AGGREGATE AND DISTRIBUTIONAL IMPACTS OF LTV POLICY IN CHINA

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Date: July 14, 2025.

Key words and phrases. LTV policy, housing investment, crowding out consumption, distributional impacts, household heterogeneity, mortgage demand, primary homes, trade up, minimum down payment.

JEL classification: G18, G21, G51, E21, E65.

We thank Manuel Adelino, Markus Brunnermier, Gueorgui Kambourov, B. Ravikumar, Nobuhiro Kiyotaki, Dirk Krueger, Fabrizio Perri, Richard Rogerson, Stijn van Nieuwerburgh, Jim Poterba, Chris Sims, Amir Sufi, Gianluca Violante, Shang-Jin Wei, Junjie Xia, Wei Xiong, Bo Zhao, and seminar participants of the 2021 NBER-SAIF Research Conference on Real Estate Markets and Housing Finance in China, 2020 NBER Summer Institute, 2020 World Congress of Econometric Society, Geneva International Finance and Macroeconomic Workshop, Boston University, Federal Reserve Bank of New York, City University of New York, Peking University, 2019 NBER Chinese Economy Conference, 2019 SWUFE International Conference in Macroeconomics, Fifth Bank of Canada-Tsinghua PBCSF-Toronto University Conference in Chinese Economy, and University of Melbourne for helpful discussions. An earlier version of this paper is entitled "Aggregate and Distributional Impacts of LTV Policy: Evidence from China's Micro Data." The views expressed herein are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of Atlanta, the Federal Reserve System, or the National Bureau of Economic Research.

Abstract: We study how China's loan-to-value (LTV) policy affects mortgage markets and household consumption, focusing on an abrupt and unprecedented relaxation in LTV limits for secondary houses from 2014Q4 to 2016Q3. Using a rich dataset of over three million loan-level records from a major Chinese commercial bank, supplemented by survey data on urban household finances, we analyze how this policy shift influenced mortgage demand, house prices, and consumption across household groups and at the aggregate level. We find that this LTV relaxation, aimed at promoting housing investments, spurred a mortgage boom, especially in primary home mortgages, while crowding out household consumption among middle-aged, high-education households. Motivated by these findings, we develop and calibrate a dynamic equilibrium model that distinguishes between primary homes for housing services and secondary houses for investment. When the LTV limit for secondary houses is relaxed, demand for these properties surges, increasing house prices and capital gains. Unlike prior literature, we identify a housing investment channel in which these capital gains enable existing homeowners—particularly middle-aged and high-income households—to upsize their primary residences. Rising house prices then drive further demand and mortgage borrowing, amplifying the effects of the LTV policy change and reducing these households' non-housing consumption.

I. Introduction

The relationship between mortgage debt, house prices, and household consumption is a central topic in economic research, particularly in advanced economies such as the United States, where home equity often serves as a line of credit for consumption. When house prices rise, American homeowners commonly use cash-out refinancing to leverage increased home equity for consumption (e.g., Mian and Sufi, 2011; Mian et al., 2013; Berger et al., 2017). In emerging markets, however, this relationship can differ due to distinct institutional structures. In China, households cannot use home equity for credit lines or cash-out refinancing, and there is no secondary market for mortgage securitization (Fang and Feng, 2018). Despite China's significance as the world's largest emerging-market economy, limited research has examined how these institutional differences shape the relationship between mortgage debt, house prices, and consumption (Sufi, 2023).

This paper studies the impact of China's loan-to-value (LTV) policy on the housing and mortgage markets and its implications for household consumption. In China, investment in secondary houses is driven mainly by expected capital gains rather than housing services or rental income.[1] Thus, LTV policy on non-primary houses plays a central role in mortgage and housing markets. We focus on an abrupt and unprecedented relaxation in LTV policy for secondary houses between 2014Q4 and 2016Q3. Using over three million loan-level records from a major Chinese commercial bank and data from urban household surveys on both consumption and housing wealth, we study how this policy shift influenced mortgage demand, house prices, and consumption across household groups and at the aggregate level. We find that relaxing the LTV limit, aimed at promoting investment in non-primary houses, stimulated primary mortgage demand while crowding out household consumption, particularly among middle-aged and highly educated households.[2] These findings motivate and discipline a dynamic equilibrium model used to evaluate aggregate and distributional effects of LTV policy on mortgage borrowing and consumption across age-income groups.

LTV policy influences both housing investment and homeownership decisions, complicating the identification of mortgage demand for investment purposes. Unlike the conventional channel, which focuses on first-time buyers overcoming borrowing constraints to purchase housing services, the housing investment channel operates through existing homeowners responding to capital gains incentives under improved credit conditions. The 2014 policy shift provides an ideal case to study this channel. In 2014Q4, China raised the LTV limit for

[1] A secondary house, or non-primary house, is a property purchased for investment rather than housing services. Examples include second, third, or fourth houses owned by a household. We use "secondary house" and "non-primary house" interchangeably.

[2] Households are classified as highly educated if any member holds a college degree or higher.

secondary houses from 30–40% to 70% (Figure 1).[3] This shift triggered a mortgage boom, particularly for primary homes. Real house prices in 70 major cities grew at an annualized rate of 5.94% during 2014Q4–2016Q3. New mortgage origination volumes were 92% higher than in 2013, while nationwide outstanding mortgage debt rose from 10.6 to 17.9 trillion RMB between December 2014 and December 2016. Meanwhile, aggregate consumption growth began to decline from 2014Q4, persisting even after the LTV policy was reversed in 2016Q4. China's targeted LTV policy thus offers a transparent natural experiment to gauge its impact on mortgage markets and consumption.

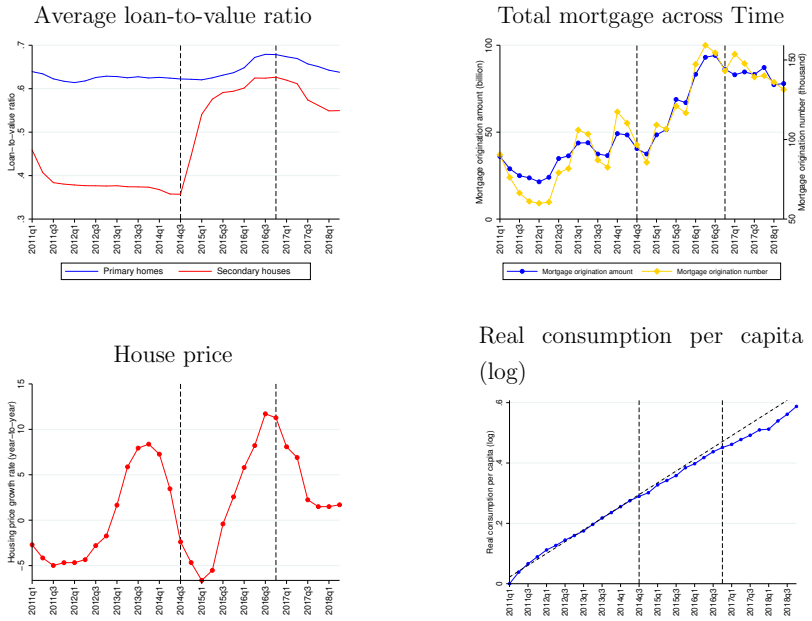


FIGURE 1. Time series of aggregate variables

Notes: The four panels are organized as follows. The top left panel: the LTV ratios for primary and secondary houses over time; the top right panel: the mortgage origination amount and number; the bottom left panel: the year-to-year growth rate of the real house price; and the bottom right panel: the logarithm of real consumption per capita (normalized to one in 2011Q1). For a given city, the real house price is calculated as the house price divided by the GDP deflator. City-level real house prices are aggregated to obtain the national average real house price, weighted by each city's 2011 population.

Sources: The Bank Loan Data, the National Bureau of Statistics of China, and China's macroeconomic time series available on the Federal Reserve Bank of Atlanta's website at `https://www.atlantafed.org/cqer/research/china-macroeconomy`.

[3]The policy aimed to lower barriers for investment-driven purchases. The 2015 Central Economic Work Conference stated: "It is necessary to encourage natural persons and various institutional investors to purchase inventories of commodity housing, ... to eliminate outdated restrictive measures" (`http://finance.people.com.cn/GB/8215/392239/401049/index.html`).

Our data highlight the pivotal role of middle-aged, highly educated homeowners in driving mortgage demand and aggregate consumption patterns. During the boom, their share of new mortgage originations rose sharply, while the share for younger households declined. Benefiting from rising house values, these middle-aged and highly educated households traded up to larger homes but reduced their non-housing consumption, while consumption among other groups remained relatively stable. The slowdown in aggregate consumption is largely attributable to this group's behavior, underscoring the housing investment channel. As a result, rising house prices induced middle-aged, highly educated homeowners to upgrade primary residences, taking on greater mortgage debt at the expense of consumption growth.

To assess the significance of the housing investment channel, we exploit cross-city variations in ex-ante exposure to the LTV policy change, using the 2011 share of secondary home mortgages as an instrument.[4] Cities with higher initial shares of secondary house mortgages were more affected by the policy. Our regression analysis shows that a one-standard-deviation increase in exposure raised the probability of primary mortgages being allocated to middle-aged, highly educated households by 1.9 percentage points. Our dynamic regressions confirm that the effects appear during the policy window (2014Q4–2015Q3), with no significant pre-policy or post-policy trends, providing further support for the policy's role.

Based on these findings, we construct a heterogeneous-agent life-cycle model. First, the model distinguishes between primary homes for housing services and secondary houses for investment, each subject to different LTV limits. Second, households' expectations of future house prices are independent of LTV policy, reflecting sustained demand from urban migration. The model is calibrated to match key pre-boom aggregate and cross-sectional moments. It explains more than 80% of the observed increase in house prices and 87% of the rise in new mortgage originations during the boom. It also replicates shifts in mortgage shares across age-education groups, especially the growing share for middle-aged and highly educated households.

Trading up primary homes emerges as the main driver of increased mortgage demand and house prices. The increase in trading-up activity accounts for 52.6% of the rise in total mortgage amounts, 66.4% of the rise in the number of originations, and 54% of the increase in housing demand. Middle-aged, high-income households account for most of this increase. Beyond the housing and mortgage markets, the model also captures the observed decline in non-housing consumption among this group, linking the LTV relaxation to broader macroeconomic impacts.

[4]Similar exposure-based methods have been used to study U.S. fiscal stimulus and housing credit programs (e.g., Mian and Sufi, 2012; Chodorow-Reich et al., 2012; Berger et al., 2021).

Several factors are crucial for the housing investment channel to influence mortgage demand and consumption. First, trading-up by existing homeowners, not first-time buyers, drives the boom. A counterfactual loosening of LTV policy for first-time buyers yields little house price increase and shifts mortgage shares toward young and low-income households. Second, due to long-term mortgage structures, tightening LTV constraints does not symmetrically reverse the boom. Existing borrowers are not forced to adjust, weakening the feedback loop that operates under relaxation. Third, when we allow cash-out refinancing, only 5.6% of households refinance, and only 0.3% of trading-up households do so, suggesting that investment motives dominate liquidity needs. Refinancing boosts consumption modestly (by 31.1% on average among refinancers), leading to a smaller aggregate consumption decline than in the benchmark.

Capital gains from rising house prices play a central role in amplifying the policy's effects. Higher house prices generate realized gains for homeowners, especially middle-aged and high-income households, enabling them to trade up despite credit constraints. This creates a feedback loop that further drives up house prices and mortgage demand. Imposing a one-period 100% capital gains tax on existing homeowners substantially dampens housing and mortgage demands and increases consumption among middle-aged and high-income households, highlighting the importance of capital gains.

Our paper contributes to the literature on the role of credit conditions in housing booms and busts.[5] Unlike previous studies focusing on first-time homebuyers, we quantify the housing investment channel as a driver of mortgage booms. Because investment-driven borrowers hold a large fraction of housing wealth, this channel is particularly important. While prior research emphasizes the positive effects of mortgage booms on consumption (e.g., Mian et al., 2013; Di Maggio et al., 2017), our model predicts a negative effect: greater mortgage debt among middle-aged and high-income households crowds out their consumption. This complements recent business cycle research on liquidity constraints and asset price feedback loops (e.g., Shi, 2015; Bigio and Schneider, 2017; Kiyotaki and Moore, 2019). Our new results support the theoretical findings of Mian et al. (2021), who show that financial expansions can generate debt-driven booms at the cost of future consumption ("indebted demand"), more than those of other studies.

The remainder of the paper is organized as follows. Section II introduces the two databases, presents aggregate and distributional facts about mortgage markets and household consumption, and provides an overview of China's LTV policy. Section III presents empirical evidence motivating the construction of our theoretical model. Sections IV and V develop and

[5]See, for example, Landvoigt et al. (2015), Favilukis et al. (2017), Kaplan et al. (2020).

calibrate a life-cycle equilibrium model distinguishing between primary homes for housing services and secondary houses for investment, and report its steady-state distributions. Section VI uses the model to quantify the aggregate and distributional impacts of LTV policy relaxation on mortgage markets and non-housing consumption. Section VII concludes.

II. Data and LTV policy

This section presents China's mortgage market background and the effects of LTV policy changes. We first introduce two granular datasets. We then describe the evolution of LTV policy during our sample period (2011–2017) and present key aggregate time series on mortgages and consumption, as well as the distribution of mortgage loans and non-housing consumption across age-education groups.

II.1. **Data.** Our analysis uses two granular databases. The first is a loan-level dataset from one of the largest Chinese commercial banks ("Bank Loan Data"). Since 2011, this bank's outstanding mortgage loans have consistently represented about 14% of all mortgage loans in China. The database covers all mortgage loans originated for new residential properties between 2011Q1 and 2018Q2, totaling over 3.2 million loans across 70 cities—matching the NBS city sample. Crucially, it identifies whether each mortgage was issued for a primary home or a secondary house, allowing us to estimate the effects of LTV policy changes on mortgage demand for primary homes. The data include house price, area, loan amount, mortgage rate, and borrower characteristics such as age, gender, occupation, education, self-reported income, number of houses owned, city, zip code, and credit score. Appendix A validates this database by comparing its aggregate and cross-sectional moments with external sources.

The second database is the China Household Finance Survey (CHFS), conducted biennially since 2011 by Southwestern University of Finance and Economics (Gan, Yin, Jia, Xu, Ma and Zheng, 2014). The inaugural survey covered about 9,000 households, growing to 19,181 urban households in 2013. The CHFS provides comprehensive data on household wealth, consumption, and income in China, surpassing U.S. and U.K. datasets such as the Consumer Expenditure Survey, the Survey of Consumer Finance, and the Living Costs and Food Survey by offering detailed breakdowns of household balance sheets and expenditures. Summary statistics for both datasets are provided in Appendix B.

II.2. **LTV policy in China.** Between 2011 and 2018, China's mortgage markets expanded rapidly. In 2013, residential mortgage loans accounted for 69.4% of total consumer loans, with medium- and long-term loans comprising 87.4%. All residential mortgages in China are used exclusively for home purchases. Unlike in the United States, Chinese households cannot

use home equity to secure a line of credit or refinance existing mortgage debt through cash-out refinancing. Moreover, there is no secondary mortgage market through securitization.[6] As a result, the maximum LTV ratios individual banks can offer closely follow government policy.

LTV policy became an effective tool for influencing mortgage demand only after 2010.[7] The policy specifies maximum LTV limits separately for (1) primary homes and (2) secondary houses. At the start of our sample in 2011, the LTV limits were 70% for primary homes and 40% for secondary houses. A timeline of key changes appears below.

Changes in Loan-to-Value Policy Over Time

Date	Policy Change	Coverage
BS—2011	LTV limit: 70% (primary), 40% (secondary)	Nationwide
03/30/2013	LTV limit for secondary houses decreased to 30%	Some cities
09/30/2014	LTV limit for secondary houses without outstanding mortgage increased to 70%	Nationwide
03/30/2015	LTV limit for secondary houses with outstanding mortgage increased to 60%	Nationwide
09/30/2015	LTV limit for primary homes increased to 75%	Nationwide
02/02/2016	LTV limit for secondary houses with outstanding mortgage increased to 70%	Nationwide
02/02/2016	LTV limit for primary homes increased to 80%	Nationwide
09/30/2016	LTV limit for secondary houses decreased to 30%	Various cities

Note: BS stands for the beginning of the sample.

Source: Official documents from the State Council, People's Bank of China, China Banking Regulatory Commission, and Ministry of Housing and Urban-Rural Development.

From 2014Q4 to 2016Q3, China relaxed LTV policy significantly by raising the secondary house limit from 30% to 70%—a 40 percentage point increase. This abrupt and unprecedented shift stands out even internationally.[8] By contrast, the LTV limit for primary homes rose only modestly, from 70% in 2011 to 80% by February 2016.

After 2016Q4, LTV policy tightened. Local governments in 20 cities—mostly first-tier and second-tier—reduced the secondary house LTV limit from 70% to 30%.[9] By June 2017, 44 cities had adopted similar tightening measures, particularly targeting secondary houses.

[6]A pilot program for reverse mortgages launched in 2014 remained negligible, with only 65 households participating nationwide by July 2017 (Fang and Feng, 2018).

[7]Before 2010, banks were not required to differentiate between primary and secondary mortgages. In early 2010, the People's Bank of China and the China Banking Regulatory Commission mandated this distinction (see https://www.chinanews.com.cn/estate/news/2010/06-05/2325187.shtml).

[8]In Spain, for example, after the 2008 Global Financial Crisis, banks reduced LTV ratios from about 100% to 80%, but changes were gradual and less drastic compared to China's 40 percentage point increase (Banco de España, 2020; Martín and Philippon, 2021).

[9]The LTV limit for primary homes simultaneously reverted to 70%.

II.3. **Key facts.** This section presents key aggregate and cross-group facts essential for our empirical results and for constructing the theoretical model.

II.3.1. *Aggregate facts.* The relaxation of LTV policy for secondary houses significantly impacted the entire mortgage market. Figure 2 shows that during the policy period (2014Q4–2015Q3), the volume of mortgages for both primary homes and secondary houses rose sharply relative to the pre-policy period. The increase was larger for primary homes, making them the main driver of aggregate mortgage growth. After 2015Q3, mortgage volume for secondary houses leveled off, while that for primary homes continued rising until LTV policy tightening in 2016Q3.

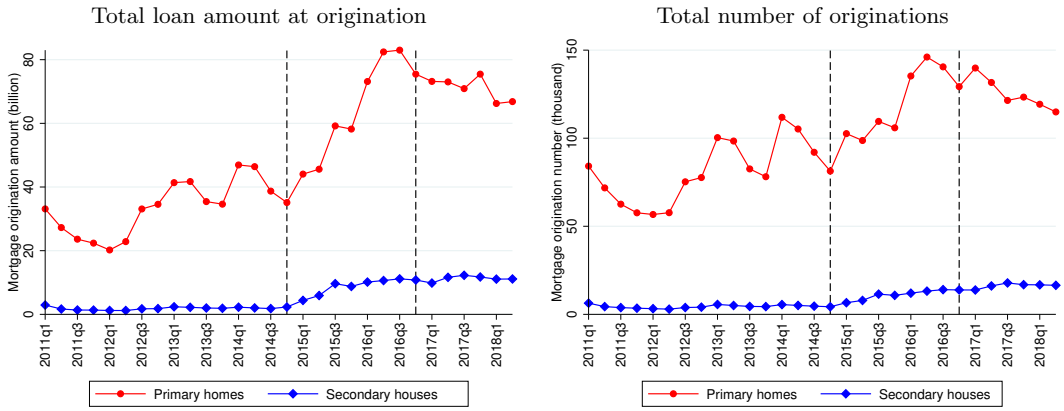


FIGURE 2. Mortgage Originations

Notes: The two panels are organized as follows: the amount of mortgage loans at origination for primary homes and secondary houses across time (left panel); and the number of mortgage originations for primary homes and secondary houses across time (right panel). The first dashed vertical line marks the beginning of the unprecedented change in LTV policy. The second dashed line marks the end of the relaxation of LTV policy. The most drastic change in LTV policy was for secondary houses.
Source: The Bank Loan Data.

To assess binding LTV constraints, we examine the distribution of LTV ratios over time (Figure 3). For primary homes, households at the 90th, 75th, and 50th percentiles had LTV ratios close to the maximum limit.[10] For secondary houses, LTV ratios before 2014Q4 were

[10]The maximum LTV for primary homes was 70% before 2015, then rose to 75% in 2015Q4 and to 80% in 2016Q1 for units smaller than 90 square meter under the Housing Provident Fund Loans program.

generally below or at the 40% limit. Following the 2014Q4 policy relaxation, LTV ratios increased significantly across all percentiles.[11]

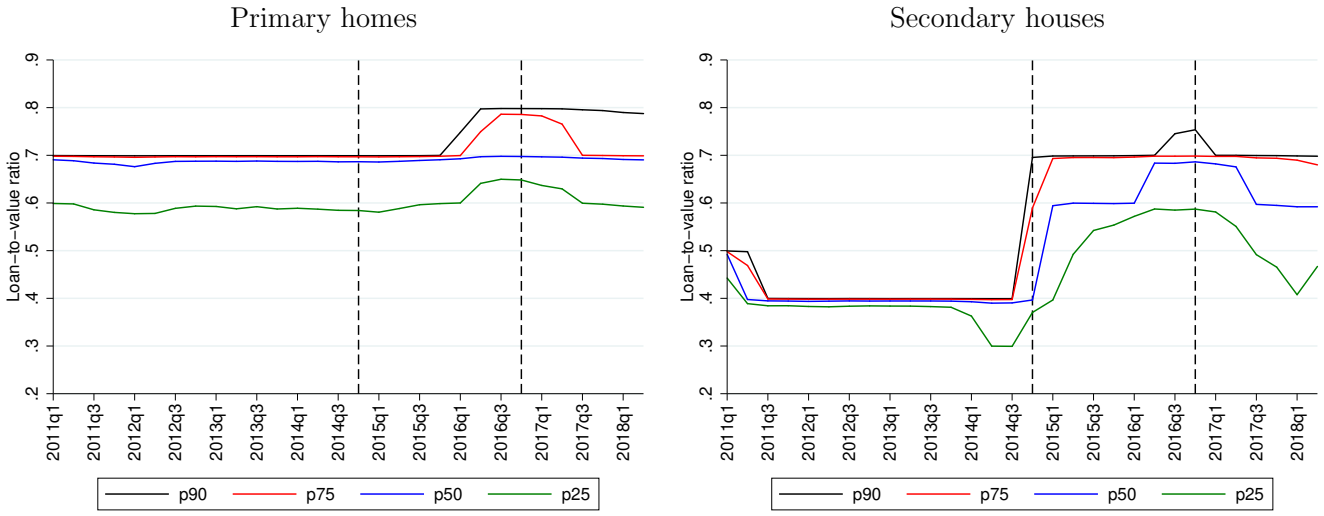


FIGURE 3. Distribution of LTV ratios

Notes: This figure plots the time series of the distribution of LTV ratio for primary homes and secondary houses. The first dashed vertical line marks the beginning of the unprecedented change in LTV policy. The second dashed line marks the end of the relaxation of LTV policy. The most drastic change in LTV policy was applied to secondary houses. The label "p90" stands for the 90$^{\text{th}}$ percentile of the distribution, "p75" the 75$^{\text{th}}$ percentile, "p50" the median, and "p25" the 25$^{\text{th}}$ percentile.

Source: The Bank Loan Data.

II.3.2. *Mortgage loans across age-education groups.* The relationship between mortgage lending and household demographics reveals how LTV policy shifts affected different groups. Figure 4 plots the age profile of average LTV ratios for 2011, 2013, and 2015. For primary homes, LTV ratios peaked around age 30 and were stable across years.[12] For secondary houses, LTV ratios were lower overall but rose substantially—from below 40% in 2013 to over 55% in 2015—consistent with LTV limit increases during this period.

Mortgage origination patterns also shifted. Figure 5 (top panels) shows a hump-shaped age profile in 2011 and 2013, with the highest share among the 25–30-year-old group. By 2015, middle-aged households (30–40) increased their mortgage share, while younger households' shares declined. This shift is visible in both loan amounts and origination numbers.

[11]The maximum LTV for secondary houses rose to 70%, except for borrowers with fully paid-off primary homes, who could exceed this limit. After 2016Q3, LTV tightening began again at the local level.

[12]See Adelino, Schoar and Severino (2018) for similar findings during the U.S. mortgage boom.

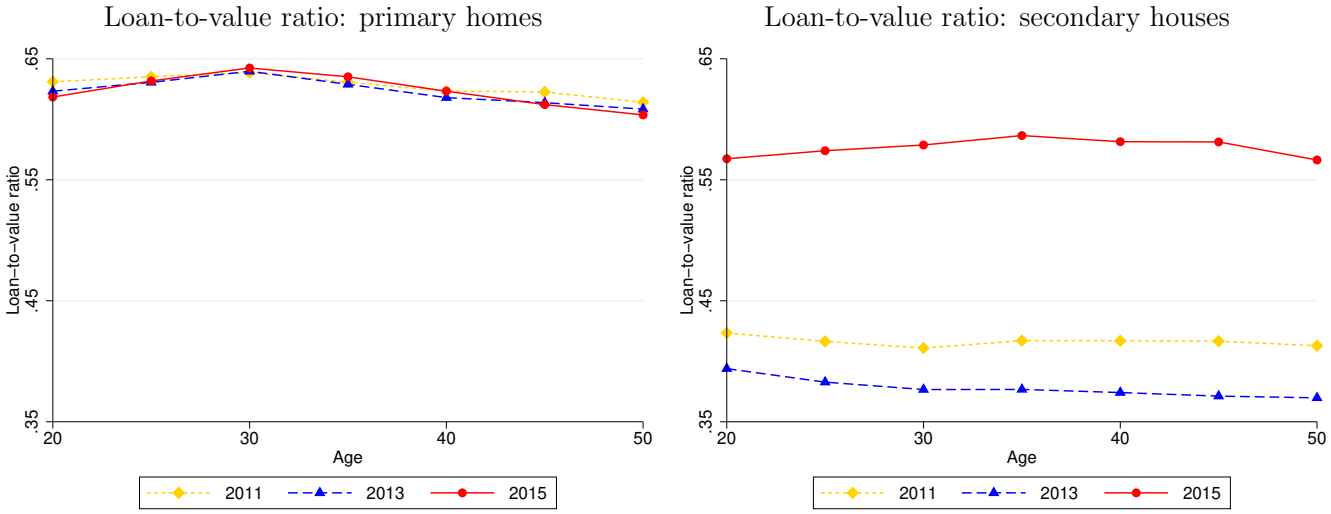


FIGURE 4. Loan-to-value ratio at origination

Notes: The left panel plots the average LTV ratio for primary homes in 2011, 2013 and 2015. The right panel plots the average LTV ratio for secondary houses in 2011, 2013 and 2015. Each LTV ratio is calculated as the average for its corresponding five-year age bin (e.g., 23–27 or 28–32).
Source: The Bank Loan Data.

To analyze indebtedness, we examine debt-to-income (DTI) ratios and mortgage participation rates (bottom panels of Figure 5). Both profiles exhibit hump-shaped patterns across ages before and after the policy change, and rose significantly between 2013 and 2015 for households aged 30–65. Increases came from both greater mortgage participation and higher DTI among borrowers, with the largest gains among the 30–50 year-old group.

Grouping households by education, we classify those with a college degree or higher as "high education" and others as "low education."[13] Tables 1a–1d show that middle-aged, high-education households saw a major rise in mortgage shares from 2013 to 2015—13.32% in loan amounts and 8.07% in originations for all houses, and similar gains for primary homes. By contrast, middle-aged and low-education households saw declines.

For house values (Figure 6), we deflate house prices by the city-specific constant-quality house price index to allow comparison over time. From 2011 to 2013, average house values were stable across age groups and education levels. Between 2013 and 2015, however, high-education households aged 30–55 experienced about a 20% rise in average house value,

[13]We use education level instead of self-reported income, due to known biases (e.g., Jiang et al. (2014), Ambrose et al. (2016), Mian and Sufi (2017)).

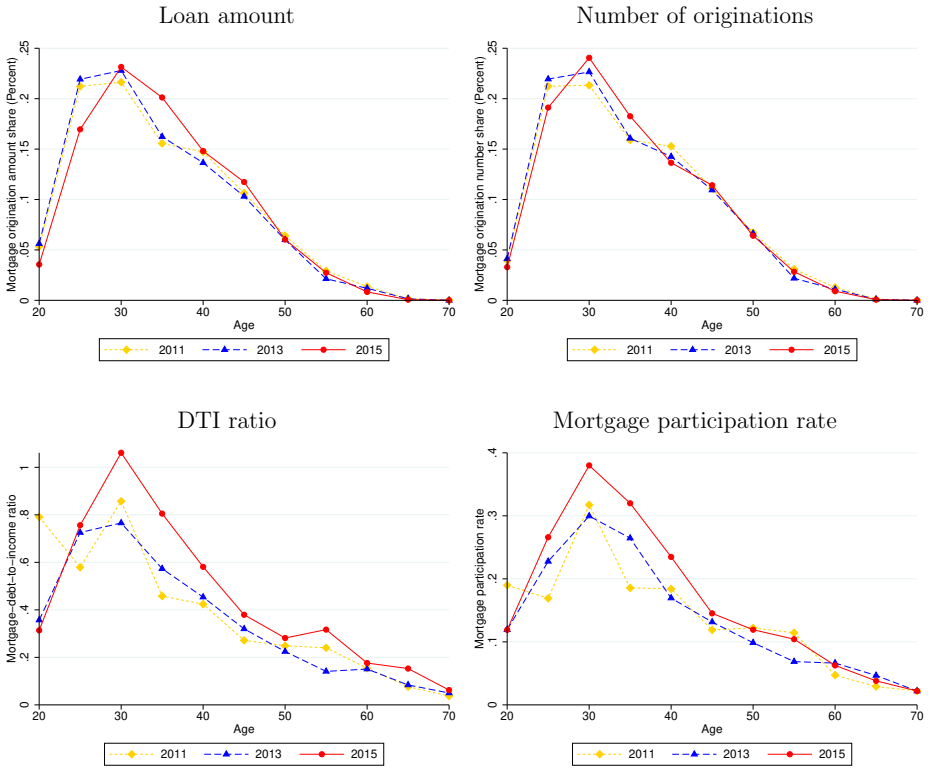


FIGURE 5. Mortgage loans across age groups

Notes: Top left panel: the share of loan amounts for each age group in the total loan amount at origination in 2011, 2013, and 2015. Top right panel: the share of origination numbers for each age group in the total number of originations in 2011, 2013, and 2015. The acronym "DTI" stands for debt-to-income (debt in this paper refers to mortgage debt). Bottom left panel: the average DTI ratio for each age group in 2011, 2013, and 2015. Bottom right panel: the average fraction of households with positive mortgage debt within each age group across all households in 2011, 2013, and 2015. The top panels are calculated from the Bank Loan data, and the bottom panels are from CHFS.

Sources: The Bank Loan Data and the CHFS.

suggesting that they actively traded up to larger homes during the mortgage boom. No such trend appeared for low-education households.

In summary, the LTV relaxation between 2014 and 2016 led to significant increases in mortgage loans for both primary homes and secondary houses. Middle-aged and highly educated households in particular used the relaxed policy to trade up to larger primary homes, increasing their mortgage burden. These patterns underscore the critical role of demographic factors—especially age and education—in shaping mortgage demand during the mortgage boom.

II.3.3. *Consumption Across Age-Education Groups.* We now turn to changes in consumption. To account for differences across age and education (income) groups, we compute the

TABLE 1. Percentage changes in mortgage share and household consumption by age and education

(A) Change in loan amount between 2013 and 2015: all houses

	Low education	High education
Age $<$ 30	-4.13	-2.58
30 $\leq$ Age $<$ 50	-6.45	13.32
Age $\geq$ 50	-1.11	0.95

(B) Chang in loan amount between 2013 and 2015: primary homes

	Low education	High education
Age $<$ 30	-3.79	-1.17
30 $\leq$ Age $<$ 50	-6.26	11.78
Age $\geq$ 50	-1.19	0.64

(C) Change in origination numbers between 2013 and 2015: all houses

	Low education	High education
Age $<$ 30	-2.66	-0.09
30 $\leq$ Age $<$ 50	-5.45	8.07
Age $\geq$ 50	-0.52	0.65

(D) Change in origination numbers between 2013 and 2015: primary homes

	Low education	High education
Age $<$ 30	-2.46	0.52
30 $\leq$ Age $<$ 50	-5.22	7.26
Age $\geq$ 50	-0.57	0.46

(E) Changes in household consumption by age and education(%)

	Low education	High education
Age $<$ 30	2.83 (-3.95, 9.62)	0.08 (-5.51, 5.67)
30 $\leq$ Age $<$ 50	-1.40 (-3.12, 0.31)	-3.59*** (-5.96, -1.23)
Age $\geq$ 50	-0.11 (-1.54, 1.31)	1.35 (-2.30, 5.00)

Notes: This table presents the changes in mortgage origination amounts and numbers, as well as changes in household consumption by age and education. The annualized changes in consumption for 2015–2017 are calculated relative to the annualized growth rate for 2013–2015 (prior to the LTV policy change). Values in parentheses represent the 95% confidence intervals. The symbol *** denotes statistical significance at the 0.01 level.
Source: The Bank Loan Data and the CHFS.

annualized change in consumption for each group during 2015–2017, relative to its own trend level based on the 2013–2015 growth rate, prior to the LTV policy change.[14]

[14]In the CHFS, consumption data refer to expenditures in the year preceding each survey. Thus, "2015" refers to consumption in 2014.

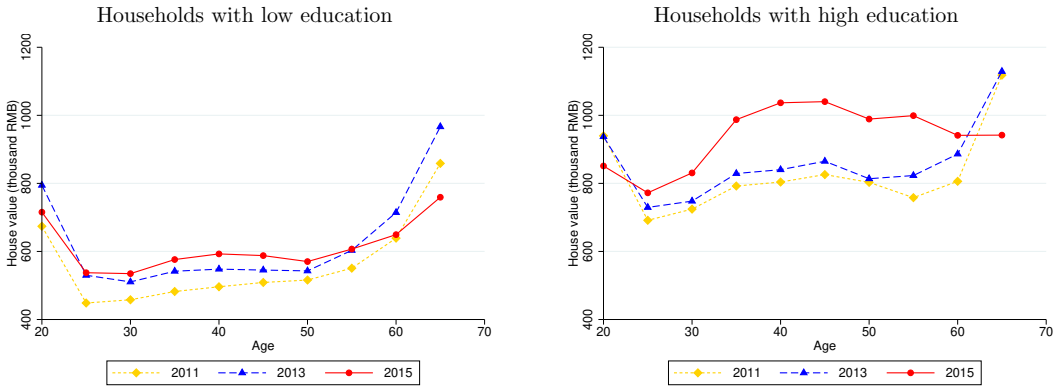


FIGURE 6. Average house value: primary homes

Notes: This figure displays house values across ages for households with low and high education levels. Each household's house value in a given year is deflated by the monthly NBS house price index for the city in which the household resided at the time of mortgage origination.

Sources: The Bank Loan Data and the NBS.

Table 1e reports consumption changes for 2015–2017 across age-education groups, including both homeowners and renters. The primary driver of the aggregate consumption slowdown during the mortgage boom was decreased consumption growth among middle-aged, highly educated households. Specifically, this group experienced a 3.59% annualized decline in consumption relative to its trend during the LTV policy relaxation. In contrast, all other age-education groups show statistically insignificant deviations from their trend growth. Importantly, this decline was not due to slower income growth; income for middle-aged, highly educated households increased during 2015–2017 compared to 2013–2015.

To investigate the role of housing and mortgage debt, we further divide middle-aged, highly educated households into homeowners and renters. If increased mortgage burdens drove the slowdown, we would expect the decline to be concentrated among homeowners. Consistent with this reasoning, consumption for middle-aged and highly educated homeowners declined significantly by 3.61% annually,[15] statistically significant at the 0.01 level, while no statistically significant change was observed for renters.[16]

Thus, the consumption slowdown during the mortgage boom was driven entirely by middle-aged and highly educated homeowners, supporting the view that rising mortgage burdens suppressed consumption for this group.

[15]This decline occurred despite a 5.25% increase in income relative to the trend.

[16]These results are available upon request.

III. Motivating evidence

During the period of policy relaxation, we observe that middle-aged households with high education, on average, increased the size of their primary homes. An important question is whether the relaxation of the LTV limit for secondary houses affected mortgage demand for primary homes among this group. In this section, we explore the link between the relaxation of LTV policy and the share of primary home mortgages held by middle-aged households with high education.

III.1. **Policy exposure.** For assessing the impact of changes in LTV policy, one key concern is to disentangle the effects of policy from those of fundamental economic factors to which the policy may respond. For example, as the bottom panel of Figure 1 shows, the LTV policy relaxation was implemented after a slowdown in house price growth. Therefore, the 2014Q4-2016Q3 mortgage boom could have been influenced by factors driving both the previous boom and its subsequent slowdown in 2013-2014. To address this concern, we exploit cross-city variation in ex-ante exposure to the relaxation of the LTV limit on secondary houses. Households in cities with fewer potential buyers of secondary houses serve as a "control group." The difference in the average responses of secondary mortgages between the treatment and control groups of cities helps isolate the effect of this policy change from other nationwide policy shifts and aggregate shocks.

Since the LTV policy targets secondary house buyers, we expect its impact to be more pronounced in cities where households had historically purchased secondary houses before the policy change. Note that the exposure measure is not merely a reflection of city size, as there is significant variation in LTV policy exposure across cities. For instance, exposure ranges from 2.4% at the 10th percentile to 14.5% at the 90th percentile, with a standard deviation of 5%. The mean exposure is 7%, and the median is 4.7%. Figure 7 shows that high-exposure cities include not only large cities like Beijing, Shanghai, Guangzhou, and Shenzhen (tier-one cities in China) but also medium and small cities (tier-two and tier-three) such as Beihai, Haikou, and Wenzhou. These high-exposure medium and small cities had exposure rates around 20%, reflecting a strong inclination to invest in secondary houses in these areas.

We use the 2011 measure as an instrument, accounting for the possibility that the LTV policy relaxation was partially a response to the housing market slowdown in 2013-2014. Specifically, we measure a city's exposure to LTV policy by calculating the number of mortgage originations for secondary houses in 2011 (the beginning of our sample) as a share of total mortgage originations in that city, using the Bank Loan Data. A potential concern about our identification design is that our exposure measure may capture the effects of other

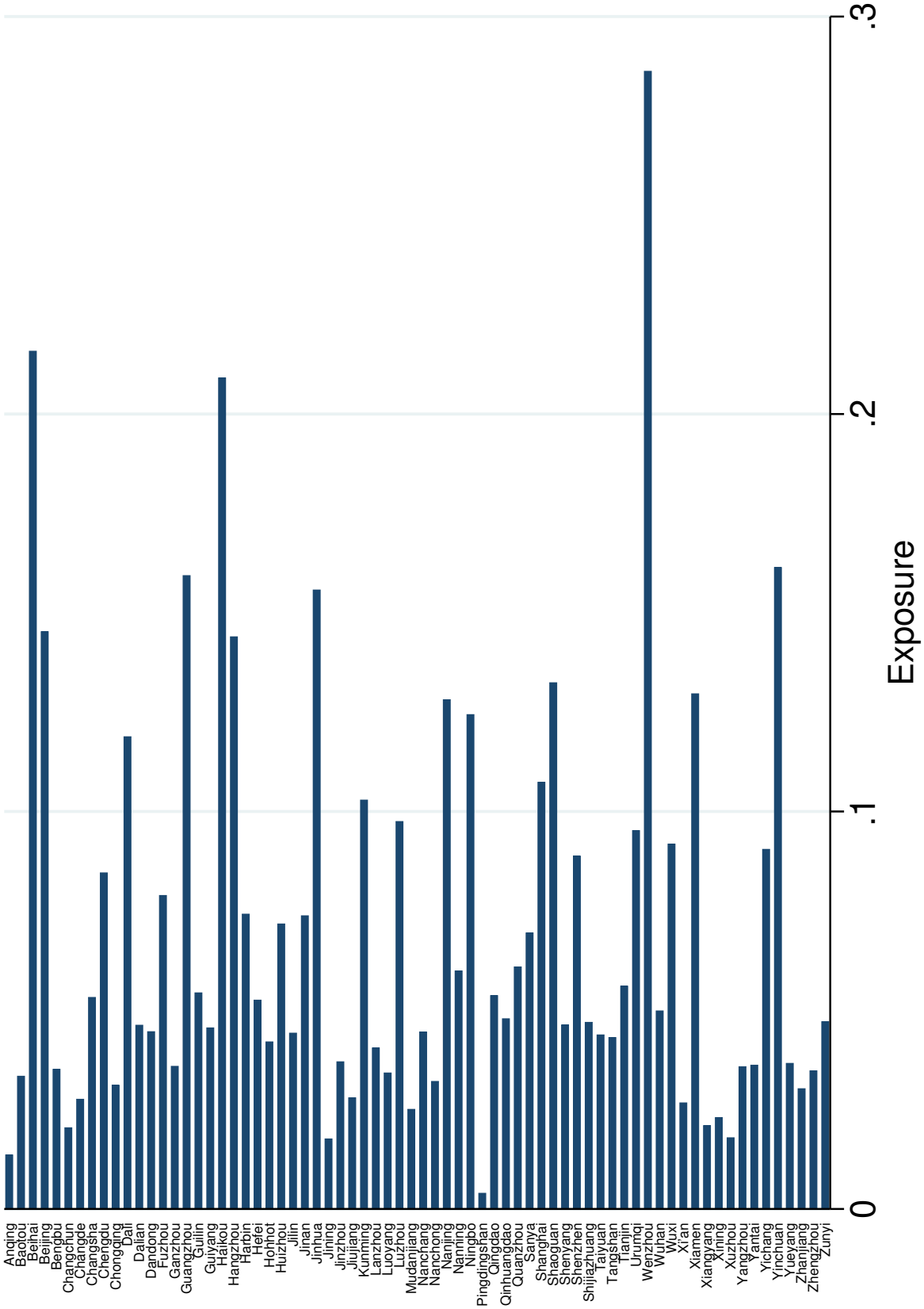


FIGURE 7. Exposure measures for various cities

city-specific pre-policy characteristics on changes in the mortgage origination share during the mortgage boom. We address this concern in the following section.

III.2. **Impacts of LTV policy on age-education groups.** There are two common issues associated with our policy instrument. First, the policy exposure measure may correlate with characteristics of the treatment cities that are unrelated to the LTV policy. Table 2 reports bivariate regressions of policy exposure on various city-level characteristics in 2011 that may affect the demand for secondary houses as investments. As the table shows, cities with higher policy exposure tend to have lower income growth, longer mortgage maturities for both primary homes and secondary houses, lower mortgage interest rates for primary homes, higher LTV ratios for secondary houses, and higher house price growth before the sample period. There is no statistically significant correlation between policy exposure and population growth, unemployment changes, mortgage interest rates for secondary houses, the LTV ratio for primary homes, or local house price sensitivity.

To account for the correlations between policy exposure and city pre-policy characteristics, we estimate a regression that includes interactions between these characteristics (as detailed in Table 2) and the change in LTV policy. In this regression, the change in LTV policy is represented by a policy dummy variable, which equals one from 2014Q4 to 2016Q3 and zero otherwise. This approach is widely used in the literature (e.g., Mian and Sufi (2012); Berger et al. (2021)), and we apply it here in our regression analysis. If the policy effect is driven by other city-specific characteristics, we would expect the coefficient of the interaction between our policy exposure and the policy dummy variable to become statistically insignificant when these interaction terms are included.

We categorize households into three age groups: below 30 (young households), 30-49 (middle-aged households), and 50 and above (old households). This classification is consistent with the age profile of mortgage loans before the relaxation of the LTV policy, which peaked at age 30. To estimate the effects of the LTV policy on primary home mortgages held by middle-aged and highly-educated households, we apply a difference-in-differences approach to the subsample of mortgage loans made for primary homes. We estimate the following loan-level regression:

$$y_{ict} = \beta Exposure_c \times Policy_t + \Gamma X_{c,2011} \times Policy_t + \Psi Z_{ct} + \alpha_c + \delta_t + \varepsilon_{ict}, \tag{1}$$

where y_{ict} is a dummy variable equal to one if mortgage loan i was made to a middle-aged household with high education and zero otherwise; $Exposure_c$ is the share of mortgage originations for secondary houses in city c in 2011, $Policy_t$ is a dummy equal to one from 2014Q4 to 2016Q3; $X_{c,2011}$ includes city characteristics in 2011 (from Table 2); Z_{ct} includes the lagged city-level mortgage interest rate for primary homes, the lagged average urban

TABLE 2. Correlates of exposure to LTV policy on secondary houses

	Dependent variable is exposure		
	beta	R^2	N
Income growth in 2011	-0.309***	0.095	70
	(0.115)		
Population growth in 2011	0.001	0.000	70
	(0.121)		
Unemployment rate change in 2011	0.027	0.001	70
	(0.121)		
Median mortgage rate for 1st H in 2011	-0.274**	0.075	70
	(0.117)		
Median mortgage rate for 2nd H in 2011	0.010	0.000	70
	(0.121)		
Median mortgage maturity for 1st H in 2011	0.373***	0.139	70
	(0.112)		
Median mortgage maturity for 2nd H in 2011	0.304**	0.093	70
	(0.116)		
Median mortgage LTV for 1st H in 2011	0.021	0.000	70
	(0.121)		
Median mortgage LTV for 2nd H in 2011	0.322***	0.104	70
	(0.115)		
Average house price growth between 2006 and 2009	0.309***	0.095	70
	(0.115)		
Local house price sensitivity	0.119	0.014	70
	(0.120)		

Notes: This table reports results from bivariate regressions of policy exposure on city-level characteristics in 2011. Local house price sensitivity is calculated using house price index data between 2006 and 2009, following Guren et al. (2021). Variables are normalized by their cross-sectional standard deviations. The coefficient, reported as *beta*, is interpreted as a β-standard-deviation change in exposure produced by a one-standard-deviation change in a city-level observable. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

income per capita, the lagged city population, and the lagged city unemployment rate; α_c represents city fixed effects and δ_t represents year-quarter fixed effects. The coefficient β captures the average effect of the LTV policy on primary home mortgages during 2014Q4-2016Q3, with the exposure measure normalized by its cross-sectional standard deviation.

Table 3 presents the estimated results. The estimated coefficient β is positive and statistically significant at the 1% level, even when controlling for interactions between the policy variable and various correlates. After including all correlates in one regression, the coefficient remains highly significant, indicating that a one-standard-deviation increase in policy exposure raises the probability of primary home mortgages for middle-aged, high-education households by 1.9 percentage points (column 13).

The second issue with our policy instrument involves the impact of city-specific time trends and potential confounders arising from the LTV policy change for primary homes during the same period. Note that the policy change for primary homes was much smaller than that for secondary houses. To further distinguish the effects of relaxing the LTV policy for secondary houses from those for primary homes, we estimate a regression with quarterly coefficients. Specifically, we estimate the following rolling regression:

$$y_{ict} = \beta_t Exposure_c + \Gamma_t X_{c,2011} + \Psi Z_{ct} + \alpha_c + \delta_t + \varepsilon_{ict}, \tag{2}$$

where β_t and Γ_t are time-varying coefficients.

Figure 8 illustrates the time series of these quarterly coefficients. In the pre-policy period (prior to 2014Q4), the estimates of β are statistically insignificant and those values are very stable since 2013Q1, indicating parallel pre-trends. After 2014Q4, the coefficients become positive and statistically significant, especially during 2014Q4-2015Q3, when only the LTV policy for secondary houses was relaxed.

As a comparison, we estimate the same regression as in equation (1), but change the dependent variable to a dummy variable indicating whether the mortgage loan was made to a middle-aged and low-education household. Table C.1 shows that the coefficient of exposure is negative and statistically significant in most specifications, and becomes statistically insignificant when all interaction terms are included. These results suggest that the LTV policy change did not increase mortgages for primary homes among middle-aged households with low education. This finding is consistent with Figure 6, which shows that only middle-aged, high-education households increased their average housing values for primary homes.

In conclusion, although only a small share of mortgages were for secondary houses, the relaxation of the LTV limit on secondary houses during 2014Q4-2016Q3 fueled a mortgage boom, particularly among middle-aged and highly-educated households. This policy effect did not extend to middle-aged households with low education, indicating that the LTV policy

TABLE 3. The effect of a loosening of LTV policy for secondary houses on the mortgage share of middle-aged households with high education in total mortgages on primary homes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Exposure × Policy	0.027***	0.026***	0.027***	0.027***	0.026***	0.027***	0.026***	0.026***	0.027***	0.025***	0.027***	0.027***	0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Income growth in 2011 × Policy		-0.003											0.004
		(0.003)											(0.003)
Population growth in 2011 × Policy			-0.002										-0.011***
			(0.002)										(0.003)
Unemployment rate change in 2011 × Policy				0.001									0.014***
				(0.003)									(0.005)
Median mort rate for 1st H in 2011 × Policy					-0.003								-0.003
					(0.003)								(0.003)
Median mort rate for 2nd H in 2011 × Policy						0.002							-0.001
						(0.003)							(0.004)
Median maturity for 1st H in 2011 × Policy							0.004						0.004
							(0.003)						(0.005)
Median maturity for 2nd H in 2011 × Policy								0.006*					0.013***
								(0.003)					(0.004)
Median LTV for 1st H in 2011 × Policy									-0.009***				-0.014***
									(0.003)				(0.003)
Median LTV for 2nd H in 2011 × Policy										0.004			0.008**
										(0.003)			(0.004)
Average house price growth between 2006 and 2009											0.001		0.005
											(0.003)		(0.004)
Local house price sensitivity												-0.005*	-0.009***
												(0.003)	(0.003)
Adjusted R^2	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.049
Observations	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608
City-level time-varying controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions are based on the subsample with mortgages on only primary homes and control for time-varying city-level characteristics including lagged mortgage interest rate, lagged urban income per capita, lagged population, and lagged unemployment rate. The abbreviation "1st H" stands for primary home and "2nd H" for secondary house. All city characteristics are normalized by their cross-sectional standard deviations. Standard errors, reported in parentheses, are clustered at the city-year-quarter level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

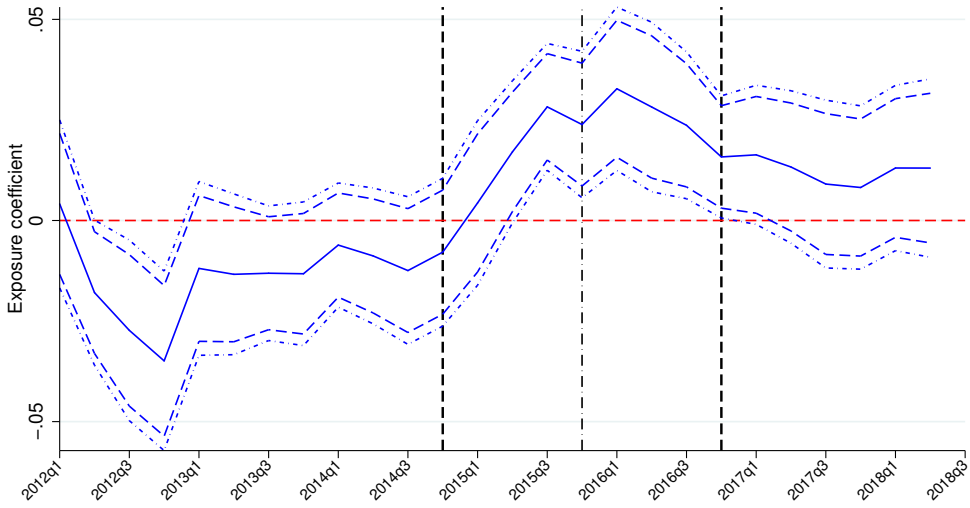


FIGURE 8. Quarterly effects of policy exposure on the likelihood of a mortgage loan allocated to the primary home of a middle-aged household with high education

Notes: This figure plots the estimated time-varying coefficients from equation (2). The solid line represents the estimate of β_t. The two dashed lines contain the 90% confidence interval, and the two dash-dotted lines contain the 95% confidence interval. The first dashed vertical line marks the beginning of the unprecedented change in LTV policy for secondary houses. The second dashed vertical line indicates the beginning of the relatively minor change in LTV policy for primary homes. The third dashed line marks the end of the relaxation of all LTV policies.

disproportionately benefited highly educated—and therefore more affluent—households, who held a significant share of the economy's wealth.

III.3. **Other considerations and robustness analysis.** We now discuss additional considerations related to the potential endogeneity of LTV policy and provide a robustness analysis to support the validity of our findings. One consideration is that although our policy exposure measure is city-specific and the nationwide LTV policy changes should be exogenous to city-specific factors, the policy may have been influenced by economic conditions in large cities. To address this concern, we re-estimate our benchmark regression in

equation (1), excluding tier-1 cities.[17] As shown in Table C.2, the results remain quantitatively similar, whether or not tier-1 cities are excluded. This finding suggests that the estimated effects are not driven by large cities.

The second consideration is that changes in mortgage regulation may be partially related to low-income growth in some parts of China. To control for potential differences in income growth across city tiers, we include interaction terms between city tier and time dummies in our regression. By incorporating these interaction terms, we account for time-varying factors specific to each city tier, allowing us to capture the differential responses to the policy change between high-exposure and low-exposure cities *within* each tier. The results, shown in Table C.3, are consistent with our benchmark results and provide further support for the robustness of our approach.

The third consideration is that the LTV policy may have affected local mortgage rates differently across cities with varying levels of policy exposure, leading to disproportionate credit allocation to middle-aged and highly-educated households via the mortgage rate.[18] Fieldhouse, Mertens and Ravn (2018) find that an increase in agency mortgage purchases in the United States stimulates mortgage originations and lowers mortgage rates. For China, we examine whether the LTV policy had significantly different effects on mortgage rates across cities with varying levels of policy exposure. Specifically, we substitute the dependent variable in regression (1) with the mortgage rate (in percentage points), while keeping all other specifications the same. The results, shown in Table C.4, indicate that the LTV policy change did not have any significant impact on mortgage rates across the regressions. When controlling for all city characteristics (column 13), the estimated coefficient remains insignificant and close to zero in magnitude. This finding suggests that the reallocation of mortgages toward middle-aged and highly-educated households during the mortgage boom is unlikely to have occurred through the mortgage rate.

[17]In China, cities are commonly classified into tiers based on various criteria, including city size and economic development. Tier-1 cities are Beijing, Shanghai, Guangzhou, and Shenzhen—large, highly developed cities that are major hubs for national and international business, finance, and trade. Tier-2 cities include large provincial capitals or significant regional hubs, such as Chengdu, Hangzhou, Wuhan, and Nanjing. Tier-3 cities are generally smaller and less economically developed compared to tier-2 cities.

[18]In China, most mortgages have variable rates. The People's Bank of China, the central bank, sets the benchmark lending rate for all commercial loans, which changes over time. During our sample period, the mortgage rate for a given loan was tied to the benchmark rate, fluctuating according to the terms specified in mortgage contracts. Banks typically reset the mortgage rate on the first day of the new year following changes in the benchmark rate. The mortgage rates across various age-education groups were very similar in our sample.

IV. A theoretical model with LTV constraints

Our empirical findings reveal that loosening LTV policy boosted mortgage demand disproportionately among middle-aged and highly-educated households, particularly for financing their primary homes. Despite only a small share of total mortgages used for secondary houses, the relaxation of the LTV limit on secondary houses during 2014Q4-2016Q3 triggered a mortgage boom, largely driven by affluent, middle-aged households who hold a substantial portion of the economy's wealth. This result provides key motivating evidence for developing a theoretical model that explains the transmission mechanism through which changes in LTV constraints on secondary houses permeate the entire mortgage market, affecting not only secondary house purchases but also mortgages for primary residences. In this section, we construct a theoretical model that captures the impact of LTV policy changes on mortgage demand and non-housing consumption, with a particular focus on middle-aged households with high incomes.

The model incorporates two distinctive aspects of China's housing market. First, it distinguishes between primary homes and secondary houses: these two types of houses are subject to different LTV limits. More important, we assume that while primary homes provide housing services, secondary houses do not. These assumptions are motivated by the institutional facts in China. In China, limited investment alternatives have led to the use of secondary houses as investment vehicles rather than for housing consumption. The stock markets are poorly regulated and dominated by state-owned enterprises, while strict capital controls and a tightly managed exchange rate further limit opportunities for household savings. Consequently, houses have become the primary store of wealth for many Chinese households. Land for real estate construction is also constrained by government regulations, including the "red-line lower limit" for arable land, which limits land supply and drives up property prices. Local governments, which rely heavily on revenues from land sales, have strong incentives to restrict land availability, further boosting real estate values.

As a result of these dynamics, secondary houses have been purchased as investments. In 2013, around 15% of urban Chinese households owned a second house for investment purposes. The price-to-income ratios in China are much higher than in developed economies, making housing an attractive investment option despite limited use as a primary residence. For example, while the price-to-income ratio in the United States peaked at around 3 during the housing bubble, the ratio exceeded 6 for middle-income households in China. In 2013, based on our calculations from the CHFS data for urban China, houses accounted for 80.4%

of urban household wealth, compared to just 40% in the United States. Meanwhile, non-housing financial assets represented only 8.63% of total wealth in China, compared to 37.9% in the United States.

For its second key aspect, the model follows Landvoigt (2017) and incorporates households' subjective beliefs about future house prices, π, to capture investment-driven housing demand. This element introduces an investment incentive for acquiring secondary houses, enabling LTV policy changes to specifically target housing investments. The model, with these two aspects, allows us to assess the distributional effects of a relaxed LTV policy on mortgage demand, household consumption, and their aggregate implications.

IV.1. **Households.** We begin by describing the model environment for households, followed by the household decisions made in each period.

IV.1.1. *The environment.* The economy is characterized by a continuum of overlapping generations of households. The life cycle of each household is divided into working and retirement phases, with ages indexed by $j = 1, 2, \ldots, J$ and retirement commencing at age J^{ret}. All households reach the end of life with certainty after age J.

The household's expected lifetime utility is given by:

$$\hat{E}\left[\sum_{j=1}^{J} \beta^{j-1} u_j\left(c_j, s_j\right) + \beta^J v(\mathfrak{b})\right],$$

where $\beta > 0$ is the discount factor, c_j is non-housing consumption, and s_j represents consumption of housing services. Each period, the household has constant elasticity of substitution (CES) utility over non-housing consumption and housing services, given by

$$u(c, s) = \frac{[(1-\phi)c^{1-\gamma} + \phi s^{1-\gamma}]^{\frac{1-\sigma}{1-\gamma}}}{1-\sigma},$$

where γ determines the elasticity of substitution between non-housing consumption and housing services, and σ determines relative risk aversion. The housing utility weight, ϕ, determines the share of housing services in total consumption.

Households' decisions depend on their beliefs about future house prices, with expectations denoted by $\hat{E}$. Following Landvoigt (2017), we assume that households have common subjective beliefs about future house prices, denoted by $\hat{E}[p'_h]$. These beliefs about future house prices reflect the anticipation of higher future demand for urban housing due to the relaxation of China's urban policy, known as the "Hukou" restriction.[19] This urban policy is

[19]According to Wu, Gyourko and Deng (2012), the urbanization rate grew on average by 1.4% per year between 1996 and 2015. Even with a slightly slower growth rate of urbanization since 2015, about 15 million new people have entered urban areas each year.

unrelated to LTV policy. Households are assumed to believe that high future house prices are sustainable, reflecting the public expectation that the Hukou relaxation, once implemented, would not be reversed.

The model includes a warm-glow bequest motive to capture the common practice in China where elderly individuals often bequeath their homes to children or grandchildren. This bequest is represented by the functional form:

$$v(\mathfrak{b}) = \varphi \frac{\mathfrak{b}^{1-\sigma}}{1-\sigma},$$

where φ represents the strength of the bequest motive.

At birth, households are ex-ante heterogeneous in their endowment of permanent (lifetime) labor ability, denoted by the binary variable η_k with $k \in \{L, H\}$, where L stands for low ability and H for high ability.[20] Working-age households are subject to uninsurable idiosyncratic shocks to their labor efficiency, denoted by ϵ, which follows a first-order Markov process. The total labor income for each household is given by $y = w\varepsilon_j \eta_k \epsilon$, where w is the wage rate per efficiency unit of labor and ε_j is the deterministic efficiency profile determined by age.[21] Upon retirement, a household receives a pension benefit equal to a fraction ξ of its final working-age income, denoted as $y = \xi y^{\text{ret}}$.

Households derive housing services by either renting at rate ρ_h or buying at price p_h. For computational tractability, house size for both rented and owned homes is modeled discretely. For owned homes, size h belongs to a set $\mathcal{H}$; for rented homes, size $\tilde{h}$ belongs to a set $\widetilde{\mathcal{H}}$.[22]

To capture rental market frictions, we assume that renting generates services less than the house's size, i.e., $s = \omega \tilde{h}'$ with $0 < \omega < 1$.[23] Both rented and owned houses depreciate at rate δ_h. When a household sells its home, it incurs a transaction cost $\kappa_h p_h h$, proportional to the house value, and a fixed cost κ_j, dependent on age j, that reflects both cultural reluctance and legal difficulties for older individuals in obtaining mortgages.[24]

Households can own multiple houses with a total size of h. There is an upper bound on the size of the first house (the primary home), denoted $\hat{h}$, where $s = \min\{h, \hat{h}\}$. The

[20]Throughout this paper, we use "low-income" or "high-income" households as concise terms to refer to households with low or high permanent labor ability.

[21]Since our model abstracts from the government budget, household labor income should be interpreted as after-tax income.

[22]In our model, different house sizes reflect both physical size and quality, without distinguishing between the two for tractability. Our databases lack detailed information on housing quality, but they do provide data on house value, which reflects a combination of house quality and house size.

[23]Following standard notation, the superscript prime in $\tilde{h}'$ denotes the current period, and $\tilde{h}$ without a prime denotes the previous period. This notation applies to other housing-related variables as well.

[24]The longest mortgage term in China is 30 years. For example, a 50-year-old borrower cannot obtain a 30-year mortgage and must pay higher costs for shorter terms.

remainder, $\max\{0, h - \hat{h}\}$, constitutes the secondary house. A secondary house provides no utility, and households hold them purely for potential capital gains due to their beliefs about future house price. Because households believe house price would grow to a higher level in future (e.g. $\hat{E}[p'_h]$), they have incentives to hold a secondary house now and sell it later at a higher future price for capital gains. We assume that households do not rent out their secondary properties.[25] This assumption is motivated by the institutional facts in China, where the absence of a comprehensive credit scoring system, combined with a low rent-to-price ratio, discourage homeowners from leasing their secondary homes. In 2013, for instance, the average rent-to-price ratio in tier-1 cities was around 2.4%, compared to the benchmark deposit rate of 3% and lending rate of 6%, further incentivizing homeowners to keep secondary houses as vacant investments.

Households can finance the purchase of both primary and secondary houses with a mortgage if they are younger than J^M (corresponding to age 65 in China).[26] The maximum LTV ratios at origination for primary and secondary houses, denoted by λ_1 and λ_2, differ. At the time of origination, borrowers are subject to the maximum LTV constraint $m' \leq \lambda_m(h')p_h h'$, where m' is the mortgage amount in the current period, and $\lambda_m(h')$ is defined as follows:

$$\lambda_m(h')p_h h' = \begin{cases} \lambda_1 p_h h' & \text{if } h' \leq \hat{h} \text{ and } j \leq J^M \\ \lambda_1 p_h \hat{h} + \lambda_2 p_h (h' - \hat{h}) & \text{if } h' > \hat{h} \text{ and } j \leq J^M \\ 0 & \text{if } j > J^M \end{cases}.$$

All mortgages are subject to a fixed origination cost, κ_m.[27] The minimum mortgage payment in each period, denoted by π_m, follows a constant amortization schedule over the remaining life of the mortgage:

$$\pi \geq \pi_m = \frac{r_m(1 + r_m)^{J+1-j}}{(1 + r_m)^{J+1-j} - 1} m,$$

where r_m is the mortgage interest rate, and π is the actual mortgage payment. The outstanding principal evolves according to $m' = (1 + r_m)m - \pi$. Following institutional practices

[25]High vacancy rates in China indicate that many secondary houses are purchased as investments rather than for housing services or rental incomes. Data from the CHFS shows an average vacancy rate of 20% between 2011 and 2017 across 35 major cities, with some areas showing rates as high as 42%. In 2013, the vacancy rate for all urban houses was 22.4%. These high vacancy rates, coupled with rapid price growth, illustrate that demand for secondary houses in China is driven largely by investment motives, not housing consumption.

[26]In China, mortgage borrowers must be between 18 and 65 years of age.

[27]The fixed mortgage origination cost discourages households from taking very small size of mortgage. Consistent with this implication, only 32 out of more than 3.2 million loans have LTV lower than 0.05 in the Bank Loan Data.

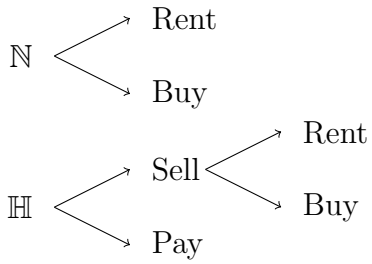
in China, we assume that the mortgage cannot be refinanced once originated, and default is not an option.

In addition to houses, households can hold a one-period, risk-free bond, denoted by b, available at an exogenous price q_b. The corresponding interest rate is $r_b = 1/q_b - 1$. Households are restricted from borrowing against their home equity, as homeowners do not have access to a home equity line of credit in China.

IV.1.2. *The household decision.* At the beginning of each period, a household without a house chooses between renting and buying, while a household that owns a house decides whether to keep the house and continue mortgage payments or sell it. If the household sells its house, it then needs to decide whether to rent or buy a new house. Diagram 1, below, summarizes the housing state at the beginning of each period and the housing tenure decision options during the period.

Diagram 1: Initial state and housing tenure decision during the period

State at beginning of the period		Housing tenure decision			
With house	Without house	Sell	Pay	Rent	Buy
$\mathbb{H}$	$\mathbb{N}$	$\mathbb{S}$	$\mathbb{P}$	$\mathbb{R}$	$\mathbb{B}$



The decision tree rules out the possibility of a household simultaneously purchasing and renting, as the housing decision is lumpy. The housing decision is driven by the costs and benefits of owning. The cost includes a down payment, while the benefits include (a) higher utility from housing services compared to renting and (b) potential capital gains with expected returns higher than those from risk-free assets.

We now describe a household's problem in recursive form. Each period, a household's idiosyncratic state is represented by the vector $\chi = (b, m, h, y)$. Let $\mu \equiv \mu(\chi)$ denote the probability measure of households indexed by the idiosyncratic state χ, and Ω represent the aggregate state. We solve the household problem in two steps. First, we determine the household's tenure decision (i.e., whether to buy or rent a house). Second, conditional on this decision, the household selects the size of the house to purchase or rent and chooses consumption and non-housing financial assets.

A household without a house begins each period by choosing between renting or buying:

$$V_j^N(b, y; \Omega) = \max\{V_j^r(b, y; \Omega), V_j^b(b, y; \Omega)\},$$

where V_j^N, V_j^r, and V_j^b represent the value functions for a household at age j without a house, for staying as a renter, and for becoming a buyer, respectively.

A household choosing to rent solves the following problem:

$$V_j^r(b, y; \Omega) = \max_{\{c, b', \tilde{h}'\}} u(c, s) + \beta \hat{E}_{y'}[V_{j+1}^N(b', y'; \Omega')|y],$$

subject to

$$\begin{aligned} s.t. \quad & c + \rho_h \tilde{h}' + q_b b' \leq b + y, \\ & b' \geq 0, \\ & s = \omega \tilde{h}', \tilde{h}' \in \widetilde{\mathcal{H}}. \end{aligned}$$

The renter maximizes utility by choosing consumption, future financial assets, and rental house size, subject to a budget constraint and a non-negative financial asset constraint. The renter will remain a non-homeowner in the following period. The left side of the budget constraint includes expenditures on consumption, rent, and future financial assets, while the right side includes initial financial assets and labor income. Since borrowing is limited to mortgages, households cannot have negative financial assets. When households rent, their housing service s is a discounted value of the rental housing size $\tilde{h}'$.

For the household that decides to become a homebuyer, it solves the following utility maximization problem:

$$V_j^b(b, y; \Omega) = \max_{\{c, b', m', h'\}} u(c, s; \phi) + \beta \hat{E}_{y'}[V_{j+1}^H(b', m', h', y'; \Omega')|y],$$

subject to

$$\begin{aligned} s.t. \quad & c + p_h h' + q_b b' + \kappa_m \cdot 1_{\{m'>0\}} + \kappa_j \leq b + y + m', \\ & b' \geq 0, \ m' \geq 0, \\ & s = h', \quad h' \in \mathcal{H}^1, \\ & m' \leq \lambda_m(h') p_h h'. \end{aligned}$$

The homebuyer selects consumption, future financial assets, housing size, and mortgage size to maximize utility and will start as a homeowner in the next period. The left-hand side of the budget constraint includes expenditures on consumption, house purchase, future financial assets, mortgage origination cost, and moving cost, while the right-hand side includes financial income, labor income, and the mortgage. First-time homebuyers can only purchase

a primary home from the set $\mathcal{H}^1$, and the size of the mortgage is constrained to satisfy the LTV policy for mortgage origination.

In the case where a household chooses to change its housing position, it must first sell its current house.[28] Accordingly, it solves the following problem:

$$V_j^H(b, m, h, y; \Omega) = \max\{V_j^p(b, m, h, y; \Omega), V_j^s(b, m, h, y; \Omega)\},$$

where V_j^H, V_j^p, and V_j^s denote the value functions for a household with a house, the value function for keeping the house, and the value function for selling the house, respectively.

A homeowner who decides to keep the house and continue making mortgage payments solves the following problem:

$$V_j^p(b, m, h, y; \Omega) = \max_{\{c, b', \pi\}} u(c, s; \phi) + \beta \hat{E}_{y'}[V_{j+1}^h(b', m', h', y'; \Omega')|y],$$

subject to

$$\begin{aligned} s.t. \quad & c + \delta_h p_h h + \pi + q_b b' \leq b + y, \\ & b' \geq 0, \\ & s = \min\{h', \hat{h}\}, \quad h' = h, \\ & \pi \geq \pi_m \equiv \frac{r_m(1 + r_m)^{J+1-j}}{(1 + r_m)^{J+1-j} - 1} m, \\ & m' = (1 + r_m)m - \pi. \end{aligned}$$

If the homeowner decides to keep the house, they choose consumption, future financial assets, and mortgage payment to maximize utility. The left side of the budget constraint includes expenditures on consumption, housing maintenance costs, mortgage payment, and bonds, while the right side includes returns from holding bonds and labor income. Only the primary home provides housing services, and the household's housing position remains unchanged in the next period. The mortgage payment has a lower bound, following a constant amortization schedule, and the outstanding mortgage evolves accordingly.

If a household opts to sell the house, it must repay the outstanding mortgage associated with the sold property. The financial wealth after selling the house is given by:

$$b_n = b + (1 - \delta_h - \kappa_h)p_h h - (1 + r_m)m - \kappa_j, \tag{3}$$

which includes financial assets carried over from the previous period, net-of-costs proceeds from the sale of the home, and excludes the repayment for outstanding mortgage and moving cost.

[28]For simplicity, we assume that once a household decides to sell the house, it sells all of its housing stock.

After selling the house, the household can then decide whether to rent or purchase a new property by solving the following problem:

$$V_j^s(b, m, h, y; \Omega) = \max\{V_j^{sr}(b_n, y; \Omega), V_j^{sb}(b_n, y; \Omega)\},$$

subject to (3). Here, V_j^{sr} is the value function for a household that sells its house and chooses to rent, and V_j^{sb} is the value function for a household that sells its house and decides to buy a new house.

Similar to the renter's decision-making process, a household that sells its house and chooses to rent solves:

$$V_j^{sr}(b_n, y; \Omega) = \max_{\{c, b', \tilde{h}'\}} u(c, s; \phi) + \beta \hat{E}_{y'}[V_{j+1}^n(b', y'; \Omega')|y],$$

subject to

$$\begin{aligned} s.t. \quad & c + \rho_h \tilde{h}' + q_b b' \leq b_n + y, \\ & b' \geq 0, \\ & s = \omega \tilde{h}', \quad \tilde{h}' \in \widetilde{\mathcal{H}}. \end{aligned}$$

Similar to the homebuyer's problem, a household that sells its house and chooses to buy a new one solves:

$$V_j^{sb}(b_n, y; \Omega) = \max_{\{c, b', m', h'\}} u(c, s; \phi) + \beta \hat{E}_{y'}[V_{j+1}^h(b', m', h', y'; \Omega')|y],$$

subject to[29]

$$\begin{aligned} s.t. \quad & c + p_h h' + q_b b' + \kappa_m \cdot 1_{\{m' > 0\}} \leq b_n + y + m', \\ & b' \geq 0, \ m' \geq 0, \\ & s = h', \quad h' \in \mathcal{H}, \\ & m' \leq \lambda_m(h') p_h h'. \end{aligned}$$

IV.2. **The rental sector.** In each period, a representative rental company purchases houses to rent to tenants, incurring an operating cost ψ per housing unit. The representative rental company's objective is given by:

$$J(\tilde{H}; \Omega) = \max_{\tilde{H}'} [\rho_h(\Omega) - \psi]\tilde{H}' - p_h(\Omega)[\tilde{H}' - (1 - \delta_h)\tilde{H}] + \frac{1}{1 + r_b} E_{\Omega'|\Omega} J(\tilde{H}'; \Omega'),$$

[29]For computational tractability, we assume that a household incurs the mortgage origination cost κ_m when it sells a secondary house and downsizes to a primary home with a new mortgage origination. This assumption does not materially affect the robustness of our results, as the share of such households is small (less than 0.7% of all households in the steady state) and the sale value of the secondary house is substantially larger than the mortgage origination cost.

where $\rho_h(\Omega)$ is the rental price. The zero-profit condition implies the equilibrium rental rate as

$$\rho_h(\Omega) = \psi + p_h(\Omega) - \frac{1-\delta_h}{1+r_b} E_{\Omega'}[p_h(\Omega')|\Omega].$$

In equilibrium, the rent is equal to the sum of the operating cost and the user cost.

IV.3. **Production sectors.** Following Kaplan, Mitman and Violante (2020), the economy includes two production sectors: a non-housing consumption goods sector and a construction sector that produces new houses. Labor is perfectly mobile between the two sectors. Competitive firms in the non-housing sector operate with a technology characterized by constant returns to scale in labor:

$$Y = \Theta N_c \,,$$

where Y is aggregate output, Θ is aggregate labor productivity, and N_c is aggregate efficiency labor employed in the non-housing sector. The first-order condition for labor determines the wage rate as $w = \Theta$.

In the construction sector, the government issues new permits equivalent to $\bar{L}$ units of land each period, sold in a competitive market to real estate developers. The government collects all rents from its land ownership. After acquiring a land permit, a competitive real estate developer combines labor and land to produce new houses using a Cobb-Douglas production technology:

$$\max_{N_h} \; p_h I_h - w N_h$$
$$s.t. \; I_h = (\Theta N_h)^{\alpha} (\bar{L})^{1-\alpha},$$

where I_h represents new houses, and N_h is aggregate efficiency labor employed in the construction sector. The Cobb-Douglas technology implies zero profit in equilibrium for the developer. The supply function of new houses follows from the first-order condition with respect to N_h and the equilibrium condition $w = \Theta$:

$$I_h = (\alpha p_h)^{\frac{\alpha}{1-\alpha}} \bar{L}. \tag{4}$$

Equation (4) defines the supply curve of new housing as a function of housing prices. Accordingly, the price elasticity of (new) housing supply is $\frac{\alpha}{1-\alpha}$.

IV.4. **Equilibrium.** Let $\chi^H = (b, m, h, y)$ and $\chi^N = (b, y)$ denote the idiosyncratic state vectors for homeowners and non-homeowners, respectively. Define μ_j^H and μ_j^N as the measures of these two types of households at age j. A recursive competitive equilibrium consists of household value functions

$$\{V_j^N\left(\chi^N;\Omega\right), V_j^H\left(\chi^H;\Omega\right), V_j^r\left(\chi^N;\Omega\right), V_j^b\left(\chi^N;\Omega\right), V_j^p\left(\chi^H;\Omega\right), V_j^s\left(\chi^H;\Omega\right)\},$$

household decision rules, and aggregate functions for construction labor $N_h(\Omega)$, rental units $\tilde{H}'(\tilde{H};\Omega)$, homebuyers' housing stock $H'(H;\Omega)$, housing investment $I_h(\Omega)$, rental price $\rho_h(\Omega)$, house price $p_h(\Omega)$, and a law of motion for aggregate states such that

(1) Households optimize with respect to value functions and associated decision rules.
(2) Firms in the construction sector maximize profits according to labor demand and housing investment functions $\{N_h, I_h\}$.
(3) The labor market clears, establishing a wage rate $w = \Theta$.
(4) The rental market clears at the rental price ρ_h.
(5) The housing market clears at the house price p_h:

$$\tilde{H}' + H' = (1 - \delta_h)(\tilde{H} + H) + I_h.$$

(6) The aggregate law of motion is derived from the exogenous stochastic processes and all decision rules, and is consistent with individual behaviors.

V. Calibration and steady-state distributions

V.1. **Calibration.** We calibrate the model to match key aggregate and cross-sectional moments observed before the loosening of LTV policy in 2014Q4. Since the CHFS is conducted every two years, we use data from 2013 to calculate these moments, establishing the steady state of the model that corresponds to the Chinese economy prior to the LTV policy change in 2014Q4.[30] The parameters in our model fall into two categories. The first set of parameters is directly sourced from existing literature; the second set is calibrated to target key moments in the data. Tables 4 and 5 report calibrated parameter values and targeted moments, which we discuss in detail below.

Demography. Each period in the model corresponds to a two-year span in the data. Households enter the economy at age 20, work until age 55 (implying $J^{\text{ret}} = 19$), and live until age 76, which aligns with the average life expectancy in China (corresponding to $J = 29$). Households with high (low) labor ability in our model correspond to households with a college degree or above (a high school diploma or below) in the data. The proportion of households with high labor ability is calibrated to match the proportion of households with a college degree or above in the CHFS data. To maintain consistency in terminology, we refer to households with high labor ability as households with high incomes or high education.

Preferences. In the model, households' expectations about future house prices, $\hat{E}[p'_h]$, govern investment incentives. We calibrate this expectation to target the 2013 homeownership rate of secondary houses (14.6%). A higher value of $\hat{E}[p'_h]$ would yield a higher steady-state rate of secondary homeownership. The housing preference parameter ϕ is chosen to ensure

[30]When 2013 data are unavailable, we use data from 2012 or earlier.

TABLE 4. Calibrated values of model parameters

Parameter	Interpretation	Value
Demographics		
J^{ret}	Retirement age	19
J	Length of life	29
ν	Share of high ability households	0.4
Preference		
$1/\gamma$	Elasticity of substitution	1.25
σ	Risk aversion	2.00
β	Discount factor	0.96
ϕ	Housing preference	0.20
$(\hat{E}[p_h'] - p_h)/p_h$	Expected house price growth	0.25
ω	Utility discount from renting	0.4
φ	Strength of bequest motive	45
Endowments		
ε_j	Life-cycle profile	He, Ning and Zhu (2017)
ρ_ϵ	Income correlation	İmrohoroğlu and Zhao (2018)
σ_ϵ	Std of income shocks	İmrohoroğlu and Zhao (2018)
η_H	High labor ability	Wang (2012)
ξ	Replacement rate	0.4
Housing		
$\mathcal{H}$	Owner housing grid	$\{0.7, 1.6, 2.5, 3.4, 4.8\}$
$\widetilde{\mathcal{H}}$	Renter housing grid	$\{0.7, 1.6, 2.5\}$
$\hat{h}$	2nd house cutoff	3.4
κ_h	Housing sale transaction cost	0.03
δ_h	Housing depreciation rate	0.02
ψ	Rent company operation cost	0.015
$\alpha/(1-\alpha)$	Housing supply elasticity	4.0
$\bar{L}$	Land endowment	0.271
Financial instruments		
r_b	Interest rate	0.03
r_m	Mortgage rate	0.048
κ_m	Mortgage origination cost	0.04
LTV policy		
λ_1	LTV limit for primary homes	0.7
λ_2	LTV limit for secondary houses	0.4

Notes: This table presents the calibrated parameter values in the model. One model period corresponds to two years in the data, and all time-dependent values are annualized.

that the average share of housing services in total expenditures remains at 0.2 in the steady state, consistent with the weight in the official consumer price index basket in China.

TABLE 5. Targeted aggregate moments for the calibration

Moments	Data	Model
Overall homeownership rate	0.86	0.85
Homeownership rate under age 30	0.66	0.69
Share of mortgage origination number for 2nd houses	0.05	0.05
Homeownership rate for 2nd houses	0.15	0.09
Aggregate wealth-to-income ratio	10.21	8.16
Ratio of outstanding mortgage amount to income	3.08	2.97
Ratio of purchased house value to income	7.30	8.29
Ratio of net worth of households with age 75 to that of those with age 55:	0.82	0.83
Share of mortgage origination number for middle-aged households:	0.58	0.58
Share of mortgage origination number for old households:	0.06	0.05
Ratio of net housing wealth to net worth: 10^{th} percentile	0.61	0.67
Ratio of net housing wealth to net worth: median	0.93	0.96
Ratio of net housing wealth to net worth: 90^{th} percentile	1.00	1.00

Notes: This table shows the targeted aggregate moments for the calibration in the data and those steady-state values in the model. We construct housing wealth as the sum of the values of both primary homes and secondary houses. We construct net worth (total net wealth) as the sum of housing wealth and net financial wealth. Net financial wealth is defined as financial assets (bank accounts, cash, bonds, stocks, mutual funds, other financial assets, private business wealth, and private cars), minus financial liabilities (mortgages on primary homes and secondary houses, other debts for houses, debts for cars, education, and private business, and other financial debts). Net housing wealth is measured as housing wealth, minus outstanding mortgage debts and other debts for houses. Ratio of outstanding mortgage amount to income is calculated based on those households with outstanding mortgage. The data moments for the share of origination number for secondary houses in the total number of mortgage originations, and the share of origination number for middle-aged and old households in the total number of mortgage originations are calculated from the Bank Loan Data; the ratio of the house value to income is calculated from E-House China; and other data moments are calculated from the CHFS.

Following Piazzesi, Schneider and Tuzel (2007), we set $1/\gamma$, the elasticity of substitution between non-housing consumption and housing services, to 1.25. The risk aversion parameter σ is set to 2, which is standard in the literature. The utility discount factor β is calibrated to target the 2012 average ratio of wealth to labor income, which is 10.21, as estimated by Xie and Jin (2015) using China Family Panel Studies data. The rental utility discount parameter ω is calibrated to 0.40 to match China's 2013 average homeownership rate (86%). The bequest motive parameter φ is calibrated to target the ratio of net worth for households aged 75 to net worth for those aged 55.

Labor endowment. The age-specific pattern of labor efficiency follows He, Ning and Zhu (2017), who estimate it using data from the China Health and Nutrition Survey. The idiosyncratic labor income shock ϵ follows an AR(1) process in log, with values for ρ_ϵ and σ_ϵ from İmrohoroğlu and Zhao (2018). Low labor ability η_L is normalized to 1, while high labor ability $\eta_H = 2.4$ matches the college premium estimated by Wang (2012), who uses China

Household Income Project data. The social security replacement rate is set to 0.4, consistent with the national average replacement rate from 2010 to 2013.

Housing. Following Kaplan, Mitman and Violante (2020), we calibrate three parameters for the owner-occupied housing size set $\mathcal{H}$: the minimum owner-occupied housing unit size, the number of discretized sizes in $\mathcal{H}$, and the interval between adjacent sizes. We target the 10th percentile, median, and 90th percentile of the ratio of net housing wealth to total net wealth among homeowners, where (total) net wealth includes housing wealth and net non-housing financial wealth. The steady-state distribution of housing wealth is crucial for evaluating the quantitative effects of an LTV policy change at both household and aggregate levels. We normalize moving costs for young households to zero, calibrate moving costs for middle-aged and older households to match their respective shares in mortgage origination numbers for 2013, and calibrate the threshold value for secondary houses, $\hat{h}$, to target the 2013 share of secondary mortgage originations in total originations (approximately 5%).

The house depreciation rate δ_h is set to 2%, in line with the depreciation rate estimated by the OECD for urban owner-occupied houses in China. Transaction costs for selling a house, κ_h, equal 3% of the house value. The rental company's operating cost is calibrated to match the homeownership rate for households under age 30. The value of a new land permit $\bar{L}$ is set to target the average house price-to-income ratio.[31]

The price elasticity of (new) housing supply determines the value of the construction technology parameter α. To estimate housing supply elasticity, we leverage variations in housing demand exogenous to price changes, using our policy exposure measure as an instrument for housing demand from 2013 to 2018. This approach yields an estimated inverse housing supply elasticity of 0.25, implying $\alpha = 0.8$ or a housing supply elasticity of 4. See Appendix F for details.

Financial variables and LTV policy. The risk-free interest rate r_b is set to 3% per annum, matching the average benchmark deposit rate in 2010–2013. The mortgage interest rate r_m is set at 4.94%, reflecting the average rate for households in 2013 according to CHFS data. The mortgage origination cost κ_m is calibrated to target the average ratio of homeowners' outstanding mortgage debt to income in 2013, which is 3.08. We calibrate the minimum down payment ratios for primary homes and secondary houses in the model to match pre-2014Q4 LTV limits for these types of properties, yielding $\lambda_1 = 0.7$ and $\lambda_2 = 0.4$.

V.2. **The steady state distribution.** To understand the distributional impacts of loosening LTV policy, we discuss in this section a set of model predictions in the steady state that

[31]For the 35 major cities in China, the average house price-to-income ratio was 7.3 in 2012, according to E-House China (`http://www.ehousechina.com/index`).

are not calibrated to the data. The effect of a policy change on housing demand depends on both the distribution of LTV ratios and the distribution of housing wealth across age-income groups in the steady state. The LTV distribution reveals how tight the LTV constraints are across these groups, while the distribution of housing wealth determines which age-income groups benefit most from capital gains when house prices rise. We illustrate how the model predicts the LTV distribution and the life-cycle profile, and we compare these predictions to cross-sectional moments of housing wealth and net worth across age-education groups in the data.

LTV distribution. We calculate the model's distribution of LTV ratios for homebuyers with outstanding mortgage loans and compare it with the empirical distribution from the Bank Loan Data.[32] Figure 9 displays the distribution of LTV ratios at origination for mortgages on primary homes among middle-aged households, comparing the data with results from the benchmark model. In both the data and the model, the LTV distribution peaks at 0.7, corresponding to the LTV limit on primary houses in 2013. For over 70% of middle-aged households with high incomes, LTV ratios reach the policy limit. Overall, the model's steady-state results closely track the LTV distributions in the data, particularly for middle-aged households with high education.

Life-cycle profile of wealth. Figure 10 illustrates the model's prediction of the empirical life-cycle profile of wealth. In the data, net worth and housing wealth of households with high incomes surpass those of low-income households from an early age and increase more rapidly. The top two panels detail net worth across ages for both low-income and high-income households, where the model successfully captures the hump-shaped life-cycle profile of net worth for both income groups, peaking around age 55. The net worth of households at age 40 with high education is about three times that of similarly aged households with low education and twice that of younger high-education households.

The bottom panels show that the model reasonably replicates the empirical age profile of housing wealth for households with high education. For instance, the housing wealth of high-income households at age 40 is approximately twice that of their low-income counterparts and thrice that of high-income households at age 20. These results indicate that middle-aged households with high incomes benefit significantly more from increases in house prices than do their lower-income or younger high-income peers.

Cross-sectional moments. The model's ability to match various empirical cross-sectional moments is evaluated first with the Gini coefficients for housing wealth and net worth (top

[32]Our granular mortgage data includes only homebuyers with positive LTV ratios at origination.

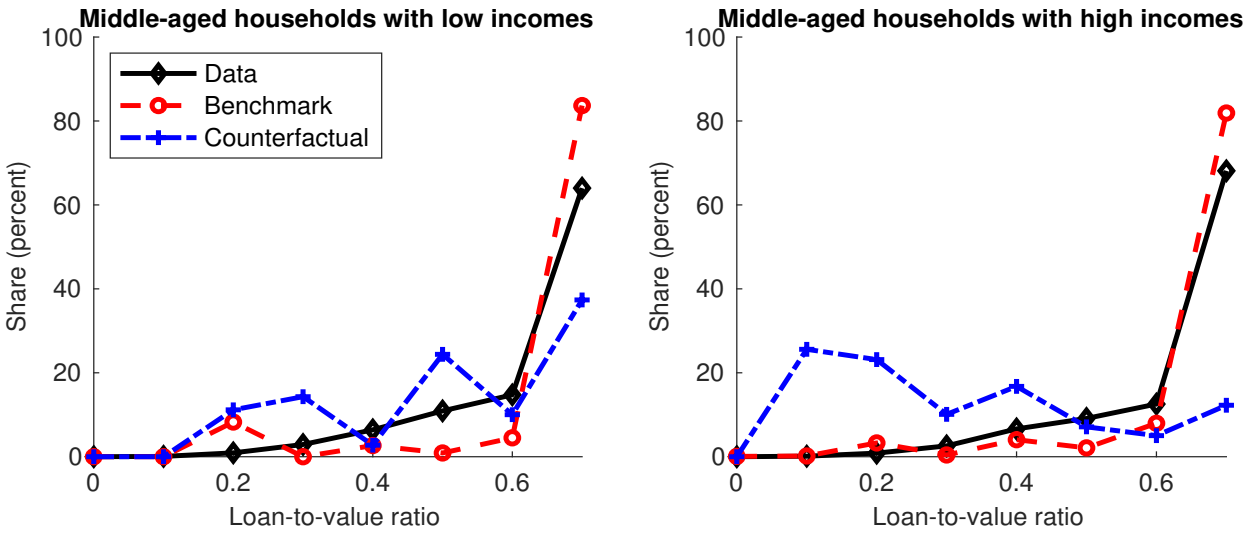


FIGURE 9. Model versus data: the LTV distribution for primary homes financed by mortgages.

Notes: The panels display the LTV distribution at origination for middle-aged households. The vertical axis, labeled "Share (percent)," represents the share of households with various LTV ratios within each age-income group. The empirical LTV distributions are based on the data in 2013 from the Bank Loan Data. The counterfactual economy is the standard life-cycle model in which households' beliefs about future house prices remain at the steady-state level while keeping all other parts of the model intact.

portion of Table 6). The predicted Gini coefficient for housing wealth is similar to the empirical counterpart. The modeled results also approximate the empirical shares of households' net worth across different quintiles (middle portion of the table). Although the model adequately predicts the median ratio of housing wealth to income, it struggles to accurately represent this ratio for households in the 10th and 90th percentiles (bottom portion of the table).

Summary. Our model performs well in predicting the empirical distribution of LTV ratios and the life-cycle profile of wealth for various age-education groups, as well as other cross-sectional distributions of wealth. Since the LTV distribution and housing wealth distribution in the steady state are critical for understanding how housing demand reacts to LTV policy changes, our theoretical framework is well-suited for analyzing the quantitative impacts of these policy changes on mortgages for both primary homes and secondary houses.

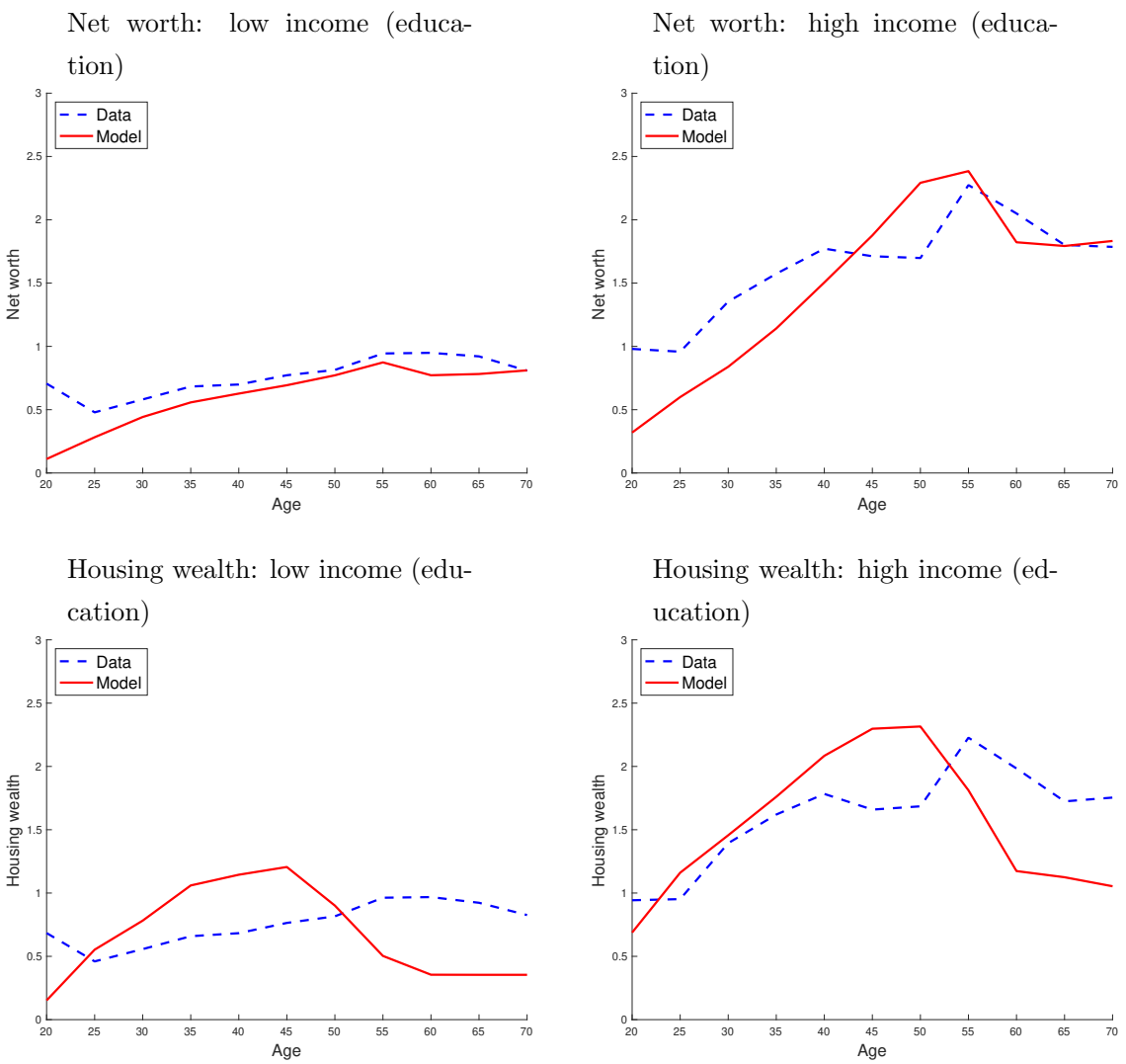


FIGURE 10. Life-cycle profile of wealth

Notes: The top panels display net worth (normalized by the average net worth) for low-income and high-income groups. The bottom panels display housing wealth (normalized by the average housing wealth) for low-income and high-income groups. See the notes in Table 5 for the definitions of housing wealth and net worth. The empirical profiles are based on the survey data in 2013. Education in the survey data is used as a proxy for income.

Source: The CHFS.

VI. IMPACTS OF LTV POLICY ON HOUSING INVESTMENT AND NON-HOUSING CONSUMPTION

In this section, we assess the quantitative impacts of LTV policy on the mortgage market. Our goal is to replicate the actual LTV policy changes that occurred from 2014Q4 to

TABLE 6. Cross-sectional moments from the calibrated model

Moments	Data	Model
Gini coefficient: net worth	0.61	0.48
Gini coefficient: housing wealth	0.56	0.51
Share of net worth for the bottom quintile	0.01	0.03
Share of net worth for the middle quintile	0.10	0.15
Share of net worth for the top quintile	0.64	0.53
Ratio of homeowners' housing wealth to their incomes: 10^{th} percentile	1.78	4.42
Ratio of homeowners' housing wealth to their incomes: median	8.18	8.95
Ratio of homeowners' housing wealth to their incomes: 90^{th} percentile	40.19	12.52

Notes: This table presents various empirical cross-sectional moments that are not targeted by our calibration. See the notes in Table 5 for the definitions of housing wealth and net worth. The data moments are calculated from the CHFS.

2016Q3. To this end, we relax the LTV limit on secondary houses, matching the duration and magnitude of the observed policy change, and examine the impacts of this policy shift on mortgage markets and non-housing consumption. This analysis serves as our benchmark case. In the last part of this section, we extend our benchmark analysis to other policy considerations.

VI.1. **Benchmark results.** Our benchmark policy experiment involves increasing the LTV limit for secondary houses. The model economy is in the steady state at period 0. At the beginning of period 1, the LTV limit for secondary houses increases from 0.4 to 0.65.[33] We treat the increase in the LTV policy limit for secondary houses as an MIT shock due to its sudden and exceptionally large nature.

Since a period in our model represents two years in data, the LTV policy relaxation for secondary houses lasts for one period, corresponding to the two-year span of 2014Q4-2016Q3 during which the relaxed policy was in effect. During this period, households expect the new LTV limit ($\lambda_2 = 0.65$) to continue in the future.[34] In period 2, the LTV limit unexpectedly

[33]Actual LTV policy in China permitted households owning a fully paid primary home to purchase a secondary house with an LTV ratio as high as 70%. For households with outstanding mortgages on their primary homes, the LTV ratio was 60%. We approximate the LTV limit for secondary houses as 65%.

[34]While China does not provide survey data on expectations about the persistence of the LTV policy change, official announcements and communications during the 2014Q4–2016Q3 LTV relaxation period emphasize this policy's long-term goals to "further improve financial services for the construction of affordable housing" and promote the "sustainable and healthy development of the real estate market" (`https://www.gov.cn/xinwen/2014-09/30/content_2759366.htm`). Such official statements,

returns to its steady-state value of $\lambda_2 = 0.4$. To isolate the effects of this LTV policy change, we maintain the LTV limit for primary homes and other parameters, such as mortgage interest rates, at steady-state levels in this experiment.

VI.1.1. *Aggregate effects.* Table 7a details the annualized changes in key aggregate variables resulting from the relaxation of the LTV limit on secondary houses. House prices increase by 4.86% (per annum) during the policy period, accounting for 81.82% of the observed increase in housing prices from 2011Q1-2014Q3 to 2014Q4-2016Q3 (5.94%).[35] The total amount of newly issued mortgage loans surges by 80.03%, accounting for 87.2% of the observed increase (91.78%).[36] Mortgage originations grow by 33.36%, explaining 71.73% of the observed increase (46.51%). For primary homes, the mortgage amount and the number of originations increase by 51.63% and 22.53%, accounting for 65.37% and 53.38% of the observed changes respectively. For secondary houses, both the amount and number of mortgage originations are consistent with the data. All these results suggest that the LTV policy relaxation is a primary driver of the boom in housing and mortgage markets.

VI.1.2. *Effects on different age-income groups.* Our motivating evidence reveals that the relaxation of the LTV limit on secondary houses had significant impacts on mortgage loans for primary homes, specifically benefiting middle-aged and highly-educated households who held a substantial portion of the economy's wealth. Table 7b summarizes the percentage changes in the mortgage shares for different age-income groups in total mortgages on primary homes. For comparison, the data's percentage changes in mortgage shares across age-education groups appear in parentheses next to the model's values in Table 7b. The middle-aged, high-income group stands out for its notable increases in mortgage origination shares, both in terms of amount (10.10 percentage points) and the number (6.72 percentage points) of mortgages for primary homes, closely resembling their data counterparts (11.78 and 7.26 percentage points). By contrast, all other groups experience declines in their shares of primary home mortgage originations, consistent with the data. These comparisons reinforce our finding that relaxing the LTV policy significantly increases mortgage loans among middle-aged and highly educated households.

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rather than actual economic fundamentals themselves, often exert a lasting influence on market expectations, reinforcing public beliefs in policies' enduring effects (Brunnermeier et al. (2017); Allen et al. (2024)). Thus, it is reasonable to assume that households expect the LTV policy change to be permanent.

[35]Since the model abstracts from house price growth at the steady state, a percentage increase in the model corresponds to a growth change in the data.

[36]In the model, growth in mortgage loan originations is calculated as the increase in these values between the policy period and the steady state. In the data, this growth is the observed increase in annualized levels between 2011Q1–2014Q3 and 2014Q4–2016Q3.

TABLE 7. Impacts of a loosening of the LTV limit on secondary houses from 0.4 to 0.65

(A) Aggregate impacts on the house price and key mortgage variables (Annualized growth rate %)

	Model	Data
House price	4.86	5.94
Mortgage origination amount	80.03	91.78
Mortgage origination number	33.36	46.51
Mortgage origination amount (primary homes)	51.63	78.98
Mortgage origination number (primary homes)	22.53	42.21
Mortgage origination amount (secondary houses)	379.63	323.92
Mortgage origination number (secondary houses)	202.80	124.36

(B) Changes in the mortgage share of an age-income group in total mortgages on primary homes

	Mortgage share change (percentage points)			
	Origination amount		Origination number	
	Low income	High income	Low income	High income
Young	-1.20 (-3.79)	-4.46 (-1.17)	-2.23 (-2.46)	-3.11 (0.52)
Middle-aged	-1.80 (-6.26)	10.10 (11.78)	-0.60 (-5.22)	6.72 (7.26)
Old	-0.44 (-1.19)	-2.19 (0.64)	-0.20 (-0.57)	-0.59 (0.46)

Notes: This table compares the aggregate and distribution effects of the LTV relaxation policy in the benchmark model and in the data. In Table 7a, house price growth in model is calculated by the increase of house price between the LTV policy change period and the steady state, while house price growth rate in data is calculated by the observed increase in housing prices from 2011Q1-2014Q3 to 2014Q4-2016Q3. In the model, growth in mortgage loan originations is calculated as the increase in these values between the policy period and the steady state. In the data, this growth is the observed increase in annualized levels between 2011Q1–2014Q3 and 2014Q4–2016Q3. Values in parentheses in Table 7b are actual data across age-education groups.

VI.1.3. *The role of trading up homes.* In our model, increased mortgage demand following an LTV policy change is driven primarily by two factors: (i) an increase in housing demand from existing homeowners trading up their primary homes, and (ii) a shift of households from renting to homeownership.[37] Although the literature often emphasizes the second factor, our findings highlight the importance of the first factor through home price appreciation. Rising home prices offer capital gains to homeowners and motivate them to trade up to larger homes, rather than remain in their current homes due to the fixed costs associated with moving and mortgage origination.

[37]The first factor includes an increase in both the number of homeowners trading up and the size of homes purchased.

In our model, trading-up serves as a primary channel through which a relaxation of LTV policy for housing investments influences aggregate mortgage demand in China. As shown in Table 8a, trading up accounts for 52.60% of the increase in the origination amount, 66.41% of the increase in the origination number, and 54.01% of the increase in housing demand.[38] Table 8b further breaks down the increase in mortgage originations and housing demand due to trading up across age-education groups, showing that middle-aged households with high incomes contribute to the majority of these increases. Thus, a relaxation of LTV policy for housing investments disproportionately affects middle-aged, high-income households who trade up their homes as house prices rise—a channel that is absent in standard life-cycle models, where the LTV limit typically does not bind for middle-aged, high-income households.

TABLE 8. Contributions (%) to the increase in total mortgages from an increase of households who trade up their primary homes

(A) Contributions to an increase in total mortgages and in housing demand

	Origination amount	Origination number	Housing demand
Primary homes	52.60	66.41	54.01

(B) Contributions by age-income groups

	Origination amount		Origination number		Housing demand	
	Low income	High income	Low income	High income	Low income	High income
Young	8.64	1.16	8.65	1.65	8.68	1.16
Middle-Aged	35.72	54.48	38.15	51.56	35.70	54.46
Old	0.00	0.00	0.00	0.00	0.00	0.00

Notes: This table reports the aggregate and decomposed contributions of trade-up to the mortgage and housing boom. For each variable, the contributions across age-income groups in Table 8b sum to 100.

[38]See Section IV.4 for the measurement of housing demand in the model. The contributions of trade-up are calculated by including only those households who trade up their homes to a size below or equal to $\hat{h}$. Households who purchase secondary houses after the LTV policy relaxation are excluded, and any up-sizing to $\hat{h}$ during the purchase of a secondary house is not considered in the calculation of trade-up. This approach ensures that our model provides a conservative estimate of the role of trade-up during the policy relaxation period.

Some may have concerns that trade-up for primary homes may be due to the setup of secondary houses in our model. Consider an alternative model setup where households can purchase secondary houses separately without up-sizing their primary homes first. For a household who starts with a small house and trades up her house to a size less than or equal to $\hat{h}$ in our model, the household would have the option to keep the small initial house and buy a secondary house in the alternative setup. However, this option would not be optimal choice, compared with the choice of trading up for a larger primary home with the incremental primary home size the same as the size of a secondary house. This is because, (1) secondary houses provide no housing utility services, while primary homes do; (2) secondary houses incur a higher minimum downpayment ratio than the primary homes; (3) secondary houses have the same purchasing cost (house prices) and maintenance cost as that for primary homes. Therefore, those existing homeowners would not choose to purchase separate secondary houses while keeping the current primary homes.

VI.1.4. *Consumption effects.* Despite the transitory nature of the LTV policy change, its impact on consumption persists over multiple periods because housing investments are illiquid, and mortgage burdens remain high among households who purchased homes during the relaxed LTV period. The left panel of Figure 11 displays the transitional path of non-housing consumption for middle-aged, high-income households after a one-period relaxation of LTV policy. The impact on consumption is negative, falling below the steady-state level due to households' persistent mortgage debt burdens after the LTV limit relaxation. The right panel shows that the ratio of total outstanding mortgage debt to total income for middle-aged, high-income households rises sharply in the first two years and remains elevated, highlighting the lasting effect of these mortgage burdens.

Existing literature emphasizes the wealth effect of rising house prices, which would not predict a simultaneous decline in consumption alongside an increase in mortgage levels for middle-aged, high-income households. By contrast, our findings uniquely show that house price appreciation has a negative effect on household consumption. In the initial period, households' housing stock is below their desired levels due to LTV restrictions and the discreteness of house sizes. Although higher house prices generate positive wealth effects for these households—most of whom are already homeowners during the LTV relaxation—they choose to trade up to larger homes at the expense of both current and future consumption, motivated by expectations of future capital gains. The initial decline in consumption reflects

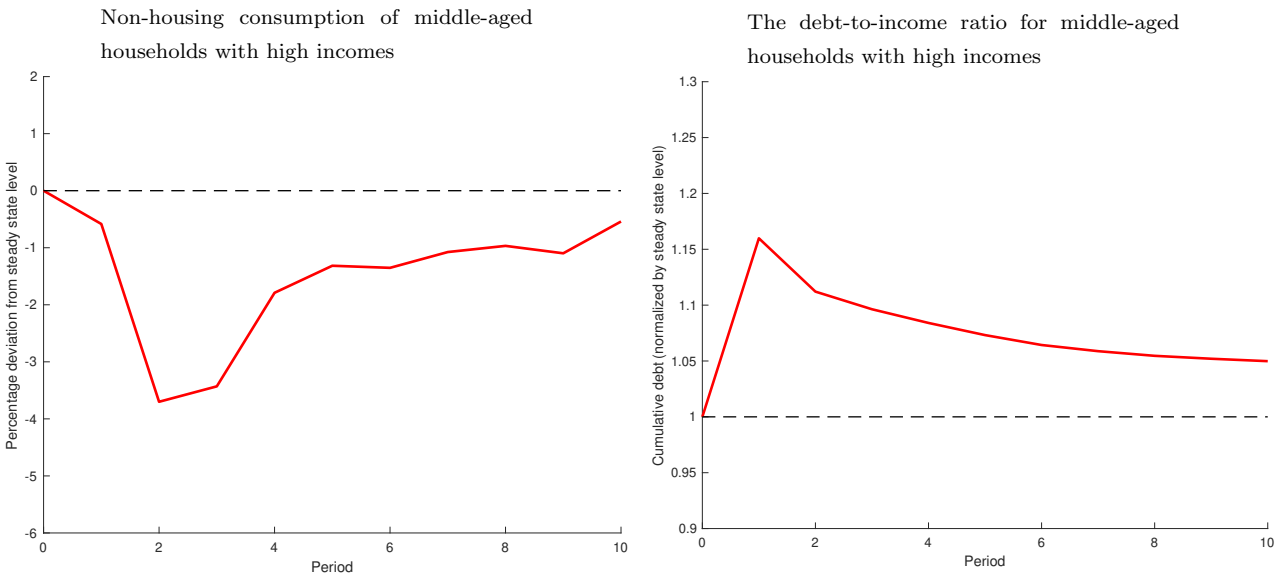

FIGURE 11. A relaxation of LTV policy for housing investments: long-run impacts on consumption and debt burden

Notes: This figure illustrates the long-run impacts of relaxing the LTV policy for housing investments on households' consumption and debt burden in the model. The debt-to-income ratio is defined as the cumulative outstanding mortgage debt divided by the total income of middle-aged, high-income households.

not only intertemporal substitution toward future consumption, but also the lack of a cash-out option during the policy relaxation period.[39] Consumption remains low even after the policy reverts to the steady-state LTV limit, as these households finance larger homes at high leverage relative to income, facing prolonged mortgage obligations.

VI.2. **The housing investment channel.** A central component of our model is what we refer to as "the housing investment channel," through which housing investments drive mortgage demand and influence consumption. In this section, we discuss key factors affecting this channel and examine how rising house prices impact both mortgage demand and non-housing consumption.

VI.2.1. *Incentives for housing investment.* As shown in Figure 9, the LTV constraint is binding for most middle-aged, high-income households in steady state. During the LTV relaxation period, capital gains from house prices exceeding steady-state levels allow these

[39]In Section VI.3.3, we show that when refinancing becomes available during the LTV policy relaxation, households that choose to refinance increase their consumption by an average of 31.1% relative to the benchmark model.

households to overcome the LTV constraint and trade up to larger homes. These observed LTV distributions, however, cannot be explained by standard life-cycle models, in which the LTV constraint is mostly non-binding for middle-aged, high-education households, especially without an investment motive for purchasing secondary houses.

For illustration, we consider a counterfactual economy in which households' beliefs about future house prices remain at the steady-state level, as in standard life-cycle models. The blue dashed line in Figure 9 shows that fewer households face binding borrowing constraints in this counterfactual scenario than in the benchmark case. In particular, the LTV distribution for middle-aged, high-income households shifts significantly leftward. Approximately 30% of homebuyers in this category hold LTV ratios between 0.05 and 0.15, and only about 10% reach the LTV limit on primary homes. By contrast, in our benchmark results, most middle-aged, high-income homebuyers borrow up to the LTV limit due to investment motives.

VI.2.2. *The role of middle-aged, high-education households in the mortgage boom.* As previously noted, middle-aged households with high incomes played a key role in the mortgage boom, who hold the largest share of mortgage originations and account for the majority of home trade-ups.

This prominent role is driven by two main factors. First, house equity and income are primary drivers of the trade-up activity observed during the mortgage boom. For both young and middle-aged households, there exists a threshold level of house equity beyond which existing homeowners are likely to trade up their primary homes.[40] Furthermore, within each age group, the threshold house equity for high-income households is smaller than that for low-income households. This implies that, given the same level of house equity, high-income households are more likely to trade up than their low-income counterparts.

Second, middle-aged households with high incomes, on average, possess higher house equity compared to households in other age-income groups. Figure 12 displays the distribution of house equity—defined as the increased house price multiplied by the initial house size, minus the outstanding mortgage ($p_h \cdot h - m$)—for young and middle-aged households during the policy period. Middle-aged households with high incomes tend to hold substantial house equity. On average, their house equity is 1.35 times that of middle-aged, low-income households, 1.66 times that of young, high-income households, and 2.27 times that of young, low-income households.

Together, these two factors suggest that middle-aged households with high incomes are more likely to increase their housing size compared to households in other age-income

[40]See Figure E.1 in Appendix E.

groups.[41] As a result, capital gains from rising house prices increase the house equity of middle-aged, high-income households, incentivizing them to upsize. This added demand then drives house prices even higher, creating a positive feedback loop among house prices, house equity, and housing demand.

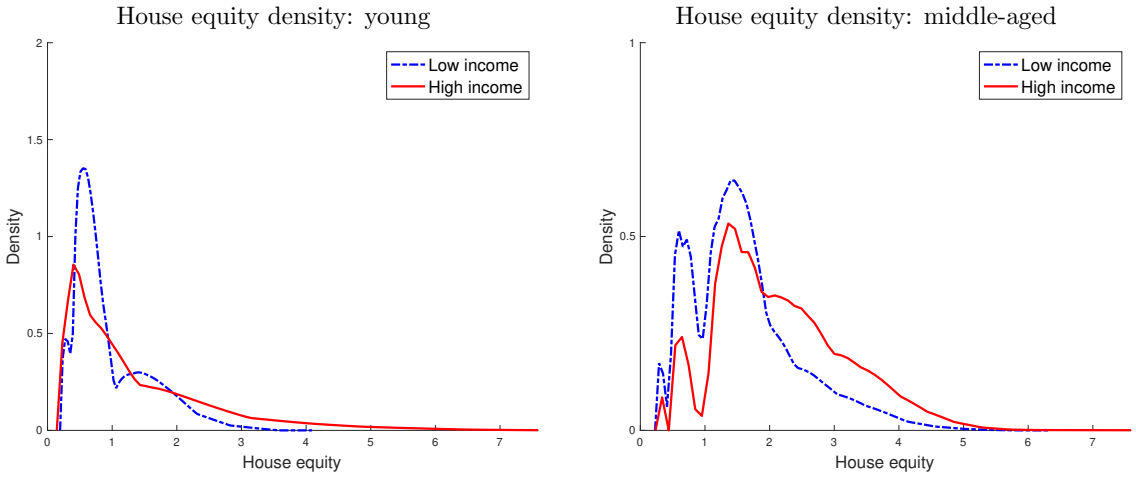

FIGURE 12. The distribution of house equity during the LTV policy relaxation

Notes: The panels display the distribution of house equity for young and middle-aged households during the policy relaxation period. House equity is defined as the increased house price multiplied by the initial house size, minus the outstanding mortgage.

VI.2.3. *Capital gains from rising house prices.* An increase in house price enables existing homeowners to realize capital gains when they sell their homes. Larger homes generate greater capital gains, and middle-aged homeowners with high incomes, who typically own larger homes, benefit most from this wealth effect.[42]

To gauge the significance of capital gains, we conduct a counterfactual exercise imposing a one-period 100% tax on capital gains, while keeping the increase in the LTV limit on

[41] In our benchmark model, refinancing with cash-out options is not allowed in accordance with China's reality and institutional restrictions. Nonetheless, we conduct a counterfactual experiment allowing for such refinancing in Section VI.3.3. In that case, most households who trade up in the benchmark model still choose to upsize their primary homes even when refinancing is available, indicating investment incentives for trading up.

[42] Analysis of NBS data from 2011Q1 to 2018Q1 shows that year-over-year growth rates for house prices across three size categories—less than 90 square meters, between 90 and 144 square meters, and above 144 square meters—are quantitatively similar. This supports our model's prediction that house size influences the magnitude of capital gains.

secondary houses the same as in the benchmark model (Section VI.1). The tax applies only during the policy relaxation period and does not apply in future periods. This experiment isolates the role of realized capital gains from trading-up activities while preserving investment incentives driven by potential future capital gains. Imposing a high tax substantially dampens the response of the housing and mortgage markets to the change in LTV policy.

As shown in Table 9, the house price increases by only 0.53%, and the total amount of mortgage originations rises by just 5.16%, compared to 80.03% in our benchmark model. The total number of originations actually declines by 1.75%, and mortgage originations for primary homes fall sharply. Without capital gains, homeowners have little incentive to trade up to larger homes even though their LTV limit is relaxed,[43] and middle-aged and high-income homeowners allocate more spending to non-housing goods rather than trading up when the LTV policy is relaxed for secondary houses.

TABLE 9. Impacts of a relaxation of the LTV policy targeting investment houses with a 100% tax on capital gains

	Counterfactual (1)	Benchmark model (2)	Data (3)
House price	0.53	4.86	5.94
Mortgage origination amount	5.16	80.03	91.78
Mortgage origination number	-1.75	33.36	46.51
Mortgage origination amount (primary homes)	-12.29	51.63	78.98
Mortgage origination number (primary homes)	-8.05	22.53	42.21
Mortgage origination amount (secondary houses)	195.22	379.63	323.92
Mortgage origination number (secondary houses)	96.81	202.80	124.36

Notes: This table shows the aggregate effects of the LTV relaxation policy in a counterfactual exercise with a 100% tax on capital gains from increases in house prices. Values reported in the table are annualized growth rates (%). The heading "Counterfactual" represents the counterfactual exercise. For comparison, columns (2) and (3) repeat the values reported in Table 7a. See the notes of Table 7 for how aggregate moments are calculated in the benchmark model and data.

The housing investment channel of the LTV policy relies on several key elements. Loosening the LTV policy for secondary houses directly boosts mortgage demand by housing investors, raising the values of primary homes and capital gains for existing homeowners, especially for middle-aged, high-income households with substantial house equity. These capital gains then allow middle-aged and high-income households, who expect further capital gain, to overcome LTV constraints and trade up their primary homes at the expense of non-housing consumption. Since this group constitutes a substantial portion of housing

[43]Our results confirm that trade-ups are nearly nonexistent under this scenario.

demand, their increased mortgage demand and rising house prices become primary drivers of the overall surge in mortgage demand when LTV constraints on housing investments are relaxed.

VI.3. **Other considerations.** To provide a more comprehensive understanding of the housing investment channel in our theoretical model, we explore in this section additional scenarios relevant to our analysis.

VI.3.1. *A relaxation of LTV policy for first-time homebuyers.* Unlike the LTV policy for secondary houses, which directly boosts housing demand by investors, a relaxation of the LTV policy for primary homes mainly influences initial housing tenure decisions, specifically for first-time buyers. We compare the effects of these two distinct policies on house prices and mortgage markets to emphasize the significance of the housing investment channel in interpreting China's actual LTV policy. In a counterfactual experiment, we raise the LTV ratio for first-time homebuyers by the same magnitude as in the benchmark model, from $\lambda_1 = 0.4$ to $\lambda_1 = 0.65$.[44] All other parameters remain the same as in the benchmark model.

Columns (1) and (2) of Table 10a compare the aggregate effects of the LTV policy change for primary homes and secondary houses. Relaxing the LTV constraint for primary homes results in only a 0.30% increase in house prices, compared to a 4.86% increase generated by relaxing the constraint for secondary houses. This limited price response relies on the assumption of costless conversion from rental units to owner-occupied homes—an assumption made by Kaplan et al. (2020) and adopted in our model. If substantial segmentation between rental and owned housing markets were present, a larger house price response would be expected following a relaxation of the LTV constraint on primary homes, as suggested by Greenwald and Adam (2021). When the LTV policy is loosened for primary homes, total mortgage originations and originations for primary homes both increase accordingly. In contrast, for secondary houses, the policy leads to declines of respective 4.06% and 2.43% in the total amount and number of mortgage originations.

A fundamental difference between our model and Kaplan et al. (2020) is our distinction between secondary houses (for investment) and primary homes (for housing services). Kaplan et al. (2020) treat all homes as primary, focusing solely on housing tenure choice. By contrast, our model allows LTV policy for secondary houses to directly stimulate investor-driven housing demand. Since existing homeowners satisfy this investment demand by purchasing secondary houses, house prices rise, generating capital gains on existing primary homes.

[44]For robustness, we also examine an increase in the LTV limit for first-time homebuyers consistent with the adjustment in China's LTV policy from 2014Q4 to 2016Q3, from $\lambda_1 = 0.7$ to $\lambda_1 = 0.8$. The results are qualitatively similar. These additional findings are available upon request.

This, in turn, allows existing homeowners to trade up their primary homes, boosting aggregate housing demand that can be only met by newly built houses, rather than converted rental houses. This feedback mechanism amplifies both house prices and mortgage borrowing in equilibrium.

Table 10b presents the distributional impacts of the LTV policy relaxation for primary homes on mortgage demand across different age-income groups. There are two notable differences from the benchmark model results (reported in parentheses). First, the mortgage share of middle-aged and high-income households in total mortgages on primary homes decreases, in both amount (-11.02 percentage points) and number (-7.93 percentage points), whereas it increases in our benchmark experiment where the LTV constraint for secondary houses is relaxed. Second, young and low-income households experience an increase in mortgage shares, reversing the declines observed under the relaxation of the LTV policy for secondary houses. These households tend to be credit-constrained in entering homeownership; increasing the LTV limit for first-time homebuyers loosens their borrowing constraints and facilitates home purchases. The limited increase in house prices, however, discourages existing homeowners from trading up, resulting in a decrease in mortgage shares among high-income, middle-aged households.

VI.3.2. *A tightening of the LTV limit on secondary houses.* We examine whether the impacts of changes in LTV policy on secondary houses are asymmetric between relaxation and tightening. Specifically, we consider the exercise in which, instead of a relaxation, a sudden tightening of the LTV limit on secondary houses occurs by setting the LTV limit on secondary houses to decrease from 0.4 to 0.15.[45] The results are presented in Table 11.

In this counterfactual exercise, the impacts of a tightening of the LTV limit on housing and mortgage markets are more dampened than in the benchmark model. House prices decrease only slightly, with a magnitude much smaller than in the benchmark model (-0.69% versus 4.86%). The amount and number of mortgage originations for secondary houses decrease significantly due to the direct effect of the tightened LTV policy. Mortgage originations for primary homes, however, increase slightly due to the reduced house price. Because mortgage originations for primary and secondary homes move in opposite directions, the overall effect on total mortgage originations mostly cancels out and remains minimal in magnitude.

The asymmetry between the effects of tightening and relaxing LTV limits arises mainly from the long-term mortgage structure in our model. Unlike a short-term mortgage scenario in which changes in the LTV policy for originations and house prices affect both new originations and outstanding mortgages, changes in our long-term mortgage model are linked only

[45]The results are qualitatively similar if the LTV limit on secondary houses decreases from 0.65 to 0.4.

TABLE 10. Impacts of loosening the LTV policy for first-time homebuyers

(A) Aggregate impacts on the house price and key mortgage variables
(Annualized growth rate %)

	1st H LTV (1)	2nd H LTV (2)
House price	0.30	4.86
Mortgage origination amount	40.93	80.03
Mortgage origination number	43.16	33.36
Mortgage origination amount (primary homes)	48.98	51.63
Mortgage origination number (primary homes)	46.04	22.53
Mortgage origination amount (secondary houses)	-4.06	379.63
Mortgage origination number (secondary houses)	-2.43	202.80

(B) Changes in the mortgage share of an age-income group in total mortgages on primary homes

	Mortgage share change (percentage points)			
	Origination amount		Origination number	
	(1)	(2)	(3)	(4)
	Low income	High income	Low income	High income
Young	3.93 (-1.20)	4.74 (-4.46)	3.58 (-2.23)	-0.44 (-3.11)
Middle-aged	2.98 (-1.80)	-11.02 (10.10)	4.72 (-0.60)	-7.93 (6.72)
Old	-0.13 (-0.44)	-0.49 (-2.19)	-0.28 (-0.20)	0.35 (-0.59)

Notes: This table presents the aggregate and distributional effects of the LTV relaxation policy for first-time homebuyers. In Table 10a, the abbreviation "1st H" represents first-time homebuyers, while "2nd H" refers to secondary houses. For comparison, column (2) in Table 10a repeat the values reported in Table 7a from the change in LTV policy for secondary houses. Parentheses in Table 10b indicate the results from the LTV policy for secondary houses across age-income groups. See the notes in Table 7 for details on how aggregate moments are calculated in the model and data.

to new originations and do not directly affect outstanding mortgages. That is, households with existing mortgages can continue their mortgage payments and maintain their housing positions without needing to adjust their outstanding mortgage balances or housing holdings in response to changes in the LTV policy or in house price. In the counterfactual exercise, only households intending to purchase secondary houses are constrained by the stricter LTV policy, and since these households are few in number, the impact on the housing market is limited. At the same time, the drop in house price fails to generate capital gains. Since households with primary homes have investment incentives, they maintain their housing positions rather than downsize existing homes. The feedback loop between house prices and

TABLE 11. Impacts of reducing the LTV limit on secondary houses from 0.4 to 0.15

	Counterfactual (1)	Benchmark model (2)
House price	-0.69	4.86
Mortgage origination amount	-4.81	80.03
Mortgage origination number	1.40	33.36
Mortgage origination amount (primary homes)	7.67	51.63
Mortgage origination number (primary homes)	6.67	22.53
Mortgage origination amount (secondary houses)	-96.26	379.63
Mortgage origination number (secondary houses)	-81.03	202.80

Notes: This table presents the aggregate effects of the LTV relaxation policy in a counterfactual exercise where the LTV limit on secondary houses is reduced from 0.4 to 0.15. The values reported are annualized growth rates (%). The heading "Counterfactual" indicates the counterfactual experiment. For comparison, columns (2) repeats the values reported in Table 7a. See the notes in Table 7 for details on how aggregate moments are calculated in the benchmark model.

mortgage demand, present in the benchmark model, is absent here, resulting in a minimal effect on the housing and mortgage markets. Thus, the housing investment channel of the LTV policy operates effectively through policy relaxation for secondary houses but not through policy tightening.

VI.3.3. *Allowing for refinancing.* In our benchmark model, refinancing is not allowed, an assumption that adheres to the institutional arrangement in China. To explore the effect of refinancing, we conduct a counterfactual exercise in which refinancing becomes available along with the LTV policy relaxation.[46] With this refinancing option, households can retain their homes while taking out new mortgages to obtain liquidity for consumption.[47]

In this experiment, approximately 5.6% of households opt to refinance during the policy period. Among the households that choose to trade up during the policy relaxation period in the benchmark model, however, only 0.3% opt to refinance their original homes when given the option. This finding suggests that most households trading up in the benchmark model do so primarily for investment purposes, rather than to cash out home equity for consumption. Thus, the core mechanism of our model remains robust even when refinancing is allowed.

[46]We model this refinancing option following Kaplan et al. (2020), who define it as "Mortgage borrowers always have the option to refinance, by repaying the residual principal balance and originating a new mortgage."

[47]For a clear comparison, we keep house prices the same as in the benchmark model during the policy period, ensuring that potential capital gains are the same in this exercise as in the benchmark model.

We also examine the effect of refinancing on non-housing consumption. For households that choose to refinance, consumption increases on average by 31.1% relative to the benchmark model. Refinancing enables some households to cash out accumulated home equity, thereby boosting consumption. As a result, aggregate consumption with refinancing does not decline as much as in the benchmark case.

VII. Conclusion

We investigate the impacts of LTV policy on mortgage markets and household consumption, focusing on an unprecedented relaxation of LTV limits for secondary houses from 2014Q4 to 2016Q3. The LTV relaxation, aimed at promoting housing investments, triggered a widespread mortgage boom, especially expanding primary home mortgages. Our data also shows that household consumption, particularly among middle-aged and highly educated households, declined during this period.

We develop and calibrate a life-cycle equilibrium model that distinguishes between primary homes for housing services and secondary houses for investment. The model captures the heterogeneous impacts of policy changes across age-income groups. We show that mortgage demand growth—driven by middle-aged households trading up their primary homes—accounts for over 80% of the observed increase in house prices and about 87% of the rise in total mortgage originations.

The housing investment channel illustrated by the model is essential for understanding non-housing consumption dynamics during the mortgage boom, as observed in our data. Capital gains resulting from the LTV policy relaxation on secondary houses enable existing homeowners to upsize their primary residences, creating a positive feedback loop that drives up house prices, increases mortgage debt, and ultimately crowds out non-housing consumption.The decline in consumption contrasts with prior literature linking mortgage booms to increased consumption; it underscores the critical role of the housing investment channel in shaping consumption responses in emerging markets. Our findings suggest that rising debt burdens can limit consumption for certain demographics, highlighting the potential risks and unintended consequences of credit policy adjustments on macroeconomic stability and sustainable growth in emerging-market economies.

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Online Appendices
(Not For Publication)

Appendix A. Representativeness of the data

Our loan-level data comes from one of the four largest state banks (Big Four), which may contain a potential sample bias. One concern regarding our Bank Loan Data is its representativeness, in particular, whether its aggregate and cross-sectional patterns are compatible with other representative sample. In this section, we document that our data is compatible with other data sources. We begin by comparing aggregate moments calculated from the Bank Loan Data, from the publicly available annual reports published by this particular bank that provided us with the Bank Loan Data (we refer to this bank as the Sample Bank for the rest of our discussion), and from the aggregate mortgage data published by the CEIC (a major data platform to which one can have access with a subscription fee). We then compare cross-sectional moments implied by the Bank Loan Data with those from Fang, Gu, Xiong and Zhou (2016), who use loan-level data on mortgage originations to newly-built houses from a different Big Four bank.

A.1. **Aggregate time series.** There are two potential caveats in comparing our data with the CEIC aggregate data. First, the total mortgages reported from the CEIC aggregate data include mortgages on both newly built and existing houses; the Bank Loan Data includes only newly built houses. Second, the CEIC aggregate data contains total *outstanding* mortgage loans for the whole economy in China; the Bank Loan Data contains each mortgage loan amount, which is used to obtain our aggregated loan data for comparison. We take two steps to compare our mortgage data with the CEIC aggregate data. We first compare the growth rate of total outstanding mortgage amount from the CEIC with the growth rate of total outstanding mortgage amount for the Sample Bank, which we obtain from the Loan bank's publicly available annual reports. We then compare the aggregated mortgage amount from the Bank Loan Data with the difference of total outstanding mortgage amount from the Sample Bank.[48]

The left panel of Figure A.1 reports the growth rates of total outstanding mortgage amount for the Chinese entire economy from CEIC's aggregate data and from the Sample Bank's annual reports. The growth rate from the Sample Bank tracks closely that from the CEIC. In particular, the (annualized) mortgage growth rates for both series rose rapidly in the second half of 2014 and peaked in the first half of 2016 at around 15%. Afterwards, the growth rates of total outstanding mortgage amount for both series declined steadily and fell below 10% in the first half of 2018—the end of our sample. This result suggests that the

[48]The Bank Loan Data contains mortgages in China's 70 major cities, while the Sample Bank's annual reports contain total *outstanding* mortgage amount for the entire economy.

growth rate of mortgages from the Sample Bank should be representative of the growth rate of mortgages in the whole economy.

The right panel reports the mortgage amount aggregated from the Bank Loan Data in comparison with the difference of total outstanding mortgages from the Sample Bank's annual reports (each series is normalized by its value in the first half year of 2011). We see that these two series track each other closely. Both series have a secular increase over time. Moreover, there was an accelerated rise after the second half 2014 until it peaked in the second half of 2016 for both series. Together with the result displayed in the left panel, this result suggests that the overall trend of newly originated mortgages from the Bank Loan Data should be representative of the trend for the whole economy.

A.2. **Cross-city distribution of mortgage borrowers.** Since our empirical design is based on cross-city heterogeneity in ex-ante exposure to the policy change, we now demonstrate the representativeness of our sample by comparing the cross-city distributions of various statistics for mortgage borrowers between the Bank Loan Data and Fang, Gu, Xiong and Zhou (2016). Apart from the Bank Loan Data, the only other source of mortgage-level data is Fang, Gu, Xiong and Zhou (2016), who obtained from another Big Four bank one million loans over the period of 2003-2012 across 120 cities in China. From this administrative data, Fang, Gu, Xiong and Zhou (2016) present a set of characteristics of mortgage borrowers across three tiers of cities in China.[49] We use the same criteria as Fang, Gu, Xiong and Zhou (2016) to classify cities into three tiers and mortgage borrowers into different income groups, and compare the same statistics between our data and theirs for the three tiers of cities for the year 2012, the last year in which their data overlaps with ours.[50]

Figure A.2 displays various characteristics of mortgage borrowers with mean values from the two data sources and 95% confidence intervals from the Bank Loan Data (our data source). The left column of graphs in the figure correspond to mortgage borrowers with bottom incomes and the right column mortgage borrowers with middle incomes.[51] The top row of graphs shows that across three tiers of cities, the mean down payment ratios for both

[49]It is customary to group Chinese cities into three tiers. The first tier includes four cities with the largest populations—Beijing, Shanghai, Guangzhou, and Shenzhen. There are 31 second-tier cities, including two autonomous municipalities, the capital cities of 25 provinces, and four coastal cities that are economic centers for China. The rest of cities belong to the third tier.

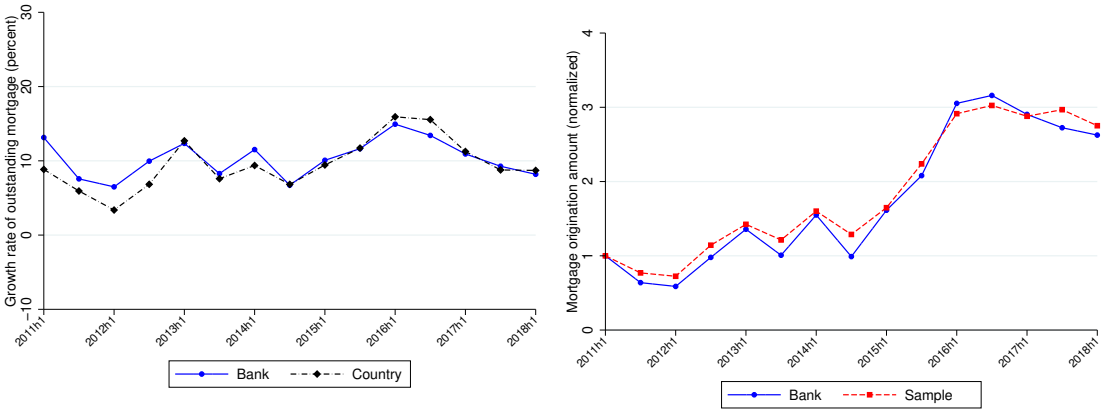
[50]Both the Bank Loan Data and the administrative data used by Fang, Gu, Xiong and Zhou (2016) cover a total of 35 tier-one and tier-two cities. The data used by Fang, Gu, Xiong and Zhou (2016), however, misses 17 tier-three cities that are contained in the Bank Loan Data.

[51]Fang, Gu, Xiong and Zhou (2016) consider only bottom-income and middle-income mortgage borrowers. According to their definition, the bottom-income group is defined as mortgage borrowers with household incomes in the bottom 10% percentile of the income distribution of all mortgage borrowers in a given city

bottom-income and middle-income groups are close between the sample of Fang, Gu, Xiong and Zhou (2016) and our sample. For instance, for both second-tier and third-tier cities, both samples reveal that the down payment ratios for the bottom-income group is 0.45, higher than those for the middle-income group (0.4). The second row of graphs shows that for the ratio of the house price to income, the mean values from the sample of Fang, Gu, Xiong and Zhou (2016) for the three tiers of cities, close to the corresponding mean values from the Bank Loan Data, are well within the 95% confidence intervals calculated from the Bank Loan Data. For example, for the tier-one cities, the ratios of the house price to income in the bottom-income and middle-income groups are 9.2 and 7.5 from the sample of Fang, Gu, Xiong and Zhou (2016), well within the 95% confidence intervals of our sample. The third row of graphs shows the average size of the houses purchased by bottom-income and middle-income mortgage borrowers in the three tiers of cities. For each tier of cities and each income group, the mean value from the sample of Fang, Gu, Xiong and Zhou (2016) falls within the 95% confidence interval from our sample. The average sizes of houses purchased by the bottom-income and middle-income groups in the tier-two cities, for example, are 80 and 90 square meters, close to the corresponding mean values from our sample. The bottom row of graphs displays the average age of mortgage borrowers. In all three tiers of cities, mortgage borrowers in the sample of Fang, Gu, Xiong and Zhou (2016) are on average in their early 30s with the borrowers in the bottom-income group slightly younger than those in the middle-income group. For each income-city-tier group, the average age of mortgage borrowers in the sample of Fang, Gu, Xiong and Zhou (2016), close to the average value from our sample, is well within the 95% confidence interval calculated from our sample.

To summarize, by comparing the Bank Loan Data with aggregate data and another representative loan-level database, we show that our data is representative of the aggregate dynamics of mortgage originations as well as various characteristics of mortgage borrowers across cities.

in 2012; the middle-income group is defined as those with household incomes between the 45th and 55th percentiles of the income distribution of all mortgage borrowers in a given city in 2012.

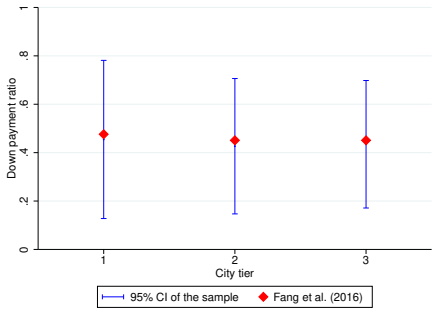


Growth rate of outstanding mortgage amount

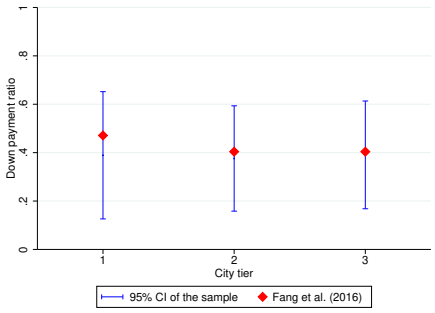
Mortgage amount

FIGURE A.1. Aggregate amount of mortgage loans: sample vs bank vs country

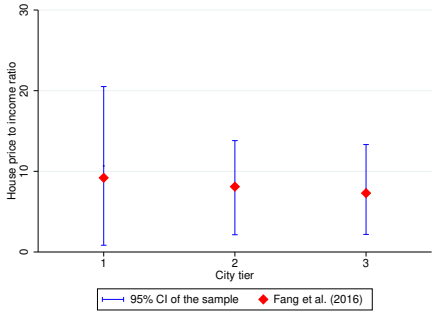
Notes: The left panel reports the growth rates of total outstanding mortgage amount for China's whole economy from the CEIC aggregate data (labeled as "Country" in the legend) and from the Sample Bank's annual reports (labeled as "Bank" in the legend). The right panel reports the amount of newly originated mortgages from the Bank Loan Data (labeled as "Sample" in the legend) and the difference in total outstanding mortgage amount from the Sample Bank's annual reports (labeled as "Bank" in the legend).



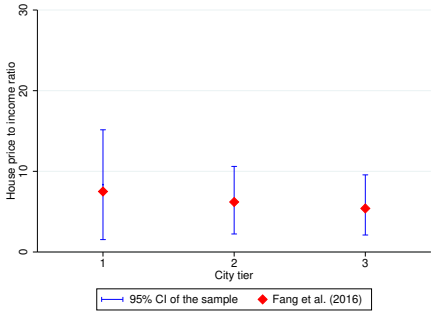
Down payment ratio: bottom-income



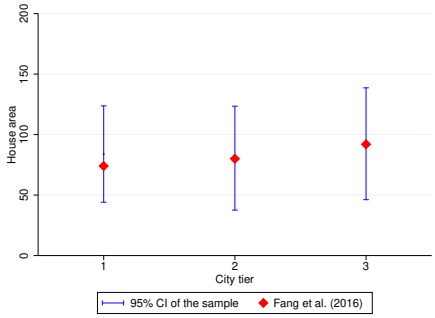
Down payment ratio: middle income



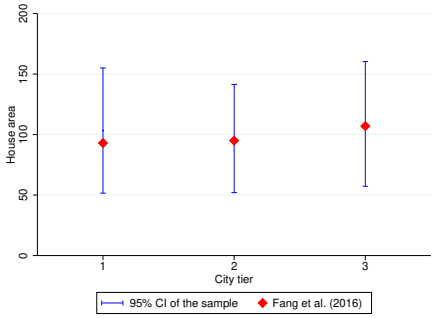
Ratio of the house price to income: bottom income



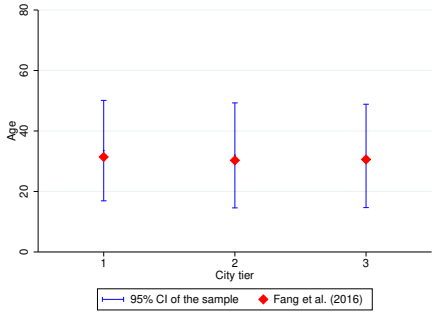
Raito of the house price to income: middle income



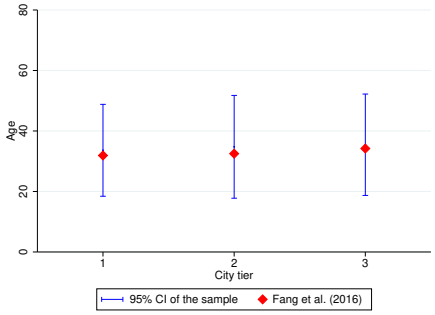
House area: bottom income



House area: middle income



Age: bottom income



Age: middle income

FIGURE A.2. A comparison of mortgage borrowers' characteristics between the Bank Loan Data and Fang et al. (2016)

Notes: The results reported here are for the year 2012, the last year in which the administrative data used by Fang, Gu, Xiong and Zhou (2016) overlaps with the Bank Loan Data. The values from Fang, Gu, Xiong and Zhou (2016) are mean values. The 95% confidence intervals are calculated from the Bank Loan Data as the mean values plus/minus 1.96 times the corresponding standard deviations.

Appendix B. Summary statistics

Table B.1 presents descriptive statistics for the main variables in our mortgage data sample. For each variable, we report its average and standard deviation for two subperiods (2011Q1-2014Q3 and 2014Q4-2016Q3) as well as the full sample period, which covers the period 2011Q1-2018Q2. The full sample has $3,011,765$ borrowers to finance primary homes and $259,024$ borrowers to finance secondary houses.

We first compare individual borrower characteristics for the primary and secondary houses during 2011Q1-2014Q3—the period before LTV policy was relaxed (comparing panels A and B in the table). The share of primary home mortgages in total mortgage origination numbers during this period is 94.8%. Borrowers for primary houses were, on average, four years younger than those for secondary houses. The fraction of borrowers with a college degree or higher was smaller for primary homes than for secondary houses (47% versus 62%). This observation implies that borrowers were, on average, wealthier than those for primary homes. The average house size and value were larger than for primary houses. On the other hand, the average mortgage balance when mortgages for primary homes were originated was similar in size to that (438,250 RMB versus 436,900 RMB). Since the average monthly mortgage payment for a secondary house was 20% higher than for a primary home (4,046 RMB versus 3,347 RMB), the mortgage maturity was shorter than that for primary houses.

The average LTV ratio when mortgages for primary houses were originated was higher than that (63% versus 38%), reflecting the different LTV policies for these two types of houses. The average mortgage rate for primary houses was about 1% lower than that (6.55% versus 7.40%), also reflecting the different mortgage rate policies on primary versus secondary houses. The ratio of debt to income (DTI) is 4.0 when mortgages were originated for primary houses, but only 2.52 for secondary houses, implying that borrowers had on average higher incomes than those for primary houses.

We now compare borrower characteristics for primary and secondary houses between the two subperiods 2011Q1-2014Q3 and 2014Q4-2016Q3. For primary houses, the fraction of borrowers with college degree and above increased from 47% in the first subperiod to 59% in the second subperiod, while the average age of borrowers increased from 34.50 to 34.68 (panel A of the table). The average size for primary homes also increased because many homeowners traded up their homes (i.e., sold their existing homes and bought larger houses) during the boom. The average initial mortgage loan increased by about 30% (from 438,250 RMB to 566,590 RMB), whereas the average LTV ratio changed little. An increase in mortgage loans for primary homes led to a higher mortgage debt burden with a 13% increase in monthly mortgage payment (from 3,347 RMB to 3,800 RMB) and an increase of the average DTI

from 4.0 to 4.19, even when the average mortgage rate fell from 6.55% in the first subperiod to 5.14% in the second subperiod.

For secondary houses, we observe a similar increase in the fraction of borrowers with college degree and above (from 62% to 72%) as well as an increase in the average age of mortgage borrowers (from 38.6 to 39.37). The initial mortgage loan per borrower was 94% higher in 2014Q4-2016Q3 than in 2011Q1-2014Q3 (849,030 RMB versus 436,900 RMB), partly because the LTV ratio increased from 0.38 to 0.59 and partly because the average house value increased by 23%. As a result, the mortgage debt burden increased substantially with a 44% increase in the monthly mortgage payment and an increase in the ratio of mortgage debt to income from 2.52 to 3.39. The average mortgage rate fell by more than 2% from 7.40% to 5.20% and the share of mortgage loan amount (number) increased from 5.2% to about 11% (8%).

Table B.2 reports summary statistics for the CHFS data. We include all three surveys from 2013 onward, as the sample in the 2011 survey (the first survey) has relatively few observations. While our mortgage loan database includes only households with new mortgages, the CHFS database includes households with and without mortgages as well as those who paid their mortgages in full. For example, the two variables, outstanding mortgage debt and the ratio of mortgage debt to income, include households without mortgages. As one can see, the outstanding mortgage debt increased significantly from 2013 to 2015 and from 2015 to 2017. The share of housing assets in total household assets declined slightly from 80.38% in 2013 to 79.24% in 2015 and then to 76.22% in 2017. The average home ownership rate increased from 86% in 2013 to 89.26% in 2015 and then fell slightly to 88.09% in 2017.

TABLE B.1. Summary statistics for mortgage origination data

	2011Q1-2014Q3		2014Q4-2016Q3		2011Q1-2018Q2	
	Mean	SD	Mean	SD	Mean	SD
Panel A: Summary statistics for borrowers purchasing the primary house						
Age	34.50	9.02	34.68	8.81	34.50	8.98
Fraction of borrowers with college degree and above	0.47	0.50	0.59	0.49	0.56	0.50
House size (square meters)	103.22	35.75	105.38	35.42	105.46	35.59
House value (thousands of RMB)	698.79	863.61	879.75	1129.47	845.14	1063.90
Mortgage Loan (thousands of RMB)	438.25	565.76	566.59	741.31	538.72	684.17
Monthly mortgage payment (RMB)	3347.46	4795.01	3800.44	4600.51	3685.97	4596.21
Loan-to-value (LTV) ratio	0.63	0.11	0.65	0.12	0.64	0.12
Mortgage rate (percent)	6.55	0.63	5.14	0.83	5.62	1.03
Mortgage debt to (annual) income ratio	4.00	1.71	4.19	1.89	4.19	1.86
Number of borrowers	1,212,014		919,998		3,011,765	
Panel B: Summary statistics for borrowers purchasing a secondary house						
Age	38.60	7.69	39.37	7.73	38.81	7.80
Fraction of borrowers with college degree and above	0.62	0.49	0.72	0.45	0.71	0.45
House size (square meters)	116.99	52.32	119.09	53.28	117.04	51.53
House value (thousands of RMB)	1158.61	1511.99	1426.21	1873.07	1372.35	1672.66
Mortgage loan (thousands of RMB)	436.90	615.26	849.03	1179.92	721.13	931.30
Monthly mortgage payment (RMB)	4046.10	5311.81	5826.17	7817.19	5174.01	6263.09
Loan-to-value (LTV) ratio	0.38	0.07	0.59	0.13	0.53	0.15
Mortgage rate (percent)	7.40	0.37	5.20	0.77	5.77	1.13
Mortgage debt to (annual) income Ratio	2.52	1.49	3.39	1.82	3.12	1.83
Number of borrowers	66,962		80,339		259,024	

Notes: Descriptive statistics for the variables used in this paper. The sample contains all new mortgage loans advanced by the bank for purchasing new residential properties, covering 70 cities that correspond to the city sample used by NBS for constructing its 70-city house price index.
Source: The Bank Loan Data.

TABLE B.2. Summary statistics for the CHFS Data

	2013		2015		2017	
	Mean	SD	Mean	SD	Mean	SD
Age	50.34	14.98	52.15	14.93	54.41	14.94
Income (thousands of RMB)	75.29	94.85	81.27	103.63	98.82	112.84
Outstanding mortgage debt (thousands of RMB)	24.59	212.10	30.86	197.95	41.08	221.65
Net wealth (thousands of RMB)	765.47	1223.51	984.67	1500.15	1226.68	1870.10
Share of housing assets in net wealth (percent)	80.38	47.81	79.24	43.50	76.22	44.17
Homeownership (percent)	86.02	34.68	89.26	30.97	88.09	32.39
Number of observations	19,181		25,607		27,245	

Notes: Descriptive statistics for the variables used in this paper. The two variables, outstanding mortgage debt and the ratio of mortgage debt to income, include households without mortgage. In addition to our mortgage sample, the CHFS database includes households who paid their mortgage debts in full.
Source: The CHFS.

Appendix C. Additional tables

TABLE C.1. The effect of a loosening of LTV policy for secondary houses on the mortgage share of middle-aged households with low education in total mortgages on primary homes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Exposure × Policy	-0.007***	-0.005*	-0.007**	-0.007**	-0.010***	-0.008***	-0.008***	-0.007**	-0.007**	-0.006**	-0.008***	-0.007***	-0.003
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Income growth in 2011 × Policy		0.004											-0.002
		(0.003)											(0.003)
Population growth in 2011 × Policy			0.001										0.008**
			(0.001)										(0.003)
Unemployment rate change in 2011 × Policy				-0.005*									-0.012**
				(0.003)									(0.005)
Median mort rate for 1st H in 2011 × Policy					-0.011***								-0.008**
					(0.003)								(0.003)
Median mort rate for 2nd H in 2011 × Policy						-0.008***							-0.004
						(0.003)							(0.003)
Median maturity for 1st H in 2011 × Policy							0.004						-0.002
							(0.003)						(0.005)
Median maturity for 2nd H in 2011 × Policy								-0.000					-0.010***
								(0.003)					(0.004)
Median LTV for 1st H in 2011 × Policy									0.017***				0.017***
									(0.003)				(0.003)
Median LTV for 2nd H in 2011 × Policy										-0.002			-0.009**
										(0.003)			(0.004)
Average house price growth between 2006 and 2009											0.002		-0.002
											(0.004)		(0.004)
Local house price sensitivity												0.004	0.004
												(0.003)	(0.003)
Adjusted R^2	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.059
Observations	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608
City-level time-varying controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions are based on the subsample with mortgages on only primary homes and control for time-varying city-level characteristics including lagged mortgage interest rate, lagged urban income per capita, lagged population, and lagged unemployment rate. The abbreviation "1st H" stands for primary home and "2nd H" for secondary house. All city characteristics are normalized by their cross-sectional standard deviations. Standard errors, reported in parentheses, are clustered at the city-year-quarter level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

TABLE C.2. The effect of a loosening of LTV policy for secondary houses on the mortgage share of middle-aged households with high education in total mortgages on primary homes: dropping tier-1 cities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Exposure × Policy	0.027***	0.025***	0.027***	0.027***	0.027***	0.027***	0.026***	0.027***	0.026***	0.025***	0.027***	0.027***	0.018***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Income growth in 2011 × Policy		-0.003											0.003
		(0.003)											(0.003)
Population growth in 2011 × Policy			-0.003										-0.011***
			(0.002)										(0.004)
Unemployment rate change in 2011 × Policy				0.002									0.014***
				(0.003)									(0.005)
Median mort rate for 1st H in 2011 × Policy					-0.002								-0.002
					(0.003)								(0.004)
Median mort rate for 2nd H in 2011 × Policy						0.002							-0.001
						(0.003)							(0.004)
Median maturity for 1st H in 2011 × Policy							0.005						0.006
							(0.004)						(0.006)
Median maturity for 2nd H in 2011 × Policy								0.004					0.011**
								(0.003)					(0.004)
Median LTV for 1st H in 2011 × Policy									-0.009***				-0.013***
									(0.003)				(0.003)
Median LTV for 2nd H in 2011 × Policy										0.006*			0.008**
										(0.003)			(0.004)
Average house price growth between 2006 and 2009											0.001		0.005
											(0.003)		(0.004)
Local house price sensitivity												-0.005	-0.008**
												(0.003)	(0.004)
Adjusted R^2	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.042
Observations	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980	2569980
City-level time-varying controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions are based on the subsample with mortgages on only primary homes originated in tier-2 and tier-3 cities and control for time-varying city-level characteristics including lagged mortgage interest rate, lagged urban income per capita, lagged population, and lagged unemployment rate. The abbreviation "1st H" stands for primary home and "2nd H" for secondary house. All city characteristics are normalized by their cross-sectional standard deviations. Standard errors, reported in parentheses, are clustered at the city-year-quarter level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

TABLE C.3. The effect of a loosening of LTV policy for secondary houses on the mortgage share of middle-aged households with high education in total mortgages on primary homes: controlling citytier-time fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Exposure × Policy	0.027***	0.026***	0.027***	0.027***	0.027***	0.028***	0.027***	0.027***	0.027***	0.026***	0.027***	0.027***	0.019***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Income growth in 2011 × Policy		-0.003											0.003
		(0.003)											(0.003)
Population growth in 2011 × Policy			-0.003										-0.012***
			(0.002)										(0.003)
Unemployment rate change in 2011 × Policy				0.001									0.014***
				(0.003)									(0.005)
Median mort rate for 1st H in 2011 × Policy					-0.003								-0.002
					(0.003)								(0.004)
Median mort rate for 2nd H in 2011 × Policy						0.002							-0.001
						(0.003)							(0.004)
Median maturity for 1st H in 2011 × Policy							0.006						0.004
							(0.004)						(0.006)
Median maturity for 2nd H in 2011 × Policy								0.008**					0.012***
								(0.003)					(0.004)
Median LTV for 1st H in 2011 × Policy									-0.010***				-0.013***
									(0.003)				(0.003)
Median LTV for 2nd H in 2011 × Policy										0.004			0.008**
										(0.003)			(0.004)
Average house price growth between 2006 and 2009											0.001		0.006
											(0.003)		(0.004)
Local house price sensitivity												-0.006**	-0.009***
												(0.003)	(0.004)
Adjusted R^2	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
Observations	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608	2735608
City-level time-varying controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Citytier-year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions are based on the subsample with mortgages on only primary homes and control for time-varying city-level characteristics including lagged mortgage interest rate, lagged urban income per capita, lagged population, and lagged unemployment rate. Also, citytier-year-quarter fixed effects are controlled in all regressions. The abbreviation "1st H" stands for primary home and "2nd H" for secondary house. All city characteristics are normalized by their cross-sectional standard deviations. Standard errors, reported in parentheses, are clustered at the city-year-quarter level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

TABLE C.4. The effect of a loosening of LTV policy for secondary houses on the mortgage interest rate of primary homes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Exposure × Policy	0.015	0.003	0.014	0.014	0.017	0.015	0.020	0.019	0.014	0.013	0.012	0.015	0.004
	(0.014)	(0.014)	(0.014)	(0.014)	(0.016)	(0.014)	(0.015)	(0.015)	(0.014)	(0.016)	(0.015)	(0.014)	(0.016)
Income growth in 2011 × Policy		-0.024**											-0.018
		(0.011)											(0.013)
Population growth in 2011 × Policy			-0.009										-0.004
			(0.008)										(0.013)
Unemployment rate change in 2011 × Policy				0.009									0.015
				(0.012)									(0.017)
Median mort rate for 1st H in 2011 × Policy					0.007								-0.005
					(0.011)								(0.012)
Median mort rate for 2nd H in 2011 × Policy						-0.000							-0.016
						(0.013)							(0.015)
Median maturity for 1st H in 2011 × Policy							-0.024**						0.005
							(0.012)						(0.019)
Median maturity for 2nd H in 2011 × Policy								-0.035***					-0.029
								(0.013)					(0.018)
Median LTV for 1st H in 2011 × Policy									-0.037***				-0.039***
									(0.014)				(0.015)
Median LTV for 2nd H in 2011 × Policy										0.003			0.002
										(0.013)			(0.015)
Average house price growth between 2006 and 2009											0.013		0.004
											(0.011)		(0.014)
Local house price sensitivity												0.008	0.016
												(0.015)	(0.016)
Adjusted R^2	0.896	0.896	0.896	0.896	0.896	0.896	0.896	0.897	0.897	0.896	0.896	0.896	0.897
Observations	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803	2724803
City-level time-varying controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year-quarter fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: All regressions are based on the subsample with mortgages on only primary homes and control for time-varying city-level characteristics including lagged urban income per capita, lagged population, and lagged unemployment rate. The abbreviation "1st H" stands for primary home and "2nd H" for secondary house. All city characteristics are normalized by their cross-sectional standard deviations. Standard errors, reported in parentheses, are clustered at the city-year-quarter level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.

Appendix D. Numerical Solution Procedure

This section outlines the steps taken to solve the model numerically. First, we provide the computation strategy for the rental company and households' problems. Next, we describe how to calculate the stationary equilibria. Finally, we end with a solution algorithm for transitions.

First, given house price and current state Ω, one can solve the rental company's problem and compute the rental price ρ_h from the optimality condition of the rental company, which is

$$\rho_h(\Omega) = \psi + p_h(\Omega) - \frac{1-\delta_h}{1+r_b} E_{\Omega'}[p_h(\Omega')|\Omega].$$

The household value and policy functions are solved via backward induction starting with the final period of life. We discretize the idiosyncratic state χ by fixing grids on liquid assets $\mathcal{B}$ (20 points), mortgages $\mathcal{M}$ (30 points), house sizes $\mathcal{H}$ (5 points), and income $\mathcal{Y}$ (2×3 points). Households choose liquid assets and house sizes on the grids of $\mathcal{B}$ and $\mathcal{H}$ respectively. Household mortgage choice when purchasing a house is restricted to be on $\mathcal{M}$. However, when households repay the mortgage, the next period mortgage balance can be exactly $\mathcal{M}$, or follow the amortization schedule, which is computed via linear interpolation between grid points.

Second, stationary equilibria are calculated for a given policy regime and constant house price. The following algorithm is used to find the market clearing house price:

1. Make an initial guess of the market clearing house price $\tilde{p}_h$.
2. Given $\tilde{p}_h$, solve the rental price ρ_h from the rental company's problem. Then solve backward for the households' value and policy functions. Given households' choices, solve forward for the distribution of households over individual states.
3. Calculate the aggregate housing demand and housing investment in the stationary equilibria. With housing investment, solve the implied house price $\bar{p}_h$ from the first-order condition for the real estate developer.
4. Compare $\tilde{p}_h$ and $\bar{p}_h$. If not the same, replace $\tilde{p}_h$ by a weighted average of $\tilde{p}_h$ and $\bar{p}_h$, and return to step 2.

Third, for a given path of policies, we define the vector of equilibrium house prices as $p_{h,t}$. Recall that μ_t captures the distribution of households over individual states. The algorithm for calculating the transition paths proceeds as follows. First, guess the approximate length of the transition phase, T. If the transition can be achieved in a smaller number of periods, the last transition periods will be similar to the new steady state. After solving for the stationary equilibria before and after the policy change, we know the starting distribution

μ_0, the end house price $p_{h,T}$, and households' value functions V_T. The algorithm then iterates over the following steps:

1. Guess a sequence of house price vector $\tilde{p}_{h,t}$ for $t = 1, \ldots, T-1$.
2. Given $\tilde{p}_{h,t}$, solve the rental price $\rho_{h,t}$ from the rental company's problem. Then solve backward for the households' value and policy functions at each time t. Given households' choices, solve forward for the distribution of households over individual states across time.
3. Calculate the aggregate housing demand and housing investment for each time t. With housing investment, solve the implied house price $\bar{p}_{h,t}$ from the first-order condition for the real estate developer.
4. Compare $\tilde{p}_{h,t}$ and $\bar{p}_{h,t}$. If not the same, replace $\tilde{p}_{h,t}$ by a weighted average of $\tilde{p}_{h,t}$ and $\bar{p}_{h,t}$, and return to step 2.

Appendix E. Policy functions

In this section, we plot policy functions for choice of house size (h') for homeowners and non-homeowners during the period of LTV policy relaxation in the model. Figure E.1 shows the relationship between choice of house size and housing equity ($p_h \cdot h - m$) for homeowners, while Figure E.2 shows the relationship between choice of house size and initial financial asset position (b) for non-homeowners. We choose age 24 as an example for young households, age 38 for middle-age households and age 52 for old households.

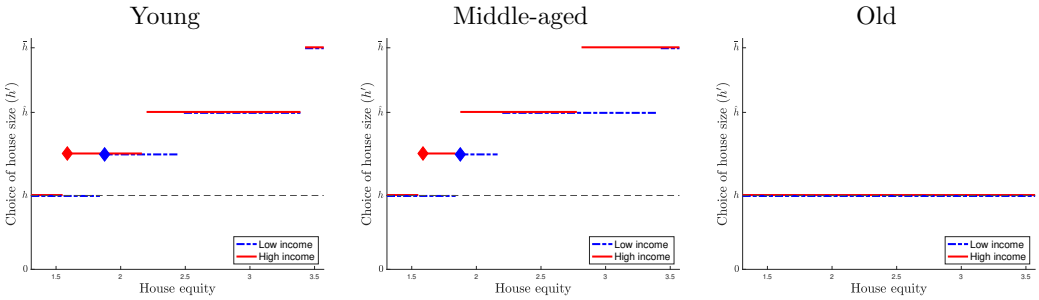


FIGURE E.1. The relationship between choice of house size and homeowners' house equity during the period of LTV policy relaxation

Notes: The panels display the relationship between choice of house size and housing equity for homeowners during the period of LTV policy relaxation in the model, where house equity is defined as house price times initial housing size minus outstanding mortgage. The black dashed lines denote the initial house size for the households. The red solid (blue dash) line denotes choice of housing size by the high-income (low-income) households. The diamond symbols mark the thresholds for households to trade up. In these panels, we choose age 24 as an example for young households, age 38 for middle-aged households and age 52 for old households, and set households' initial financial wealth to zero and their idiosyncratic income shock to the middle level.

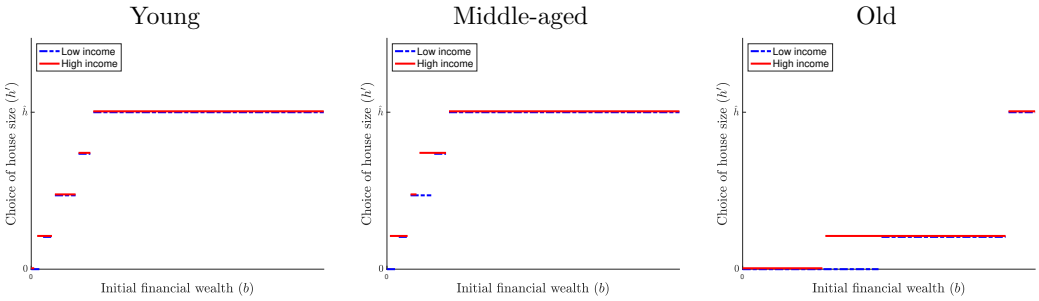


FIGURE E.2. The relationship between choice of house size and non-homeowners' initial financial wealth during the period of LTV policy relaxation

Notes: The panels display the relationship between choice of house size and initial financial wealth for non-homeowners during the period of LTV policy relaxation in the model. In these panels, we choose age 24 as an example for young households, age 38 for middle-aged households and age 52 for old households, and set households' idiosyncratic income shock to the low level. The red solid (blue dash) line denotes choice of housing size by the high-income (low-income) households.

Appendix F. Estimate of house supply elasticity

To estimate house supply elasticity, we run the following two-stage regression. The regression in the second stage is

$$\log(P_{i,t}) = \xi_i + \psi_t + \beta \log(\widehat{H_{i,t}}) + \theta X_{i,t} + \varepsilon_{i,t}, \tag{F.1}$$

where $\widehat{H_{i,t}}$ is the prediction from the first-stage regression. The first-stage regression is

$$\log(H_{i,t}) = \phi_i + \chi_t + \sum_k \gamma_k Z_i \mathbf{1}_{t=k} + \omega X_{i,t} + e_{i,t}, \tag{F.2}$$

where $P_{i,t}$ is the house price index for city i in year t, $H_{i,t}$ is the sales area of newly built houses for city i in year t, ξ_i and ϕ_i are city fixed effects in the second and first stages, ψ_t and χ_t are yearly fixed effects, $X_{i,t}$ represents a vector of controls, and Z_i is the exposure measure for city i. The vector of control variables, $X_{i,t}$, includes log of lagged average city income, log of lagged city population, lagged city unemployment rate, and log of lagged house price index. The inverse of the housing supply elasticity, β, is the coefficient of interest. Table F.1 reports the estimated value of β, which is equal to 0.250 and statistically significant at the 5% level.

Table F.1. Estimate of the inverse of the housing supply elasticity

	House price ($\log(P_{i,t})$)
$\log(H_{i,t})$	0.250**
	(0.120)
City controls	Y
City fixed effect	Y
Year fixed effect	Y
N	490
R^2	0.2207
First-stage F stat	28.20

Notes: The standard error, reported in parentheses, is clustered at the city level. The asterisk * denotes statistical significance at the 0.1 level, ** at the 0.05 level, and *** at the 0.01 level.