the National Scocial Science Fund of China [grant number 21AJY007], by the Philosophy and Social Science Fund of Jinan [grant number JNSK22C43].

CRediT authorship contribution statement

Kun Zhai: Conceptualization, Data curation, Formal analysis, Methodology, Funding acquisition, Writing - original draft. **Guoqing Zhao:** Funding acquisition, Methodology, Software, Writing – original draft. **Ding Li:** Data curation, Supervision, Validation.

Declaration of Competing Interest

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

Data Availability

Data will be made available on request.

Acknowledgements

We are indebted to Professor Javier Olivera, Hongfeng Peng, Xinliang Yu, as well as to editors and anonymous reviewers for insightful comments.

Appendix A

A.1. Derivation of the OLG model.

Construct utility functions of rational individuals:

$$U_t = \ln(C_{1,t}) + \beta \ln(C_{2,t+1}) + \gamma \ln(b_{t+1}) + \varphi \ln(m_t)$$

Here

$$\begin{cases} b_t + H_t p_t \theta = C_{1,t} + H_t p_t + m_t \\ H_t p_{t+1} + m_t(1+\kappa) = C_{2,t+1} + H_t p_t \theta(1+r) + b_{t+1} \end{cases}$$

The Lagrange multiplier method is used to obtain

$$\begin{aligned} Z = {} & \ln(b_t + H_t p_t \theta - H_t p_t - m_t) + \beta \ln(C_{2,t+1}) + \gamma \ln(b_{t+1}) + \varphi \ln(m_t) \\ & + \lambda\left(C_{2,t+1} + H_t p_t \theta(1+r) + b_{t+1} - H_t p_{t+1} - m_t(1+\kappa)\right) \end{aligned}$$

$$\frac{\partial Z}{\partial H_t} = \frac{p_t\theta - p_t}{H_t p_t \theta - H_t p_t + b_t - m_t} + \lambda p_t \theta\left(1+r\right) - \lambda p_{t+1} = 0 \tag{A1}$$

$$\frac{\partial Z}{\partial C_{2,t+1}} = \frac{\beta}{C_{2,t+1}} + \lambda = 0 \tag{A2}$$

$$\frac{\partial Z}{\partial b_{t+1}} = \frac{\gamma}{b_{t+1}} + \lambda = 0 \tag{A3}$$

$$\frac{\partial Z}{\partial m_t} = \frac{\varphi}{m_t} - \frac{1}{H_t p_t \theta - H_t p_t + b_t - m_t} - \lambda(1+\kappa) = 0 \tag{A4}$$

$$\frac{\partial Z}{\partial \lambda} = C_{2,t+1} + H_t p_t \theta\left(1+r\right) + b_{t+1} - H_t p_{t+1} - m_t\left(1+\kappa\right) = 0 \tag{A5}$$

Adding Eq. (A1) to Eq. (A4) gives:

$$\frac{\varphi}{m_t} + \frac{\lambda p_t \theta(1+r) - \lambda p_{t+1}}{p_t\theta - p_t} - \lambda(1+\kappa) = 0$$

Then, we have:

$$m_t = \frac{\varphi(p_t\theta - p_t)}{\lambda[(1+\kappa)(p_t\theta - p_t) - p_t\theta(1+r) + p_{t+1}]} \tag{A6}$$

By substituting Eqs. (A2), (A3), and (A6) into (A5), we have:

$$-\frac{\beta}{\lambda} + H_t p_t \theta(1+r) - H_t p_{t+1} - \frac{\gamma}{\lambda} - \frac{\varphi(p_t\theta - p_t)(1+\kappa)}{\lambda[(1+\kappa)(p_t\theta - p_t) - p_t\theta(1+r) + p_{t+1}]} = 0$$

The following formula can be obtained by sorting:

$$\lambda = \frac{1}{p_t}\frac{(\beta+\gamma+\varphi)(1+\kappa)(\theta-1) - (\beta+\gamma)[\theta(1+r) - (1+\pi)]}{[\theta(1+r)-(1+\pi)][(1+\kappa)(\theta-1) - \theta(1+r) + (1+\pi)]}\frac{1}{H_t} \tag{A7}$$

Substituting Eq. (A7) into Eq. (A6) gives:

$$m_t = \frac{\varphi(p_t\theta - p_t)[H_t p_t \theta(1+r) - H_t p_{t+1}]}{(\beta+\gamma+\varphi)(1+\kappa)(p_t\theta - p_t) - (\beta+\gamma)[p_t\theta(1+r) - p_{t+1}]} \tag{A8}$$

Substituting Eqs. (A7) and (A8) into Eq. (A1) gives:

$$H_t = \frac{(\beta+\gamma)(1+\pi-\theta(1+r)) - (\beta+\gamma+\varphi)(1+\kappa)(1-\theta)}{p_t(1+\beta+\gamma+\varphi)(1-\theta)((\kappa-r)\theta+\pi-\kappa)}b_t \tag{A9}$$

Substituting Eq. (A9) into Eq. (A8) gives:

$$m_t = \frac{\varphi[(1+\pi)-\theta(1+r)]}{(\beta+\gamma+\varphi+1)[(\kappa-r)\theta+(\pi-\kappa)]}b_t \tag{A10}$$

Substituting Eq. (A9) into Eq. (A7) gives:

$$\lambda = \frac{(1-\theta)(\beta+\gamma+\varphi+1)}{\theta(1+r)-(1+\pi)}\frac{1}{b_t} \tag{A11}$$

Substituting Eq. (A11) into Eq. (A3) gives:

$$b_{t+1} = \frac{\gamma[(1+\pi)-\theta(1+r)]}{(\beta+\gamma+\varphi+1)(1-\theta)}b_t \tag{A12}$$

A.2. Description of wealth inequality.

First, household net wealth is expressed as:

$$W_1 = H_{t+1}p_{t+1} - H_{t+1}p_{t+1}\theta(1+r) + m_{t+1}$$

$$= \left\{\frac{\varphi[\kappa\theta(1+r)+\pi-\kappa][\theta(1+r)-(1+\pi)]}{(1+\beta+\gamma+\varphi)^2(\theta-1)[(\kappa-r)\theta+(\pi-\kappa)]} + \frac{(\beta+\gamma)[\theta(1+r)-1][\theta(1+r)-(1+\pi)]}{(1-\theta)^2(1+\beta+\gamma+\varphi)^2}\right\}\gamma b_t$$

and set

$$\alpha_1 = \left\{\frac{\varphi[\kappa\theta(1+r)+\pi-\kappa][\theta(1+r)-(1+\pi)]}{(1+\beta+\gamma+\varphi)^2(\theta-1)[(\kappa-r)\theta+(\pi-\kappa)]} + \frac{(\beta+\gamma)[\theta(1+r)-1][\theta(1+r)-(1+\pi)]}{(1-\theta)^2(1+\beta+\gamma+\varphi)^2}\right\}\gamma$$

So $W_1 = \alpha_1 b_t$.

$$W_2 = H_t p_{t+1} - H_t p_t \theta(1+r) + m_t(1+\kappa)$$
$$= \frac{(\beta+\gamma)[(1+\pi)-\theta(1+r)]}{(1-\theta)(1+\beta+\gamma+\varphi)} b_t$$

and set

$$\alpha_2 = \frac{(\beta+\gamma)[(1+\pi)-\theta(1+r)]}{(1-\theta)(1+\beta+\gamma+\varphi)}$$

So $W_2 = \alpha_2 b_t$.

Second, wealth inequality is described by Theil index entropy.

Assume that the total population is n in t + 1, the adult population is n_1, and the elderly population is n_2 with $n = n_1 + n_2$. Then, the wealth of each agent i is $W_{1i} = \alpha_1 b_{it}; W_{2i} = \alpha_2 b_{it}$.

We use Theil index entropy $I_2(W) = \frac{1}{2n}\sum_{i=1}^{n}\left[\left(\frac{W_i}{\mu}\right)^2 - 1\right]$ to represent wealth inequality (Frost & Stralen, 2018; Cowell, 1980; Bourguignon, 1979; Shorrocks, 1980), where μ is the mean of the population and W_i is the wealth of the i th adult.

Exponential entropy $I_2(W)$ can be decomposed into two parts: within- (I_{within}) and between-group inequality ($I_{between}$):

$$I_2(W) = I_{within} + I_{between} = \sum_{g=1}^{G}\left[\frac{n_g}{n}\left(\frac{\mu_g}{\mu}\right)^2\right] I_2(W^g) + \frac{1}{2n}\sum_{g=1}^{G}\left[\left(\frac{\mu^g}{\mu}\right)^2 - 1\right]$$

where there are G groups, $g = 1, \cdots, G$.

When G = 2, there are only two groups: G = 1 for adulthood and G = 2 for old age. Then, wealth inequality within the group is:

$$I_{within} = \frac{n_1}{n}\left(\frac{\mu_1}{\mu}\right)^2 \frac{1}{2n_1}\sum_{i=1}^{n_1}\left(\left(\frac{W_{1i}}{\mu_1}\right)^2 - 1\right) + \frac{n_2}{n}\left(\frac{\mu_2}{\mu}\right)^2 \frac{1}{2n_2}\sum_{i=1}^{n_2}\left(\left(\frac{W_{2i}}{\mu_2}\right)^2 - 1\right)$$

$$I_{within} = \frac{1}{2n\mu^2}\left[\sum_{i=1}^{n_1} W_{1i}^2 + \sum_{i=1}^{n_2} W_{2i}^2 - n_1\mu_1^2 - n_2\mu_2^2\right]$$

Because $n = n_1 + n_2$, $n_1 = n_2$, so,

$$I_{within} = \frac{1}{2n\mu^2}\left[\sum_{i=1}^{n_1} W_{1i}^2 + \sum_{i=1}^{n_2} W_{2i}^2 - \frac{n}{2}\left(\mu_1^2 + \mu_2^2\right)\right]$$

Then

$$I_{within} = \frac{n}{2\left(\sum_{g=1}^{2}\sum_{i=1}^{n_g} W_{gi}\right)^2}\left[\sum_{i=1}^{n_1} W_{1i}^2 + \sum_{i=1}^{n_2} W_{2i}^2 - \frac{2}{n}\left(\left(\sum_{i=1}^{n_1} W_{1i}\right)^2 + \left(\sum_{i=1}^{n_2} W_{2i}\right)^2\right)\right] \quad \text{(A13)}$$

Let $n_1 = n_2 = M = n/2$. Substituting $W_{1i} = \alpha_1 b_{it}$ and $W_{2i} = \alpha_2 b_{it}$ into Eq. (A13) gives

$$I_{within} = \frac{n}{2(\alpha_1+\alpha_2)^2\left(\sum_{i=1}^{M} b_i\right)^2}\left[\left(\alpha_1^2 + \alpha_2^2\right)\sum_{i=1}^{M} b_i^2 - \frac{2\left(\alpha_1^2+\alpha_2^2\right)}{n}\left(\sum_{i=1}^{M} b_i\right)^2\right]$$

Thus

$$I_{within} = \frac{n\left(\alpha_1^2+\alpha_2^2\right)}{2(\alpha_1+\alpha_2)^2}\left[\frac{\sum_{i=1}^{M} b_i^2}{\left(\sum_{i=1}^{M} b_i\right)^2} - \frac{2}{n}\right] = \frac{n\left(\alpha_1^2+\alpha_2^2\right)}{2(\alpha_1+\alpha_2)^2}\left[\frac{\sum_{i=1}^{M}\left(b_i^2 - \bar{b}^2\right)}{\left(\sum_{i=1}^{M} b_i\right)^2}\right]$$

We then obtain the within-group inequality index:

$$I_{within} = \frac{\alpha_1^2+\alpha_2^2}{(\alpha_1+\alpha_2)^2} A_1$$

where $A_1 = \frac{n}{2}\sum_{i=1}^{M}\frac{b_i^2 - \bar{b}^2}{\left(\sum_{i=1}^{M} b_i\right)^2} > 0$ and $\bar{b}$ is the mean value. Since debt is paid off in old age, it is not passed on to children, so A_1 is positive.

A.3. Comparative statics

$$\frac{dI_{within}}{d\theta} = \frac{2(\alpha_1 - \alpha_2)}{(\alpha_1 + \alpha_2)^3}\left[\alpha_2 \frac{d\alpha_1}{d\theta} - \alpha_1 \frac{d\alpha_2}{d\theta}\right]A_1$$

Among,

$$\frac{d\alpha_1}{d\theta} = \frac{\varphi\gamma}{(1+\beta+\gamma+\varphi)^2}\left(\frac{\kappa(1+r)[\theta(1+r)-(1+\pi)](\theta-1)+[\kappa\theta(1+r)+\pi-\kappa](\pi-r)}{(\theta-1)^2[(\kappa-r)\theta+(\pi-\kappa)]} + \frac{(\kappa-r)[\kappa\theta(1+r)+\pi-\kappa][\theta(1+r)-(1+\pi)]}{(\theta-1)[(\kappa-r)\theta+(\pi-\kappa)]^2}\right) + \frac{(\beta+\gamma)\gamma\left[2\theta(1+r)^2-\theta(1+r)(\pi+2)-r(\pi+2)+\pi\right]}{(1+\beta+\gamma+\varphi)^2(1-\theta)^3}$$

$$\frac{d\alpha_2}{d\theta} = \frac{(\beta+\gamma)(\pi-r)}{(1+\beta+\gamma+\varphi)(1-\theta)^2}$$

Therefore,

$$\frac{dI_{within}}{d\theta} = \frac{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa)-(\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi)+\gamma\theta r)}{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa)+(\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi+2\gamma)-\gamma\theta r)}2\gamma\left(\beta+\gamma\right)\left(1+\beta+\gamma+\varphi\right)A_1$$

For $2\gamma(\beta+\gamma)(1+\beta+\gamma+\varphi)A_1 > 0$, so

$$Sign\left[\frac{dI_{within}}{d\theta}\right] = Sign\left[\frac{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa)-(\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi)+\gamma\theta r)}{\varphi\gamma(1-\theta)(\kappa\theta(1+r)+\pi-\kappa)+(\beta+\gamma)((\kappa-r)\theta+\pi-\kappa)((1-\theta)(1+\beta+\varphi+2\gamma)-\gamma\theta r)}\right]$$

For the reasonable assignment of parameters, we assume that β= 0.9, γ= 0.9, φ= 0.9, r= 1, and κ= 3, π= 2, if $\kappa>\pi$(κ=2, π=3, if $\kappa<\pi$).

The sensitivity analysis of parameter values is carried out. Because $\kappa$is the time discount factor, $\beta \in (0,1)$. The simulated image is the same as that in Fig. 1 if β= 0.95, γ= 0.95, and φ= 0.95. The simulation diagram is shown in Fig. A1 if β= 0.9, γ= 1.5, and φ= 1.5.

As shown in Figs. A1 and A2, the simulation results are still robust.

Appendix B

see Tables B1–B5.

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