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ABSTRACT

Using three unique micro datasets, we find that an unexpected and unprecedented loosening of China's LTV policy for non-primary houses fueled the entire mortgage boom during 2014Q4-2016Q3. The mortgage expansion disproportionately increased the share of mortgages to middle-aged homeowners with high education, while their consumption growth declined persistently. To interpret these empirical findings, we develop a quantitative model and identify that homeowners' trade-up of their primary homes as speculative housing investment is a key channel for a change in LTV policy to exert aggregate and distributional impacts on mortgage markets. Our cross-city evidence provides empirical support for this channel.

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A country's mortgage market is essential to the boom and bust of its housing market. Understanding what drives the mortgage market has profound policy implications on the housing market in general. This paper aims to answer two important open questions about the mortgage market. How does a relaxation of loan-to-value (LTV) policy affect the mortgage boom? And what are the aggregate impacts on the housing market and distributional impacts on households of such a policy change?

There are three challenges to address these questions. The first is to find a case in which there is a large unexpected change in LTV policy. China's recent changes in its LTV policy provide an ideal policy experiment. In 2014Q4, China relaxed its LTV policy until 2016Q3 by lowering the requirement of the minimum downpayment ratio (MDR) for non-primary houses from 60-70% to 30%.[1] The annualized growth rate of average real house prices across the 70 major Chinese cities reported by the National Bureau of Statistics (NBS) increased by 5.94% per annum during the mortgage boom period of 2014Q4-2016Q3.[2] The annual newly issued mortgage amount for theses cities was, on average, 92% higher during 2014Q4-2016Q3 than in 2013. The outstanding mortgage debt nationwide increased from 10.6 trillion RMB in December 2014 to 17.9 trillion RMB in December 2016. At the same time, the growth rate of aggregate consumption began to decline since 2014Q4 and the decline continued even after the loosening of LTV policy was reversed in 2016Q4 (Figure 1).[3] The unexpected nature of such a change in LTV policy and its unprecedented magnitude provide an ideal policy experiment to assess, empirically, how this loosening policy generated the housing boom and how it affected mortgage demands and consumption across households.

The second challenge is to gather granular data about mortgage loans for empirical analysis of distributional impacts. To understand how distributional impacts of a change in LTV policy affected aggregate movements, we exploit three unique micro datasets: (a) a proprietary loan-level mortgage dataset, provided by one of the largest banks in China, that covers all newly issued mortgages over the 70 cities during 2011-2018; (b) the China Household Finance Survey that contains household-level information on consumption, education

[1]The main purpose of this unprecedented policy change was to remove the hurdles for middle-aged high income households to enter the housing market. The 2015 Central Economic Work Conference stated the Chinese government's mandate clearly: "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`)."

[2]Note that 5.94% is an increase of *growth* (not the level) of the *real* house price.

[3]According to Financial Times on February 1, 2019, the slowdown in consumption growth had much to do with "consumption downgrading" by "middle-class Chinese households," which were heavily burdened by mortgage debts (`http://www.ftchinese.com/story/001081321?full=y&ccode=2G178003&archive`).

(income), and various balance-sheet variables (e.g., mortgage loans and house values); and (c) monthly city-level consumption from China UnionPay Merchant Services Corporation.

An unexpected large change in LTV policy and the three micro datasets together help identify the impact of such a policy change on mortgage demands and consumption across households. Our main empirical finding is that a relaxation of China's LTV policy for secondary houses played a crucial role in fueling the entire mortgage boom, including mortgages on primary houses.[4] During the mortgage boom (2014Q4-2016Q3), the share of mortgages newly issued to middle-aged homeowners with high education (incomes) increased significantly in both the origination amount and the origination number, while the share of mortgage newly issued to young households declined. Moreover, cities with high exposure to housing speculations experienced a larger increase in the mortgage share of middle-aged homeowners with high education than did cities with low exposure. The slowdown in growth of aggregate consumption was driven mainly by slow growth of consumption of middle-aged homeowners with high education. Availing themselves of the rapid rise of the house price, these homeowners took out more mortgages to trade up their primary homes than other households. As a result, mortgage loans were reallocated toward middle-aged and highly educated households, who ended up with higher mortgage debts and lower growth of consumption during the mortgage boom than in the pre-boom period.

The literature has taken two different views on the driving force of the mortgage and housing boom: changes in credit supply[5] and changes in expectations.[6] By exploiting the unique micro data and the unique change of LTV policy in China, we provide empirical evidence of important interactions between credit supply and housing speculations in fueling the housing boom. We find that an increase in the LTV limit on secondary houses had significantly positive impacts on mortgage demands by high income homeowners (middle-aged homeowners with high education) because of the expectations of higher house prices in the future. On the other hand, our empirical evidence demonstrates that a reallocation of mortgage credit to middle-aged homeowners with high education (incomes) does not

[4]A secondary house is a non-primary house in addition to the primary house, which can be a second, third, or fourth house, for example. In this paper, we use "secondary house" and "non-primary house" interchangeably.

[5]This line of research, following the seminal work of Mian and Sufi (2009, 2011), argues that changes in credit supply affect mostly the subprime borrowers, especially low income households.

[6]Recent empirical findings that are used to support the expectations view include Foote, Loewenstein and Willen (2016) who find a uniform increase in mortgage debt across income levels during the boom, Albanesi, De Giorgi and Nosal (2017) who show that credit growth between 2001-2007 is concentrated both in the middle and at the top of credit scores, and Adelino, Schoar and Severino (2018) who establish that during the housing boom, mortgage credit was extended to households with different incomes and credit scores.

necessarily stem from changes in expectations of higher house prices as the expectations view states, but from changes in credit conditions.[7]

The third challenge is to interpret our empirical findings with a structural model. There is a growing literature that uses quantitative models to study the role of changes in credit conditions or standards in the housing boom and bust[8] and to understand how various factors affect the house price and consumption across households.[9] We build a life-cycle model with household heterogeneity, which closely relates to this literature. What is new in our model incorporates two institutional facts in China as key ingredients: (i) primary and secondary houses are subject to different MDR requirements, and (ii) households' utility of housing services has two stochastic regimes to capture expectations (beliefs) about the rise of future housing demands. The first ingredient helps isolate the impacts of a change in the LTV limit on the mortgage market via changes in the house price, and the second one allows a significant fraction of middle-aged high income households to be subject to the binding LTV constraint for investment purposes. While the second ingredient draws heavily from earlier work on the housing market (Kaplan, Mitman and Violante, 2020, for example), our model's particular specification is supported by the evidence of cross-city variations in exposures to housing speculations.

We calibrate the key parameters to match various aggregate and disaggregate moments in the data. The model not only is capable of predicting our empirical results but also identifies a new channel for the distributional impacts of a change in LTV policy on the mortgage market. The conventional channel for changes in the LTV limit to influence housing demands is housing tenure decisions of credit-constrained households.[10] Our new channel relies on two key facts: (1) middle-aged wealthy households, with a nontrivial fraction of total housing demands, are constrained for housing investment (rather than housing services); and (2) a reduction of the MDR for secondary houses affects credit conditions of households' primary

[7]Our paper also contributes to the emerging literature on China's housing boom. Empirical papers include Fang, Gu, Xiong and Zhou (2016), Wei, Zhang and Liu (2017), Chen, Liu, Xiong and Zhou (2017), and Gu, He and Qian (2018); theoretical papers include Zhao (2015), Chen and Wen (2017), and Han, Han and Zhu (2018).

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

[9]These factors include monetary policy (Wong, 2016; Beraja, Fuster, Hurst and Vavra, 2018; Eichenbaum, Rebelo and Wong, 2019), heterogeneous expectations (Burnside, Eichenbaum and Rebelo, 2016)), tax policy (Sommer and Sullivan, 2018)), and changes in the payment-to-income requirement (Corbae and Quintin, 2015; Greenwald, 2016).

[10]In a recent paper, Greenwald and Adam (2019) show that the degree to which credit-insensitive agents (e.g., landlords) and credit-sensitive agents (mortgage borrowers) are segmented in housing markets determines the importance of credit conditions in affecting the price-to-rent ratio via housing tenure decisions.

houses only through indirect effects via change in the house price. Capital gains from higher house prices allow existing homeowners to overcome the credit constraint and trade up their existing homes. This new channel emphasizes households' investment motive for mortgage demands and an intertemporal substitution for future consumption. It generates the sizable aggregate impact of a change in LTV policy for secondary houses on the house price, overall mortgage demands, and consumption. We call this channel the investment channel.

In contrast to the existing literature that emphasizes positive wealth effects of the housing boom[11], our model generates an opposite effect of the housing boom on household consumption. Underlying this result is an intertemporal substitution of consumption for illiquid houses and an increasing debt burden borne by middle-aged households with high incomes. We show that the investment channel is important for the house price to have effects on *aggregate* consumption, as consumption of those households constitutes a sizable fraction of aggregate consumption. Because houses are illiquid, moreover, the effects on consumption through the investment channel persist even after the mortgage boom is over. This theoretical prediction is consistent with our empirical finding.

Our welfare analysis shows that an increase in the LTV ratio for secondary houses benefits middle-aged households with high incomes and generates an unintended welfare loss disproportionately born by young households with low incomes, who do not own a house when the policy changes. Higher house prices crowd these households out of the housing market. As a consequence, a relaxation of LTV limits generates a loss of welfare for the overall economy.[12]

The rest of the paper is organized as follows. Section I provides the institutional background of China's LTV policy and its mortgage and housing markets. Section II discuss the three micro datasets used in this paper. Section III provides and discusses the empirical findings of mortgage demands and consumption growth across households during the period when LTV policy was loosened. In Section IV, we build and calibrate a life-cycle equilibrium model with household heterogeneity. In Section V, we use the model to quantify the impacts of a relaxation of LTV policy and those of alternative policies. Section VI concludes the paper.

[11]See, for example, Mian, Rao and Sufi (2013), Berger, Guerrieri, Lorenzoni and Vavra (2017), and Guren, McKay, Nakamura and Steinsson (2018).

[12]There is a strand of literature that highlights the redistributive effects of the house price on incomes. For example, Kiyotaki, Michaelides and Nikolov (2011) argue that net house buyers (such as young workers or tenants) lose and net house sellers (such as retired homeowners) gain from a sharp rise of the house price. Along a similar line, Glover, Heathcote, Krueger and Ríos-Rull (2011) show that young households may benefit from a slump in asset values in the downturn by buying assets at low prices.

I. China's Housing Market and Policy

In this section, we discuss China's housing market and its policy that are pertinent to the subsequent empirical analysis as well as the theoretical framework for interpreting our empirical findings.

I.1. **The housing stock as a store of value.** In China, the availability of financial assets for household savings is very limited: stock markets are poorly regulated and dominated by state owned enterprises (SOEs), the national capital account is severely restricted, and the exchange rate is tightly managed. Under these circumstances, houses have become the most important store of value with an extremely high concentration of housing wealth among most Chinese households. According to our own calculation from the China Household Finance Survey (CHFS) data for urban China, the housing stock comprised 80.4% of households' wealth in 2013, as compared to about 40% for U.S. households. Within the financial asset category (i.e., bar housing wealth), the share of bank deposits was 65.21% in 2013, but the share of financial assets in Chinese households' total wealth was only 8.63%, compared to 37.9% in the U.S.

The land available for home construction is limited by the "red-line lower limit" imposed by Chinese governments for arable land. According to a law passed by the State Council of China in 2008, the amount of cultivated land was 1.818 billion acres in 2010 and remained at 1.805 billion acres in 2020. This red-line lower limit implies a de facto upper bound for the supply of land for real estate construction. Since 1994, the revenues from selling the land have been important revenue sources of local governments. A combination of revenue sources and the upper bound of the land for real estate constructions has given local governments a strong incentive to limit the supply of land to boost the land price.

The use of housing as a store of value, together with the limited supply of land, has created speculative investment demands for houses. In 2013, for instance, around 15% of urban Chinese households owned a second home as an investment. The ratio of house value to income (price-to-income ratio) is much higher than the developed economies. According to Fang, Gu, Xiong and Zhou (2016), the price-to-income ratio for the bottom income group has been sustainably above 8. For the middle income group, the ratio reached a level above 6 in 2012. By contrast, the price-to-income ratio for the U.S. was only around 3 during and after the housing bubble that peaked in 2006.

In recent years, the vacancy rate of houses of urban homeowners in China has been persistently high. According to our own calculation from the CHFS data, the average housing vacancy rates remained stabe around 20% during 2011-2017 among 35 major cities. The housing vacancy rate for secondary houses was even higher (e.g., 42.06% in 2017). Chen and

Wen (2017) show that underlying the fast price-to-income growth and the high vacancy rate in urban China were speculative demands of houses.

I.2. **Mortgage market and housing policy.** Since 1998, China's mortgage markets have developed rapidly. In 2013, for instance, the share of residential mortgage loans in total consumer loans was 69.4% and the share in medium and long term (MLT) consumer loans was 87.4%. All residential mortgage loans in China are for home purchases. Unlike in the U.S., Chinese households cannot use home equity to obtain a line of credit for consumption and neither can they refinance their original mortgage debts to use a cash-out refinance for consumption. Moreover, there is no secondary market for mortgage loans through securitization (e.g., via mortgage-backed securities).[13] As a result, the maximum LTV ratio that an individual bank can offer closely follows the government's LTV policy.

LTV policy has been an effective tool used by the Chinese government to influence housing demands. It has two separate components: the minimum downpayment for financing (1) the primary home and (2) a second house or additional houses. In 2008, as part of the economic stimulus package, the government reduced the MDR from 30% to 20% for financing the primary home and from 40% to 20% for financing a second house or more houses. In January 2010, to curtail speculative housing demands, the government reversed its previous LTV policy by raising the MDR to 30% for financing the primary home that had more than 90 square meters and to 50% for financing a secondary house. In January 2011, the government further increased the MDR for financing a second house to 60% and prohibited commercial banks from making mortgage loans to any household who would finance houses beyond the first two houses.

To boost housing demands again, China relaxed its LTV policy from 2014Q4 to 2016Q3 by reducing the MDR for financing secondary houses from 60-70% to 30%.[14] Since 2016Q4, however, LTV policy has been tightened again. In 2016Q4, local governments in 20 cities (most of them were first and second tier cities) tightened their LTV policy by increasing the MDR for financing a secondary house from 30% to 70%.[15] By June 2017, local governments in

[13]The reverse mortgage market did not exist until 2014 when the Chinese government launched a two-year pilot program for reverse mortgages introduced by a life insurance company. This pilot program, however, proved to be unpopular in China. By July 2017, only 65 households participated in the program nationwide (Fang and Feng, 2018).

[14]During this period, the downpayment requirement for financing the primary house was reduced only from 30% to 25% on August 27, 2015. Since this change was marginal relative to the MDR change for secondary houses, our paper focuses on LTV policy on secondary houses.

[15]The MDR for financing primary houses reverted back to 30%.

44 cities across China followed suit by tightening their LTV policy, especially on a secondary house.

II. Data

II.1. **Data description.** We use three unique micro datasets for our empirical work. The first is a proprietary loan-level dataset for mortgage originations in one of the largest Chinese commercial banks (we call the Bank Loan Data in the rest of this paper). The outstanding mortgage loans issued by this bank have remained around 14% of total outstanding mortgage loans in China since 2011. Our data contains all residential mortgage loans newly originated by this bank from 2011Q1 to 2018Q2. It comprises more than 3.2 million mortgage loans, covering 70 cities that correspond to the city sample used by the NBS to construct their standard 70-city housing price index. The most important information contained in the dataset relates to whether a particular mortgage is issued for the borrower's primary or secondary house. This crucial information allows us to distinguish direct and indirect effects of a change in the LTV limit on demands for mortgage financing. The dataset also contains information about each homebuyer's characteristics, including age, gender, occupation, education, self-reported income, number of houses, city, zip code, and credit score.[16]

The second dataset is the CHFS, conducted by Southwestern University of Finance and Economics every two years since 2011 (Gan, Yin, Jia, Xu, Ma and Zheng, 2014). The inaugural 2011 survey interviewed about 9,000 households; since then, the number of households interviewed has increased steadily in each subsequent survey. The 2013 survey sample, for example, includes 19,181 urban households. Within each survey, a subset of households were repeatedly interviewed, which allows us to calculate consumption growth at the household level. This dataset is the most comprehensive source of household data on wealth, consumption, and income in China. It has a clear advantage over traditional data on household spending in the United States and the United Kingdom, such as Consumer Expenditure Survey (CEX), Survey of Consumer Finance (SCF), and Living Costs and Food Survey (LCFS), because it contains disaggregate information of both household balance sheets (including wealth) and a rich array of household expenditures. We use these two pieces of information to establish an empirical linkage between the ratio of household mortgage debt to household income and its consumption growth, a key result for this paper.

The third dataset contains monthly city-level consumption from China UnionPay Merchant Services Corporation (we call China UnionPay in the rest of this paper), which is

[16]We do not use the information of self-reported incomes as they are very unreliable.

China's largest bankcard supplier of acquiring and professional services. Monthly consumption in each city is calculated as the sum of all consumed expenses through UnionPay Point-of-Sale (POS) machines from 2013M7 to 2017M10. China UnionPay offers services to 8 million offline merchants in various offline spending categories, such as groceries, restaurants, hotels, transportation, finance, and health care. In 2017, China UnionPay recorded 7.26 billion transactions, with a transaction volume of 28.6 trillion RMB. The dataset covers 330 prefecture-level cities or regions in China. To merge with the other two datasets, our analysis uses consumption in the NBS's 70 cities.

II.2. **Summary statistics.** Table 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 college degree and above was smaller for primary houses than for secondary houses (47% versus 62%). This observation implies that borrowers for secondary houses were, on average, wealthier than those for primary homes. The average house size and value were larger for secondary houses 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 for secondary houses (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 for secondary houses was shorter than that for primary houses.

The average LTV ratio when mortgages for primary houses were originated was higher than that for secondary houses (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 for secondary houses (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 for secondary houses had on average higher incomes than those for primary houses.[17]

[17]In this paper, DTI is mortgage DTI unless stated otherwise.

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 of 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 mortgage 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 for secondary houses 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 for secondary houses fell by more than 2% from 7.40% to 5.20% and the share of mortgage loan amount (number) for secondary houses increased from 5.2% to about 11% (8%).

Table 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 dataset includes only households with new mortgages, the CHFS dataset 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 mortgage. This inclusion is necessary to account for both extensive and intensive margins in our regression analysis in the later part of this paper.

In this dataset, (non-housing) consumption is the sum of household expenses on food, utility, daily necessities, transportation and travel, entertainment, education, and durable goods. The average household consumption fell between the 2015 and 2017 surveys (55,400 RMB versus 54,280 RMB), despite an increase in the average household income. The outstanding mortgage debt, on the other hand, 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 homeownership rate increased from 86% in 2013 to 89.26% in 2015 and then fell slightly to 88.09% in 2017.

III. Empirical findings

We begin with an analysis of how newly originated mortgage loans and consumption growth changed during the period when LTV policy was relaxed. We provide this analysis at both aggregate and disaggregate levels. We then establish an empirical linkage between mortgage debt and consumption growth at a granular level of households.

III.1. **Mortgage.**

In this subsection, we provide detailed results about age profile and other characteristics of mortgage loans from our granular loan data.

III.1.1. *LTV ratios.* Figure 2 reports the age profile of average LTV ratios across years when mortgage loans were originated (at origination). The three years, 2011, 2013 and 2015, are chosen to highlight changes of the age profile that were potentially attributable to changes in LTV policy. The first two years are prior to the policy changes and the third year is during the period when LTV policy was relaxed. The left and right panels plot the age profile of LTV ratios for primary and secondary houses. The LTV ratio for primary houses in three years peaked at age 30 (left panel). More important, LTV ratios for primary houses across these three years were close to one another, consistent with the fact that the relaxation of LTV policy affected mostly the leverage of secondary houses during the boom.[18] The age profile of LTV ratios for secondary houses differs significantly from that for the primary house in several aspects (right panel). First, the levels of LTV ratios were smaller in magnitude than those for primary houses in all three years, and were close in magnitude to the maximum value stipulated by LTV policies in these years. Second, the age profile of LTV ratios sprang up from a level below 40% in 2013 to a level above 55% in 2015, as the maximum downpayment ratio for a secondary house was reduced from 60-70% to 40% in March 2015 (and further to 30% in February 2016). The relaxation of LTV policy allowed homeowners who purchased secondary houses to increase their leverage substantially.

To show the extent to which LTV constraints of households are binding, we calculate the distribution of LTV ratios over time for primary and secondary houses separately (Figure 3). For visual clarity, we report the distribution of LTV ratios across four quantiles of households: the 90th, 75th, 50th, and 25th percentiles. For the primary home, except for households in

[18]Recent empirical studies on the U.S. housing booms and busts find very small changes in the LTV ratio at origination over the boom and bust cycle across the whole distribution of LTV ratios. See, for example, Adelino, Schoar and Severino (2018).

the bottom 25th percentile, the LTV ratios for all households were close to the maximum value allowed by LTV policy.[19] For secondary houses, LTV ratios were below or at the maximum value allowed by LTV policy prior to its relaxation (40%). Following the relaxation of LTV policy for secondary houses in 2014Q4, LTV ratios for all quantiles of households sprang up substantially.[20] A relaxation of the LTV constraint on second houses allowed households to borrow more against the values of secondary houses as investment.

One of our key findings is that a relaxation of LTV constraint on secondary houses had significant spillover impacts on the dynamics of mortgage loans for primary houses. Figure 4 reports the dynamics of mortgage loans and financial burdens of households for primary homes versus all houses. The time series of mortgage loans for both primary homes and all houses, aggregated from our loan-level data, tracked each other very closely prior the relaxation of LTV policy (top panels of Figure 4). The two series began to diverge when LTV policy was relaxed in 2014Q4, with an increasing share of mortgage loans for secondary houses due to the direct effect of LTV policy on secondary houses. As shown in top panels for both loan amount and number of originations, the sharp increase in aggregate mortgage loans during the boom period was mainly attributable to the increase of mortgage loans for primary home. A relaxation of LTV policy for secondary houses, therefore, had large spillover effects on mortgage demands for primary houses.[21]

We find a similar pattern in the dynamics of households' financial burdens at origination. Prior to the relaxation of LTV policy, the ratio of mortgage debt to income (DTI) was below 4. During the mortgage boom after this policy relaxation, the DTI ratio increased steadily to about 4.5 in 2016Q3 (top left panel of Figure 4). In comparison, during the U.S. housing boom in 2001-2006, even households in the lowest income quantile had the DTI ratio below 3.50 (Adelino, Schoar and Severino, 2016). The bottom right panel reports the ratio of house

[19]The maximum LTV allowed was 70% prior to the LTV policy change and 75% after the policy change with some exceptions. The most important exception was for households with primary houses less than 90 square meters *and* were qualified for the Housing Provident Fund Loans designed by the Chinese government to help low income households meet their housing needs. These households were allowed to have the MDR lower than 25%.

[20]The maximum LTV allowed for secondary houses was 70% with one exception. Homeowners who had paid in full the mortgages on their primary homes qualified for mortgage loans with the MDR below 30%. After 2016Q3, local governments tightened LTV policy, especially for secondary houses. There was, however, no uniform policy change mandated by the central government, and there were varying degrees and timings of the tightening across cities. Nonetheless, LTV ratios for primary houses and especially for secondary houses fell gradually after 2016Q3 (Figure 3).

[21]As discussed in Section I, the change in the LTV constraint on primary homes during this period was marginal relative to the change in LTV policy on secondary houses.

value to income (HVTI) over time. Prior to the LTV policy change, the HVTI ratio was 6.2 for households with only primary homes and with secondary houses. During the housing boom after the relaxation of LTV policy, the HVTI ratio increased steadily to a level of 6.75 in 2016Q3. The steady increase of DTI and HVTI ratios indicates homeowners' increasingly heavy financial burdens since the housing boom.[22]

III.1.2. *Mortgage loans across ages and across education levels.* Another important empirical finding relates to the distribution of mortgage loans across ages. We calculate the age profile of mortgage loans in 2011, 2013, and 2015 for both the amount of loans and the number of loan originations. Top panels of Figure 5 report the share of mortgage loans for each age group in the total loan amount as well as the total number of originations for all ages. The age profiles of these shares were hump-shaped. The age profiles for 2011 and 2013 were very similar, and households of ages 25-30 had the highest share (more than 20%). In 2015, the age profile shifted to the right: the share for households of ages 30-40 (middle-age households) increased significantly, whereas the share for households of ages 20-30 (young households) declined. This distributional shift holds for both the amount of mortgage loans and number of originations.

To understand the role of extensive margins in household indebtedness, we calculate the age profile of the DTI ratio and a fraction of households with positive mortgage debts in all households including those without mortgages (a mortgage participation rate). The age profiles between 2011 and 2013 were similar and hump shaped with peaks at age 30 (bottom left panel of Figure 5). The peak age is consistent with top panels of Figure 5. From 2013 to 2015, however, the DTI ratio for households of ages 30-65 increased significantly. This increase was attributable to a combination of an increase in the mortgage participation rate (extensive margin) and a higher DTI ratio for those households who had outstanding mortgage debts prior to the housing boom (intensive margin). As the bottom panels show, the age profile of mortgage participation rates was similar to the age profile of DTI ratios. Extensive margins in the age profile of DTI ratios for households of ages 30-50 were important as the mortgage participation rate for these households increased most (bottom right panel).

We summarize all these findings by classifying households into three age groups: those of ages below 30 as young households, of ages 30-49 as middle-aged households, and of ages 50 and above as old households. This classification is consistent with the age profile of mortgage loans prior to the relaxation of LTV policy, which peaked at age 30. We then classify households into a high-education group and a low-education group: those with college

[22]As LTV policy was tightened again after 2016Q3, however, the total amount of mortgage loans, the number of mortgage originations, and the DTI ratio reversed their upward trends.

degree and above as a proxy for a high income group and with high school diploma and below as a proxy for a low income group.[23]

Table 3 reports mortgage shares across age-education groups in 2013, the year prior to the relaxation of LTV policy. The mortgage loan amount for all houses was more or less evenly distributed among middle-aged households with high education, middle-aged households with low education, and young households with high education, all of which were above 25% (panel A). Panel B exhibits a similar pattern for primary houses, implying that the distribution of mortgage loan amounts across age-education groups was mainly driven by the distribution for primary houses. For the number of originations, middle-aged households with low education had the largest share (above 33%), followed by young and middle-aged households with high education (panels C and D).

We find that a loosening of LTV policy after 2013 redistributed mortgage loans across age-education groups. In particular, middle-aged households with high education were the only age-education group whose mortgage share increased substantially, by 13.32% in the loan amount and by 8.07% in the number of originations (panels A and C of Table 4). By contrast, the mortgage shares of age-education groups other than old highly-educated households, especially middle-aged households with low education and young households with high education, declined substantially. Although the maximum LTV ratio barely changed for primary houses, this reallocation was mainly driven by the reallocation of mortgage credit to primary houses, as shown in panels B and D of Table 4.

What drove the increase in the mortgage share of middle-aged households with high education, especially in their primary houses? Figure 6 provides a quantitative answer. It reports the age profile of the average value of newly purchased houses with mortgages in 2011, 2013 and 2015. The average house value of each household in a particular year was scaled by the constant-quality house price index of the city where the household resided at the time during that year when the mortgage was originated. For a given age of the household, therefore, changes in the average house value captured an increase in the average house size or the quality of the average house for households of that age.

Between 2011 and 2013, the average house value increased across households of different ages with low education in similar magnitude (left panel of Figure 6). This pattern holds for the increase of the average house value for households with high education (right panel of Figure 6). Between 2013 and 2015 after the relaxation of LTV policy, however, the average house value for households of age 30-55 with high education increased by about 20%, significantly higher than the increase of the average house value for young households

[23]Unlike the education data in the CHFS, the income series reported in the Bank Loan Data were fragmentary and unreliable.

with high education and those whose age was 60 and above. This asymmetric increase of the average house value between 2013 and 2015 is not true for households with low education, implying that a disproportionate fraction of middle-aged households with high education traded up their primary homes during the mortgage boom. In Section IV, we build a life-cycle model to help interpret these novel findings from our granular data.

Summary. We find that a loosening of LTV policy for secondary houses had spillover effects on mortgage loans for primary homes. The share of mortgages to primary homes of middle-aged households with high education increased significantly during the mortgage boom. At the same time, the share of mortgages to primary homes of other age-education groups, especially of young households with high education, declined. Underlying the increase of mortgage demands by middle-aged households with high education was the fact that these households traded up their existing homes with an increased burden of their mortgage debt.

III.2. **Consumption growth.** In this section, we first use the CHFS data to provide a descriptive analysis of changes in consumption growth during the mortgage boom across households of different ages and education levels. We then establish an empirical linkage between households' consumption growth and their mortgage debt burden by controlling for various household characteristics.

III.2.1. *Consumption across ages and across education levels.* We now explore the impacts of LTV policy on consumption growth across ages and across education levels. Table 5 reports the results for two periods: 2013-2015 survey years (prior to the relaxation of LTV policy) and 2015–2017 survey years (during the relaxation of LTV policy).[24] For each panel in this table, we also report (surveyed) income growth in each of the two periods to control for its effects on changes of consumption growth within each period. Consistent with Figure 1, consumption growth during 2015-2017 is slower than its counterpart during 2013-2015, despite faster income growth during the second period (panel A).

The main factor attributed to this slowdown in aggregate or average consumption during the housing boom (the second period) is slower consumption growth of middle-aged households. Despite their faster income growth in 2015-2017, middle-aged households experienced a decline of 2% (annualized) in consumption growth from the first period to the second period, whereas consumption growth of the other two age groups either increased or remained almost the same (panel B). A further analysis finds a significant decline of consumption growth both statistically and in magnitude (3.59% per year) in middle-aged households with

[24]In the CHFS, the questionnaire for household consumption is about expenditures that occur during the previous year of each survey. For instance, 2017 in this table indicates consumption in 2016.

high education (panel C). This finding is in contrast to an insignificant change in consumption growth of middle-aged households with low education. Clearly, as shown in panel C of Table 5, the consumption slowdown of middle-aged households with high education in 2015-2017 was not due to a slowdown of income growth, as their income actually grew from 2013-2015 to 2015-2017.

Since the observed decline of consumption growth in middle-aged households with high education was not associated with their income growth, we now analyze whether this decline was related to these households' housing demands and their mortgage debt burdens.[25] We calculate consumption growth for two subgroups of households in the CHFS sample: homeowners and renters. If housing demands and mortgage debt burdens are the key to understanding a consumption slowdown, we should observe this slowdown for homeowners, not for renters. As shown in panel A of Tables 6 and 7, we find a significant slowdown in consumption growth between 2013-2015 and 2015-2017 for homeowners, but not for renters. For homeowners, average consumption growth fell by 1.23% between these two subperiods; for renters, it increased by 3.32%. These findings remain true especially for middle-aged households: average consumption growth fell by 2.62% for homeowners but increased by 4.39% for renters (panel B of Tables 6 and 7). Moreover, consumption growth of middle-aged homeowners with high education fell by 3.61% even though their incomes increased by 5.25%, while there was no statistically significant evidence of a decline in consumption growth and of an increase in income growth for the same age-education group of renters (panel C of Tables 6 and 7).

In short, during the mortgage boom, middle-aged households with high education experienced a significant increase of their mortgage share but a decline of consumption growth. The observed slowdown in average consumption growth was driven entirely by a slowdown in consumption growth of middle-aged homeowners, especially those with high education, but not of renters. This observation holds despite the fact that middle-aged homeowners experienced faster income growth in 2015-2017 than in 2013-2015 (survey years).

III.2.2. *Consumption growth and mortgage debt burden.* In this subsection, we establish an empirical linkage between consumption growth and mortgage debt burden by quantifying the effects of mortgage debt burden on households' consumption growth with both extensive and intensive margins. Along the extensive margin, we regress consumption growth on a mortgage dummy equal to 1 if the household had a mortgage debt and 0 otherwise. Along the intensive margin, we use a subsample of households who had positive mortgage debts, and

[25]We show in Section V.4 that housing demands were driven most by speculative motives for investment, rather than by housing services, even for households with only primary houses.

regress consumption growth on the ratio of outstanding mortgage debt to income. Because households with mortgage debts or with a higher ratio of mortgage debt to income were more financially burdened by mortgage payments and thus less cash on hand than other households, our main control variable is income growth.[26]

Table 8 presents these regression results. Households with mortgage debts had, on average, slower consumption growth than households without mortgage debts by 2.66% (column (1)). If households' DTI ratio increased by one, their consumption growth rate would fall by 0.27% (column (2). In both regressions, the estimated coefficients are statistically significant. These empirical findings imply that an increase in the mortgage share of middle-aged households with high education during the period when LTV policy was relaxed contributed to a significant slowdown of their consumption growth by making them more financially burdened with mortgage debts.

In the next section, we use a theoretical model to explain our empirical findings. The model aims at answering the following three questions: Why did middle-aged households with high education, rather than other households, respond to the relaxation of LTV policy by demanding more mortgage loans? How did the relaxation of LTV policy on secondary houses fuel the demands of these households for primary houses? Why did consumption growth of these households fall while their demands for mortgage loans increased?

IV. A model with LTV constraint on housing investment

In this section, we develop a dynamic equilibrium model to interpret the empirical facts we find in Section III. To this end, therefore, the model has two key ingredients: (i) primary and secondary houses that are subject to different MDR requirements and (ii) households' housing service utility that has two stochastic regimes to capture beliefs about future housing demands. These ingredients are based on China's unique institutional facts.

We begin with the household's problem and then introduce the rental and production sectors into the model economy. The model is calibrated to match both aggregate and cross-sectional moments of the Chinese economy. The technical details of how to formulate the household problem recursively, as well as the definition of the equilibrium, are contained in Appendices A and B. Appendix C provides details of how to solve the model numerically.

IV.1. **Households.**

We first describe the economic environment for households in our model and then specify the household decision each period.

[26]Control variables for both regressions include age, age squared (controlling for nonlinearity), an education dummy, and growth of family size.

IV.1.1. *The environment.* The economy is populated by a continuum of overlapping generations of households whose life cycle is divided between work and retirement. Each household lives multiple periods, age is indexed by $j = 1, 2, \ldots, J$, and the household retires at age J^{ret}. All households die with certainty after age J.

The household's expected lifetime utility is

$$E_0 \left[\sum_{j=1}^{J} \beta^{j-1} u_j \left(c_j, s_j; \phi \right) + \beta^J v(\mathfrak{b}) \right],$$

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

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

where γ determines the elasticity of substitution between non-housing consumption and housing services and and σ the relative risk aversion. The housing utility weight ϕ determines the share of housing services in total consumption. It is a stochastic variable common for all households, capturing the common belief about aggregate housing demands in the future. We assume a two-state Markov process for $\phi \in \{\phi^L, \phi^H\}$ with the transition probability matrix

$$\Pi = \begin{bmatrix} 1 - \Pi_{lh} & \Pi_{lh} \\ 0 & 1 \end{bmatrix}.$$

From the state of a low housing preference, there is a probability Π_{lh} that the low housing preference moves into the state of a high housing preference and stays in that state.[27] The stochastic belief about future housing demands can be interpreted as anticipated higher future demands for urban housing due to the relaxation of China's unique policy on urbanization known as the "Hukou" restriction.[28] A high housing preference is an absorbing state because it captures the institutional fact that once the Hukou restriction was eased, the relaxation would not be reversed.

To evaluate the impact of a policy change, we assume that each household is endowed with a low housing preference (ϕ_L) in the initial state and stays in that state after housing policy is relaxed. Since a preference change is not realized, this stochastic housing preference

[27]Our belief modeling follows Kaplan, Mitman and Violante (2020). Unlike their paper, however, the trigger for the housing boom in our model is a change in mortgage policy instead of an exogenous change in belief about housing demands in the future.

[28]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, there have been about 15 million new people entering urban areas every year.

captures a belief about higher housing demands in the future. This modeling approach shares some key features of a rational bubble, but unlike the rational bubble literature it allows for the utility of housing services. In the stochastic steady state in which the house price is constant, households always demand speculative investment in houses because of a positive probability of switching to the state of higher housing demands with higher house prices.

We introduce a warm-glow bequest motive into the model to capture the reality in China that old people tend to give houses to their children or grandchildren as a bequest. This bequest takes the functional form

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

where the parameter φ reflects the strength of a bequest motive.

At birth, households are ex-ante heterogeneous in their endowment of permanent (lifetime) labor ability, denoted by a binary variable η_k with $k \in \{L, H\}$, where L stands for low ability and H high ability. Working age households are subject to uninsurable idiosyncratic shocks to their efficiency of labor, denoted by ϵ that 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.[29] When a household retires, it receives a pension benefit each period equal to a fraction ξ of the income in the last period of working age, denoted as $y = \xi y^{\text{ret}}$.

The household enjoys housing services by either renting a house at the rental rate ρ_h or buying a house at the price p_h. The size of a purchased or rented house is modelled discretely. For a purchased house, the size h belongs to a set $\mathcal{H}$; for a rented house, the size $\tilde{h}$ belongs to a set $\widetilde{\mathcal{H}}$.[30]

Rental markets in China are underdeveloped because of various institutional frictions. Home ownership has clear advantages over renting in several respects. First, homeownership gives the homeowner's children a top priority over a residential lease to gain access to a high-quality school district in which the purchased house is located. Second, incomplete laws of leasing houses do not safeguard tenants' lawful rights and interests. According to a 2017 survey of 5000 young adults about their housing status conducted by the Beijing government, one-third of the surveyed adults were evicted by landlords, 41.3% experienced rent increases

[29]Since our model abstracts from the government budget, a household's labor income in our model should be interpreted as labor income after tax payments and government transfers.

[30]Although our micro datasets do not have information about the quality of a house financed by a mortgage, we do have information about the house value. After controlling for an increase of the house price, an increase of the house value captures an increase of size or quality or both. In the model, therefore, we assume that different house sizes reflect differences not only in physical size but also in quality. For tractability, we do not distinguish physical size and quality in the model.

that violated the lease agreement or contract, and 43.8% had to deal with rental agencies that were not creditworthy. Third, owning a house has increasingly become a prerequisite for a male to marry a female because of the unbalanced sex ratio in China. According to Wei, Zhang and Liu (2017), the unbalanced sex ratio helps explain rapid increases in house prices.

All these institutional facts reflect China's rental market frictions, which have contributed to high rates of homeownership among Chinese households, especially among those below age 30. In 2013, the homeownership rate in China was 86%, compared to 65% in the U.S. In particular, China has the highest homeownership rate among young households (reaching 66% in 2013), as compared to only 35% for the U.S. and 31% for the UK.

To capture these rental market frictions in our model in a tractable way, we assume that renting generates services less than the size of the rented house, i.e. $s = \omega \tilde{h}'$ with $0 < \omega < 1$.[31] Both rented and owned houses depreciate at a rate of δ_h. When a household sells its home, it incurs a transaction cost $\kappa_h p_h h$, which is proportional to the house value. When a household sells its home or purchases a new house, there is a fixed cost κ_j that is age-dependent, where j denotes the household's age (i.e., the age of the head of the household in the CHFS). This age-dependent cost reflects two factors in China: the reluctance for the old people to move to a new neighborhood (the cultural factor) and the difficulty of obtaining mortgage loans by the old people (the legal factor).[32]

Households can purchase multiple houses with the total housing size h. There is an upper bound on the size of the first house, denoted by $\hat{h}$, such that $s = \min\{h, \hat{h}\}$. The rest of h, $\max\{0, h - \hat{h}\}$, is the size of a secondary house. A secondary house provides no utility to the homeowner. Homeowners do not rent out their secondary houses but hold them purely for the purpose of possible capital gains in the future. This assumption is consistent with China's institutional facts. China does not have a credit score system for individual households such as FICO and Equifax in the U.S. As a result, it is difficult for the landlord to identify potentially good tenants and effectively protect the landlord against defaults on rental payments. More important is the fact that the rent-to-price ratio has long remained low. In 2013, for instance, the average rent-to-price ratio for residential housing in first tier cities was around 2.4%, while the benchmark deposit rate was 3% and the benchmark lending rate was 6% during the same period. Such a low rent-to-price ratio discourages homeowners

[31]Following the standard notation, the superscript prime in $\tilde{h}'$ indicates the current period and $\tilde{h}$ without the superscript prime indicates the last period. This notational convention applies to other housing-related variables as well.

[32]The longest mortgage term in China is 30 years. A borrower of age 50, for example, is not permitted to obtain a 30-year mortgage loan and must pay a high cost to get a shorter term mortgage loan.

from leasing their secondary houses and encourages them to hold these empty houses for investment purposes.

Households can finance the purchase of both primary and secondary houses by mortgage if their age is less than J^M (corresponding to age 65 in China).[33] The maximum LTV ratios at origination for these two types of houses, denoted as λ_1 and λ_2, are different. At the time of origination, the borrower is subject to the maximum LTV ratio constraint $m' \leq \lambda_m(h')p_h h'$, where m' is the amount of mortgage in the current period and $\lambda_m(h')$ is defined as

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

All mortgages are subject to a fixed origination cost, denoted by κ_m. The minimum mortgage payment in each period, denoted by π_m, follows a constant amortization schedule during the remaining lifetime such that

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

where r_m is the mortgage interest rate and π is an actual mortgage payment. The outstanding principle evolves according to $m' = (1+r_m)m - \pi$. Consistent with China's institutional facts, we assume that the mortgage, once originated, cannot be refinanced and there is no mortgage default.

In addition to houses as a financial asset, the household can own a one-period risk-free government bond, denoted by b, at an exogenous price q_b. The interest rate is $r_b = 1/q_b - 1$. The household cannot borrow by short selling its houses. That is, homeowners have no access to a home equity line of credit in our model (another institutional fact of China).

In each period, a household's idiosyncratic state is represented by the vector $\chi = (b, m, h, y)$. Let $\mu \equiv \mu(\chi)$ be a probability measure of households indexed by the idiosyncratic state χ and let $\Omega = (\phi, \mu)$ represent the aggregate state. We solve the household problem in two steps. First, we solve for the household tenure decision (e.g., buying or renting a house). Second, conditional on this decision, the household chooses the size of a house to purchase or rent, along with its choice of consumption and savings in non-housing financial assets.

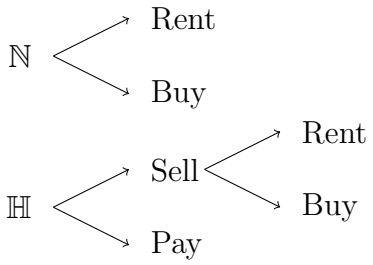
IV.1.2. *The household decision.* At the beginning of each period, a household with no house chooses between renting and buying a house, and a household that owns a house chooses between selling its house and keeping it while making mortgage payments. If the household sells the house, it then needs to choose between buying and renting a new house. Diagram 1,

[33] In China, mortgage borrowers are required to be between 18 and 65 years of age.

below, summarizes the housing state at the beginning of the period and the housing tenure decision choice during the period.

Diagram 1: Initial state and housing tenure decision during the period[34]

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



In the decision tree, we rule out the possibility that a household purchases a house and at the same time rents another house so that the housing decision is lumpy, depending on costs and benefits of owning a house. The cost is a downpayment; the benefits are as follows: (1) it generates more utility from housing services than renting a house and (2) it allows the household to enjoy potential capital gains with expected returns much higher than investing in risk-free assets.

Homeowners have the option of keeping their houses or changing their housing positions. In the model, a homeowner with an idiosyncratic shock that leads to high labor incomes is likely to upsize her house for investment purposes, while a homeowner with an idiosyncratic shock that leads to low labor incomes is likely to downsize her house or become a renter to smooth consumption. In the stochastic steady state, therefore, there are always demands for newly originated mortgages demand and a positive fraction of households trading up their primary houses.

IV.2. **The rental sector.** In each period, the representative rental company purchases houses and rents them to renters with an operating cost ψ for each housing unit. The problem of the representative rental company is

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

[34]The symbols $\mathbb{S}$, $\mathbb{P}$, $\mathbb{R}$, $\mathbb{B}$ are used as superscripts for various value functions in the recursive household problem described in Appendix A.

where $\rho_h(\Omega)$ is the rental price. The zero profit condition gives 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 the sum of the operating cost and the user cost. The parameters in this rental sector are calibrated to target China's high homeownership for young households in the data, which in turn is important for our welfare analysis.

For advanced economies such as the U.S., a traditional channel for a change in the LTV ratio to influence the housing price is through housing tenure decisions. An increase of the LTV ratio, for instance, would simultaneously reduce demands of houses for rent and increase demands of owner-occupied houses. The response of house prices, as discussed in Greenwald and Adam (2019), depends on how costly it is for the landlord (the rental company in our model) to convert rentals into owner-occupied houses. This mechanism is absent in our model for the following reasons. First, a change in the LTV ratio for secondary houses does not have a *direct* effect on a household's housing tenure decision (except for the house price in equilibrium) or on demands for homeownership. Thus, it does not influence the rental company's available stock of rentals that it could convert to owner-occupied houses. The increasing demand for owner-occupied houses in our model, which we show later in the paper, stems largely from trading up the existing (primary) homes; this demand is largely met by new houses supplied by real estate developers. Only through changes in the house price does a change in the LTV limit on secondary houses influence households' demands for homeownership. Even if we allow households to rent out their secondary homes as in the traditional model, a change in the LTV ratio for secondary houses does not shift the demand curve describing the relationship between the house price and the homeownership rate, which makes the house price insensitive to the supply elasticity of owner-occupied houses. Households' housing tenure decisions, therefore, are not the main channel for a change in the LTV limit on secondary houses to drive housing demands and thus the house price.

For all these reasons, we assume that households with more than one house do not have the option to rent their secondary houses. This assumption is also consistent with various frictions on the supply side of China's rental market: the absence of a credit score system on potential tenants, the lack of laws to penalize the tenant for the delay or delinquency of rental payments, and no property tax. These institutional arrangements discourage homeowners from renting their secondary houses.

IV.3. **Production sectors.** Following Kaplan, Mitman and Violante (2020), there are two production sectors in the economy: 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 are endowed with a technology with constant returns to scale in labor:

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

where Y is aggregate output, Θ the aggregate labor productivity, and N_c 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, and these permits are 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 according to 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 aggregate efficiency labor employed in the construction sector. The Cobb-Douglas technology implies that the developer makes zero profit in equilibrium. The investment function follows from the first-order condition with respect to N_h and the equilibrium condition $w = \Theta$:

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

IV.4. **Calibration.** We calibrate the model to match the key aggregate and cross-sectional moments prior to the loosening of LTV policy in 2014Q4. Given the fact that the CHFS is conducted every two years, we use the year 2013 to calculate these moments for the initial steady state of the model, which maps into the Chinese economy prior to a change in LTV policy in 2014Q4.[35] The calibrated parameter values are summarized in Table 9 and a comparison of the targeted moments between the model and the data in Table 10.

There are two sets of parameters in our model. A first set of parameters are assigned externally, whose values are taken from the existing literature. The other set of parameters are calibrated to the key moments in the data.

Demography. A period in our model corresponds to a two-year horizon. Households enter the economy at age 20, work until age 55 (corresponding to $J^{\text{ret}} = 19$), and live until age

[35]When some data in 2013 are not available, we use the data in 2012 or earlier.

76, the average life expectancy in China (corresponding to $J = 29$). Households with high (low) labor ability in our model correspond to households with college degree and above (high school diploma and below) in the data. The fraction of households with high labor ability is calibrated to match the fraction of households with college degree and above in the CHFS. In the rest of the paper, therefore, we refer to households with high labor ability in our model as households with high education to be compatible with the data.

Preference. The key preference parameter in our model is the transition probability Π_{lh}, which governs the magnitude of the speculation incentive. We choose its value to target the average value of exposures to housing speculations, measured across 70 cities in the data: the share of the mortgage amount for secondary houses in the total mortgage amount in 2013, which is about 5%. A higher value of Π_{lh} would lead to a higher steady-state share of the mortgage amount for secondary houses in the total mortgage amount for speculative investment purposes. This share is proposed by Gao et al. (2020) to measure a region's exposure to housing speculations in the U.S. In Section V.4, our cross-city empirical evidence shows that this share is more relevant to China as a measure of a city's exposure to housing speculations, mainly because most non-primary houses were used for investment, not as vacation homes. The housing preference parameter in the low state, ϕ_L, is chosen so that the average share of housing services in total expenditures is 0.2 in the stochastic steady state, consistent with the weight used in the official consumer price index (CPI) basket in China. We choose ϕ_H to target the homeownership rate (14.6%) of secondary houses in 2013.

We follow Piazzesi, Schneider and Tuzel (2007) and set $1/\gamma$, the elasticity of substitution between non-housing consumption and housing services, at 1.25. The risk aversion parameter, σ, is set to 2, which is also standard in the literature. The utility discount factor β is calibrated to target the average ratio of wealth to labor income in 2012, which is 9.2 as estimated in Xie and Jin (2015) using the China Family Panel Studies (CFPS) data. The utility discount parameter for renting, ω, is calibrated as 0.50 to target the average homeownership rate of China in 2013 (86%). The parameter for bequest motives, φ, is calibrated to target the ratio of net worth of households in age 75 to net worth of those in age 55.

Labor endowment. The age profile of labor efficiency units is the same as He, Ning and Zhu (2017), who estimate the profile using the data in the China Health and Nutrition Survey (CHNS). The process of an idiosyncratic labor income shock, ϵ, is specified as an AR(1) process in log with the same values of ρ_ϵ and σ_ϵ as in İmrohoroğlu and Zhao (2018). We normalized the low labor ability η_L to 1 and set the high labor ability $\eta_H = 2.4$ to match the the college premium as estimated by Wang (2012) with the data from China Household Income Project. The social security replacement rate is set to 0.4, which is the average national replacement rate in 2010-2013.

Housing. We follow the strategy of Kaplan, Mitman and Violante (2020) to choose three parameters for the house size set $\mathcal{H}$ among homeowners: the minimum size of owner-occupied housing units, the number of discretized house sizes in $\mathcal{H}$, and the interval between two adjacent house sizes. For the distribution of ratios of net housing wealth to total net wealth among homeowners, we target the 10th percentile, median, and the 90th percentile. Total net wealth is defined as the sum of housing wealth and net financial wealth, and we call total net wealth "net worth." We use "total net wealth" and "net worth" interchangeably throughout this paper. The distribution of housing wealth in the initial steady state is crucial for the quantitative impacts of a change in LTV policy at both the household and aggregate levels. For the house size set $\widetilde{\mathcal{H}}$ among renters, we calibrate the smallest size to target the ratio of the average earning of homeowners to that of renters under age 30 (this ratio was 2.65 in 2013) and keep the other two sizes the same as those for the first house. We normalize the moving cost for the young to be zero and calibrate the moving costs of the middle-aged and old households to target the corresponding shares of their mortgage origination numbers in 2013. We choose the threshold value of secondary houses, $\hat{h}$, to target the share of mortgage origination numbers for secondary houses in total mortgage origination numbers in 2013, which is about 5%.

The house depreciation rate, δ_h, is set to 2%, the same as the depreciation rate for China's urban owner-occupied houses estimated by OECD. The transaction cost for selling a house, κ_h equals 3% of the value of house. The rental company operating cost is chosen to match the homeownership rate of households under age 30. The construction technology parameter α is set to 0.9, so that the price elasticity of (new) housing supply equals 9. The value of a new land permit $\bar{L}$ is calibrated to target the ratio of house price to income.[36]

Financial instruments. The risk-fee interest rate, r_b, is set to 3% per annum, which equals the average benchmark deposit rate in 2010-2013. The mortgage interest rate, r_m, is set to 4.94%, which is the average mortgage interest rate for households in 2013 according to the CHFS. The mortgage origination cost, κ_m, is calibrated to target the average ratio of homeowners' outstanding mortgage debt to their income in 2013, which is 3.38.

LTV Policy. We calibrate the minimum downpayment ratio for the first and secondary houses in the model to match actual LTV policies prior to 2014Q4 for these two types of houses. Accordingly, $\lambda_1 = 0.7$ and $\lambda_2 = 0.3$.

IV.5. **Distribution in stochastic steady state.** To understand the dynamics following a loosening of LTV policy, we first discuss a set of model predictions in the stochastic steady

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

state that are not targeted in the calibration. The effects on housing demands of a change in credit conditions depend on both the initial LTV distribution and the distribution of housing wealth across ages and incomes. The LTV distribution reflects how tight the LTV constraints are, and the housing wealth distribution reflects the distributional effects on potential capital gains via an increase in the house price following a relaxation of LTV policy. We show how the model predict the LTV distributions for different age-education groups, followed by the life-cycle profile and cross-sectional moments of housing wealth and net worth.

LTV distribution. We compute the model distribution of LTV ratios for homebuyers with positive mortgages and compare them to the empirical distribution from our Bank Loan Data.[37] Figure 7 displays the distribution of LTV ratios for primary houses at origination in four age-education groups, and compares the model results to the data. Consistent with Figure 3, the empirical LTV distribution peaked at the value of 0.7 (the LTV limit for primary houses in 2013) for all age-education groups. In particular, more than 70% of middle-aged households with high education had their LTV ratios at the LTV policy limit. Such a finding is explained by our model in which these households are constrained to invest in houses. Indeed, the model's stochastic steady state can replicate the LTV distributions at origination across age-education groups reasonably well, and especially for middle-aged households with high education. By contrast, these empirical distributions cannot be explained by the standard life-cycle model because the LTV policy limit for middle-aged households with high education is largely unbinding.[38]

Life-cycle profile of wealth. Figure 8 demonstrate how much the model explains the empirical life-cycle profile of wealth. The top two panels report net worth across ages for both low income and high income households. The model matches the empirical life-cycle profile of net worth for households with low education and high education, which was hump-shaped and peaked around age 55. Net worth of households of age 40 with high education was about three times that of households of age 40 with low education and twice that of young households with high education. The bottom panels show that the model replicates, reasonably well, the empirical age profile of housing wealth of households with high education.

Both net worth and housing wealth of households with high incomes (education) are higher than those of households with low incomes (education) at the initial level and increase with age at a much faster rate than those of households with low incomes (education). Housing wealth of high income households of age 40, for instance, is about twice that of low income

[37]Our granular mortgage data contains homebuyers only with positive LTV ratios at origination.

[38]In Section V.2.1, we show that without a speculative investment incentive ($\Pi_{lh} = 0$), only about 20% of middle-aged households with high education in the stochastic steady state have their LTV ratios reaching the policy limit.

households of age 40 and about three times the housing wealth of high income households of age 20. These results imply that middle-aged households with high incomes enjoy much larger capital gains from increases of the house price than middle-aged households with low incomes or young households with high incomes.

Cross-sectional moments. To see how much the model can explain various empirical cross-sectional moments, we begin with the Gini coefficients for housing wealth and net worth (top portion of Table 11). The Gini coefficient for housing wealth produced by the model is particularly close to the empirical Gini coefficient. The model's results are also close to the empirical shares of net worth of households in the different quintiles (middle portion of Table 11). The model matches the data reasonably well for the ratio of housing wealth to income for median households, but does not predict this wealth-to-income ratio for households in the bottom and top quintiles (bottom portion of Table 11).

Summary. Our model predicts, reasonably well, the empirical LTV distribution across age-education groups, the life-cycle profile of wealth, and other cross-sectional distributions of wealth. Since the initial LTV distribution across age-education groups and the initial distribution of housing wealth are crucial for understanding the transmission of LTV policy into housing demands and consumption, our model provides a theoretical framework for exploring the quantitative impacts of such a policy change.

V. Impacts of loosening the LTV limit

This section provides a quantitative assessment of the aggregate and distributional impacts of relaxing LTV policy. To follow the practical change of LTV policy for secondary houses during the period 2014Q4-2016Q3, our policy experiment in the model is a surprising relaxation of LTV policy for secondary houses. We explore, in Section V.1, the impacts of this policy change on the house price, mortgage originations, and consumption. Section V.2 conducts counterfactual exercises to highlight key factors driving the benchmark results. In Section V.3, we explore the welfare implications of a relaxation of the LTV limit on secondary houses. Section V.4 uses cross-city evidence to provide additional support to the model's key mechanism.

V.1. **Benchmark results.**

Our benchmark policy experiment is to reduce the minimum downpayment ratio for secondary houses. In period 0, the model economy is at the steady state. At the beginning of period 1, the maximum LTV ratio for secondary houses increases from 0.3 to 0.65 unexpectedly.[39] Since a period in our model corresponds to two years in

[39]According to actual LTV policy, a household who owned a house with mortgage fully paid could purchase a second house with the MDR as low as 30%. But for households who owned a house with a positive mortgage, the MDR is 40%. We take the midpoint 35% as the minimum downpayment ratio for secondary houses.

the data, the relaxation of LTV policy lasts for one period to be consistent with the two-year period 2014Q4-2016Q3 when LTV policy was relaxed. During this period, however, households expect that the new LTV policy ($\lambda_2 = 0.65$) will last forever. In period 2, the LTV policy is reversed unexpectedly to the initial steady state value of $\lambda_2 = 0.3$. Throughout this policy experiment, we keep unchanged the MDR for the primary house as well as other parameters such as mortgage interest rates. In particular, the parameter Π_{lh} is kept at its steady state value to help isolate the effects of LTV policy.

V.1.1. *Short-run effects.* Table 12a shows how well the model can explain the aggregate effects of this policy change on annualized growth rates of various key variables. The house price increases by 3.97% (per annum) in the impact period, indicating that a relaxation of LTV policy for secondary houses alone can explain about 70% of the observed increase in the housing price between 2011Q1-2014Q3 and 2014Q4-2016Q3 (5.94%). The total amount of newly issued mortgage loans is 91.75% higher than that in the initial steady state, accounting for almost all the increase in newly issued mortgages in the data (91.78%). The number of mortgage originations increases from the steady state by 30.84%, explaining about two-thirds of the increase observed in the data (46.51%). For primary houses, the mortgage amount increases by 53.54%, accounting for more than two-thirds of the observed increase (78.98%); the number of mortgage originations increases by 19.22%, explaining 45% of the observed increase (42%). These model results indicate that a relaxation of LTV policy for secondary houses is a driving force of the observed mortgage boom, especially the boom of primary houses via an increase of the house price in equilibrium.

Table 12b reports the changes in mortgage shares by age-income groups in comparison to these changes in the data by age-education groups. We highlight the results for the middle-aged high income (high education) households. This group of households experiences the largest increase, 11.62%, in the share of mortgage origination amount, close to the 13.32% increase in the data. Such an increase can be explained largely by the increase in origination numbers in the same group of households (8.75% in the model and 8.07% in the data). By contrast, the shares of mortgage origination amount and number for young high income households increase only by 1.51% and 2.60%.

To understand the model's mechanism, we report in Table 12c the changes in mortgage shares for primary houses by age-income groups. Similar to the results in Table 12b, we see that across age-income groups only middle-age high income households experience a significant increase in the shares of mortgage origination amount (7.94%) and number (5.8%). These model results explain more than two-thirds of the increases in the data (11.78% and 7.26%). By contrast, the share of mortgage origination amount of young high income

households declines by 1.11% while their share of origination number increases by only 1.98%, consistent with the corresponding changes in the data (−1.17% and 0.52%). Thus, our model can explain both aggregate and distributional impacts of a change in LTV policy for secondary houses on the mortgage market.[40]

In our model, mortgage demands arise from two groups of households in any period: those who become new homeowners (from renters) and those who change their housing positions. An increase in mortgage demands following a change in LTV policy is influenced mainly by two factors: an increase of housing demands by the existing homeowners who choose to trade up their primary homes and an increase in households who switch from renters to homeowners.[41] The literature emphasizes the second factor, which is the conventional channel for changes in credit conditions to influence mortgage demands.

For the Chinese mortgage market, the first factor is more important. An increase in the house price encourages homeowners, who would otherwise keep their existing homes (e.g., those with low idiosyncratic labor productivity) due to the fixed costs of moving and mortgage origination, to trade up their existing homes with the help of capital gains. As Table 13a shows, an increase in the number of households who trade up their existing homes contribute to nearly half of the increase in mortgage origination amount, more than 90% of the increase in origination number, and 54% of the increase in housing demands.[42] Table 13b shows that middle-aged households with high incomes account for 52% of the increase in mortgage origination amount as well as in housing demands, the highest among all age-income groups. Thus, a relaxation of the LTV limit influences middle-aged high income households disproportionally, who trade up their existing homes with the help of rising house prices. This channel is absent in standard life-cycle models because the LTV limit for middle-aged households with high incomes is largely unbinding in those models.

V.1.2. *Long-run effects.* Despite a transitory change in LTV policy, transitional dynamics following this policy change can last for many periods because of illiquid housing investments and high mortgage debt burdens for those who purchased houses during the period when the LTV limit is relaxed. The left panel of Figure 9 displays the transitional path of non-housing

[40]In Appendix D, we explore the implications of two alternative mortgage policies: a reduction of the MDR for primary houses and a reduction of the interest rate. For the first policy experiment, we find that the increase in the mortgage amount share of young high income households is the highest among all age-income groups. For the second, the increase in the share of mortgage amount for middle-aged high income households in total mortgage amount is substantially smaller than in the benchmark model.

[41]The first factor can be driven by both an increase in the number of existing homeowners who choose to trade up their primary homes, and a larger size of home purchased by these homeowners.

[42]Housing demand is measured as the total housing stock in our model (see Appendix B).

consumption of middle-aged high income households after LTV policy on secondary houses is relaxed for one period. The impact is negative (below the steady state level) and persistent mainly because of the persistent mortgage debt burdens of households who purchase houses in response to the relaxed LTV policy. The ratio of outstanding mortgage debt to income for middle-aged high income households rises sharply in the first two years and does not return to its initial steady state level until period 5 (right panel of Figure 9).

The existing literature emphasizes the wealth effects of house prices and does not predict a fall in consumption of middle-aged high income households and a simultaneous rise in the house price. In China, despite the positive wealth effects of higher house prices on middle-aged high income households, most of whom are already homeowners when LTV policy is relaxed, these households choose to trade up their existing homes by financing larger houses in anticipation of capital gains in the future. The fall in their consumption on impact reflects an intertemporal substitution for future consumption. It is persistent because these households finance larger houses with a higher leverage against their incomes and are responsible for serving their mortgages for a long time even after the reversal of loosened LTV policy.

V.2. **Understanding the benchmark results.** In this section, we discuss two key factors that underlie our benchmark results: the speculative investment in houses and the increasing housing prices associated with relaxation of LTV limits for secondary homes.

V.2.1. *Speculative investment in houses.* A key element of our model is speculative investment in houses. With beliefs of future higher housing demands, the LTV constraint for most middle-aged households with high incomes is binding in the steady state (Figure 7). Thus, capital gains generated by higher house prices than those in the steady state allow them to overcome the LTV constraint and trade up their existing homes. To quantify how important this investment incentive is for our model results, we turn off the stochastic regime in the utility of housing services by setting $\Pi_{lh} = 0$.

Comparing this counterfactual economy to our benchmark model, Figure 10 displays the steady-state distribution of LTV ratios at origination for primary houses across age-income groups. For all age-income groups except middle-aged households with high incomes, a majority of households borrow to the LTV limit on primary houses because these households are constrained for consumption of housing services. For middle-aged high income households, however, the story is different. Nearly 30% of homebuyers have LTV ratios between 0.05 and 0.15 and only about 20% of homebuyers borrow to the LTV limit on primary houses. This result is in contrast to the benchmark economy in which a vast majority of middle-aged high income homebuyers borrow to the LTV limit for investment purposes.

Indeed, if we feed the sequence of high house prices in our model economy into the counterfactual economy in which there is no speculative investment incentive,[43] demands for mortgage loans by households who trade up primary houses change little from their steady state values, while middle-aged households with high incomes increase their non-housing consumption because of capital gains associated with high house prices.[44]

V.2.2. *The role of increasing house prices.* An increase of the maximum LTV ratio for secondary houses affects households' mortgage demands for primary houses only indirectly by influencing the house price. The key channel is a decision made by middle-aged high income households to trade up their existing homes: an increase of the house price would increase capital gains for existing homeowners when they sell their houses. The larger the existing house is, the larger the capital gains are. Because a middle-aged household with high income tends to have a large home, the wealth effects of trading up existing homes are large for this group of households.[45]

To quantify the importance of this channel, we experiment with a counterfactual exercise in which a 100% tax rate is imposed on capital gains while keeping the increase of the maximum LTV ratio for secondary houses the same as in our benchmark model. The difference in results between this counterfactual exercise and the benchmark model measures the indirect effects of increasing house prices via capital gains on the mortgage market, as reported in Table 14. From columns (1) and (2) one can see that the housing price with a tax rate of 100% on capital gains increase by only 1.53%, 38.5% of the value in our benchmark model and only one-fourth of the increase in the data. The increase in the total mortgage amount is only 25.56%, as compared to nearly the 92% increase in both benchmark model and data. The increase in the mortgage amount for primary houses is even smaller (3.66%). The number of total mortgage originations decreases by 0.13% as the number of originations for primary houses declines even further by 6.97%. The declines are in sharp contrast to large increases in both benchmark model and data. Capital gains from an increase in the house price,

[43]Without a speculative incentive for investment in houses, households would not invest in secondary houses as there is no utility of housing services. When the LTV limit on secondary houses increases, therefore, the equilibrium housing price does not change.

[44]The numerical results are available upon request.

[45]Using the NBS data, we find that during 2011Q1-2018Q1, the year-over-year growth rates of house prices for houses of three size categories (i.e., less than 90 square meters, between 90 and 144 square meters, and above 144 square meters) are quantitatively very close to each other. This evidence supports our model's prediction that different magnitudes of capital gains among homeowners are driven by different sizes of their existing homes.

therefore, are the key factor for understanding an increase of mortgage demands, especially for primary houses.

Table 15a reports the counterfactual results for primary houses. With the 100% tax rate on capital gains, mortgage demands in origination amount and number, as well as housing demands, by households who trade up their existing homes would be reduced by 84-85% relative to the benchmark model. For the mortgage amount and housing demands, 46% of this reduction is explained by the demand reduction among middle-aged households with high incomes (Table 15b).

Summary. Our counterfactual exercises show that the speculative investment incentive for housing and capital gains from increases in the house price are the two main reasons for middle-aged households with high incomes to trade up their existing homes when LTV policy is relaxed. The first factor leads to a significant fraction of middle-aged high income households with binding LTV constraints for investment purposes; the second factor allows these households to overcome the credit constraints and trade up for larger homes. Since middle-aged households with high incomes represent an important share of housing demands in the entire economy, the increase of their mortgages and housing demands play a quantitatively important role for the increase in total demands for mortgages and houses when LTV constraints are loosened.

V.3. **Welfare analysis.** This section analyzes the welfare effects of a change in LTV policy. Following the literature, we measure a change of welfare by consumption equivalent variation (CEV)

$$\Delta\tilde{c}_j = \left[\left(V_j^{TR}/V_j^{SS}\right)^{\frac{1}{1-\sigma}} - 1\right] \times 100\%,$$

where V_j^{SS} is the utility value of household j in the initial steady state and V_j^{TR} is the utility value of household j in the first period of the transition. CEV captures a percentage increase of (composite) consumption in the initial steady state so that household j is indifferent between the initial steady state and the transition state induced by a change in LTV policy.

As a result of LTV policy change for secondary houses, households suffer, on average, a welfare loss of 0.53% of their consumption. This loss, however, is unevenly distributed across households (Table 16a). Young households, for example, suffer a welfare loss of 1.92% of their consumption. The only exception is middle-aged households, who experience a small welfare gain of 0.22% of their consumption. The welfare loss is entirely carried by those renters in the initial steady state across different age-income groups, and an average renter in the economy suffers a welfare loss of 4.30%. By contrast, all existing homeowners, especially middle-aged households, experience a welfare gain.

By age and income, the welfare loss is concentrated in low income households and the gain in high income households (Table 16b). For instance, young low income households suffer a welfare loss of 2.87%, while young high income households suffer a welfare loss of only 0.51%. Among old households, low income households suffer while high income households gain in welfare. Among middle-aged households, high income households have a welfare gain of 0.42%, while the welfare of low income households barely changes. Renters suffer most in welfare. Young low income renters, for example, suffer a welfare loss of 4.66%, while young low income homeowners suffer a welfare loss of only 0.17%. Among renters, the welfare loss of low income households is larger than that of high income households across all age groups. Similarly, among homeowners, the welfare gain is smaller for low income households than high income households.

Why do young households with low incomes suffer disproportionately from a relaxation of LTV policy? The main reason is the crowding out effect: higher house prices crowd these households out of the housing market and force them into the rental market in which renting a house yields a lower utility of housing services than owning a house. To highlight the role of house prices in transmitting a change of LTV policy into negative impacts on welfare, we construct a counterfactual economy in which house prices are held constant throughout the transition path when LTV policy on secondary houses is relaxed.

In this counterfactual economy of constant house prices, the relaxation of LTV policy would generate an increase of 0.08% in welfare for all households (Table 17a), in sharp contrast to a welfare loss when house prices are allowed to respond. In particular, young households experience a welfare gain of 0.07%. The welfare gain by middle-aged households, however, is smaller than the gain in the benchmark economy (0.17% versus 0.21%). The welfare for renters changes little. Thus, all the welfare gain comes from existing homeowners who take advantage of relaxed LTV policy by purchasing second houses in expectation of higher house prices in the future, even though the house price is constant at the present time.

Table 17b reports the impacts on welfare by age-income groups. The welfare gain for middle-aged homeowners with high incomes is 0.41% of their consumption (cf. 0.50% in the benchmark economy). In contrast to a significant welfare loss in the benchmark economy, however, there is little welfare change for young households with low incomes in the counterfactual economy, no matter whether they are existing homeowners or renters. A similar result holds for middle-aged households with low income, especially for renters.

To summarize, our welfare analysis shows that an increase of the LTV ratio for secondary houses generates an unintended loss in welfare. And the welfare loss is disproportionately born by young low income households, most of whom do not own a house when LTV policy

changes. Higher house prices generated by this policy change crowd these households out of the housing market.

V.4. **Exposure to housing speculations: empirical evidence.** One important mechanism of our model is a speculative incentive to invest in houses. This incentive is modeled by a probability to switch from low housing utility to high housing utility (Π_{lh}). In this section, we provide additional evidence for this mechanism by merging the Bank Loan Data and the city-level consumption data from China UnionPay.

Assume that each city in our sample is an island and differs in Π_{lh} that measures the extent to which the city is exposed to housing speculations. We exploit cross-city variations in exposure to housing speculations and examine how changes in mortgage demands, housing prices, and consumption after LTV policy was loosened varied across cities of different exposures. We follow Gao et al. (2020) and measure a city's exposure to housing speculations by a fraction of mortgages for secondary houses in all mortgages in 2013, the year prior to the loosening of LTV policy. We use these exposure measures to divide the NBS's 70 cities into two groups: a high exposure group that contains 35 cities with exposure measures in top 50 percentiles, and a low exposure group that contains the remaining 35 cities.

The top row of graphs in Figure 11 display the difference in the mortgage shares of middle-aged households with high education between the high and low exposure groups of cities. Before 2014Q4 (prior to the LTV policy change), the difference was close to zero. During the period when LTV policy was relaxed, however, the difference widened, implying that cities exposed more to housing speculations experienced more rapid increases in the mortgage share of middle-aged households with high education. From the 2013 level, the share of origination amount in high exposure cities increased by 8-10% relative to low exposure cities, and the share of origination number by 5-7%. These differences declined to about zero after LTV policy reversed course in 2016Q4.[46]

The middle row of graphs in Figure 11 displays the difference in the mortgage origination amount or origination number between the high and low exposure groups of cities, normalized by the 2013 level. The difference was close to zero before 2014Q4, but increased rapidly after 2014Q4 before reverting to the 2013 level. In 2016Q1, for example, the mortgage origination amount was 150% higher in high exposure cities than in low exposure cities, and the origination number was 75% higher.

[46]In Appendix E, we regress changes in the mortgage share of middle-aged households with high education in a city on the city's speculation exposure measure, controlling for various city-specific characteristics. Our estimated coefficient for speculation exposure is significantly positive for the period 2014Q4-2016Q3, but insignificant for the post-2016Q3 period.

For the house price, the difference of its growth rates between the two groups of cities was close to zero in the period prior to 2014Q4 (bottom left graph of Figure 11). During the period when LTV policy was loosened, however, growth of the house price for high exposure cities increased drastically (relative to low exposure cities). In 2016Q3, for instance, the difference was as high as 6%. Again, this difference narrowed and fell rapidly to around zero in 2017Q2.

The consumption difference between high and low exposure cities (normalized by their respective levels in 2013Q3), however, moved in a direction opposite of the other series in this figure during most of the policy relaxation period 2014Q4-2016Q3 and continued to widen after 2016Q3 (bottom right graph of Figure 11). During the period when LTV policy was relaxed, consumption in high exposure cities decreased steadily relative to low-exposure cities, consistent with our model's prediction. After the relaxation of LTV policy was over, consumption in high exposure cities continued to decline relative to low exposure cities, again consistent with our model's prediction that a temporary loosening of LTV policy has persistently negative effects on consumption.

Summary. We find that on the one hand, following a nationwide relaxation of LTV policy, cities exposed more to housing speculations experienced more rapid increases of the mortgage share of middle-aged households with high education, total mortgage demands, and the house prince during 2014Q4-2016Q3. On the other hand, these cities experienced lower consumption growth during the period of LTV policy relaxation and continued to have lower consumption after the loosening of LTV policy was over. All these empirical findings are consistent with our model implications. Our cross-city evidence, therefore, provides an additional support to the model's mechanism of how a change of the LTV limit affects mortgage demands, the house price, and consumption via speculative housing investment.

VI. Conclusion

This paper studies the aggregate and distributional impacts of LTV policy. China's recent changes of LTV policy are used as an ideal policy experiment because these policy changes were unexpectedly large and the magnitude of these changes was seldom observed in history. With three unique micro data sets, our key empirical finding is that a loosening of LTV policy on non-primary houses stimulated demands of middle-aged households with high education for mortgage loans to financing their primary homes at the cost of young households as well as renters. As an unintended consequence, this policy change had a negative impact on consumption of middle-aged households with high education.

We explain our empirical findings with a life-cycle equilibrium model. The model uncovers a self-reinforcing mechanism through changes in the house price: a reduction of the minimum downpayment ratio for secondary houses triggers an initial rise in the house price by encouraging investment in houses for speculative purposes. The initial rise, in turn, generates capital gains for existing homeowners and encourages them to trade up an existing home in expectation of future capital gains. Growth of non-housing consumption of middle-aged households with high incomes falls partly because of their intertemporal substitution into future consumption and partly because of increasing burdens of their mortgage debt relative to their incomes. Young households and renters suffer the most because rising house prices make it less affordable for them to own houses. This self-reinforcing mechanism is in sharp contrast to the standard mechanism in other life-cycle models. In those models, changes in credit conditions affect aggregate housing demands mainly through housing tenure decisions made by households who are credit constrained for housing services, not for housing investment.

By exploiting both the unique micro data and the unique change of LTV policy in China, our empirical findings, along with theoretical interpretations, show how important the interaction between credit supply and housing speculations was in driving the mortgage or housing boom, and how this interaction exerted distributional impacts on households by age and education (income). We hope that our work lays an empirical and theoretical foundation for designing optimal LTV policy to achieve a desirable distributional outcome across households of different ages and incomes.

TABLE 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 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
Consumption (thousands of RMB)	50.62	51.19	55.40	57.63	54.28	53.30
Incomes (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. This inclusion is necessary for accounting for both extensive and intensive margins in our regression analysis (Table 8), which includes households with and without mortgage. In addition to our mortgage sample, the CHFS dataset includes households who paid their mortgage debts in full.

Source: The CHFS.

TABLE 3. Mortgage share (percent) across age-education groups in 2013

(A) Share of loan amount: all houses

	High school and below	College and above
Age < 30	11.77	25.60
$30 \leq$ Age < 50	26.29	29.48
Age ≥ 50	4.38	2.48

(B) Share of loan amount: primary houses

	High school and below	College and above
Age < 30	12.31	26.55
$30 \leq$ Age < 50	26.50	27.90
Age ≥ 50	4.40	2.34

(C) Share of origination numbers: all houses

	High school and below	College and above
Age < 30	13.41	22.73
$30 \leq$ Age < 50	33.04	23.78
Age ≥ 50	5.02	2.02

(D) Share of origination numbers: primary houses

	High school and below	College and above
Age < 30	14.00	23.59
$30 \leq$ Age < 50	33.24	22.25
Age ≥ 50	5.03	1.88

Source: The Bank Loan Data.

TABLE 4. Percentage change in mortgage share between 2013 and 2015

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

	High school and below	College and above
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 houses

	High school and below	College and above
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

	High school and below	College and above
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 houses

	High school and below	College and above
Age $<$ 30	-2.46	0.52
30 $\leq$ Age $<$ 50	-5.22	7.26
Age $\geq$ 50	-0.57	0.46

Source: The Bank Loan Data.

TABLE 5. Household consumption

(A) Average growth rate of household consumption and income (percent)

	2013-2015	2015-2017	Difference
Consumption	4.05	3.15	-0.90*
Income	6.72	10.84	4.11***

(B) Growth rate of household consumption and income by age (percent)

	Consumption			Income		
	2013-2015	2015-2017	Difference	2013-2015	2015-2017	Difference
Age $<$ 30	5.01	6.21	1.20	10.74	13.51	2.77
30 $\leq$ Age $<$ 50	4.75	2.67	-2.08***	9.15	11.55	2.40**
Age $\geq$ 50	3.19	3.29	0.10	3.70	10.11	6.41***

(C) Changes in growth rates of household consumption and income by age and education (percent)

	Consumption		Income	
	Low education	High education	Low education	High education
Age $<$ 30	2.83	0.08	6.15	0.48
30 $\leq$ Age $<$ 50	-1.40	-3.59***	1.19	5.15***
Age $\geq$ 50	-0.11	1.35	6.21***	7.76***

Notes: Growth rates are annualized. Changes in growth rates reported in panel C are differences in growth rates between 2015-2017 and 2013-2015. The symbol * represents the 0.1 significance level, ** the 0.05 significance level, *** the 0.01 significance level.

Source: The CHFS.

TABLE 6. Household consumption: homeowners

(A) Average growth rate of household consumption and income (percent)

	2013-2015	2015-2017	Difference
Consumption	3.88	2.65	-1.23**
Income	6.15	10.49	4.33***

(B) Growth rate of household consumption and income by age (percent)

	Consumption			Income		
	2013-2015	2015-2017	Difference	2013-2015	2015-2017	Difference
Age < 30	3.97	2.95	-1.02	9.84	11.45	1.61
$30 \leq$ Age < 50	4.68	2.06	-2.62***	8.62	11.00	2.37**
Age ≥ 50	3.05	3.07	0.02	3.24	10.05	6.81***

(C) Changes in growth rates of household consumption and income by age and education (percent)

	Consumption		Income	
	Low education	High education	Low education	High education
Age < 30	-1.07	-0.96	7.13	-2.33
$30 \leq$ Age < 50	-2.16**	-3.61***	1.05	5.25***
Age ≥ 50	-0.19	1.20	6.67***	7.73***

Notes: Growth rates are annualized. Changes in growth rates reported in panel C are differences in growth rates between 2015-2017 and 2013-2015. The symbol * represents the 0.1 significance level, ** the 0.05 significance level, *** the 0.01 significance level.
Source: The CHFS.

TABLE 7. Household consumption: renters

(A) Average growth rate of household consumption and income (percent)

	2013-2015	2015-2017	Difference
Consumption	5.24	8.56	3.32**
Income	10.76	14.60	3.83*

(B) Growth rate of household consumption and income by age (percent)

	Consumption			Income		
	2013-2015	2015-2017	Difference	2013-2015	2015-2017	Difference
Age < 30	7.37	16.14	8.76**	12.80	19.79	6.99
$30 \leq$ Age < 50	5.29	9.68	4.39*	13.42	17.82	4.39
Age ≥ 50	4.35	5.93	1.58	7.37	10.84	3.46

(C) Changes in growth rates of household consumption and income by age and education (percent)

	Consumption		Income	
	Low education	High education	Low education	High education
Age < 30	14.18**	5.52	3.25	10.05
$30 \leq$ Age < 50	6.07**	-2.26	3.96	5.68
Age ≥ 50	1.45	3.50	3.06	8.05

Notes: Growth rates are annualized. Changes in growth rates reported in panel C are differences in growth rates between 2015-2017 and 2013-2015. The symbol * represents the 0.1 significance level, ** the 0.05 significance level, *** the 0.01 significance level.
Source: The CHFS.

TABLE 8. Effects of mortgage debt on consumption growth

Consumption growth rate	(1)	(2)
Mortgage debt dummy	-2.66***	
Ratio of mortgage debt to income		-0.27**
Income growth rate	0.13***	0.18***
Controls	Y	Y
City/time fixed effects	Y	Y
N	28457	2739

Notes: Results of regressions of mortgage debt on consumption growth. Control variables for both regressions include age, age squared (controlling for nonlinearity), education dummies, and family size growth rate. The symbol * represents the 0.1 significance level, ** the 0.05 significance level, *** the 0.01 significance level.
Source: The CHFS.

TABLE 9. Model parameter values

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_L	Housing preference in low state	0.20
ϕ_H	Housing preference in high state	0.30
Π_{lh}	Probability from ϕ_L to ϕ_H	0.4
ω	Utility discount from renting	0.5
φ	Strength of bequest motive	75
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	$\{0.7, 1.6, 2.5, 3.4, 5.75\}$
$\widetilde{\mathcal{H}}$	Renter housing grid	$\{0.25, 0.7, 1.6\}$
$\hat{h}$	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	9.0
$\bar{L}$	Land endowment	0.007
Financial instruments		
r_b	Interest rate	0.03
r_m	Mortgage rate	0.049
κ_m	mortgage origination cost	0.02
LTV policy		
λ_1	MDR for first houses	0.7
λ_2	MDR for secondary houses	0.4

Notes: A period in the model corresponds to two years. All values for which the time period is relevant are annualized.

TABLE 10. Targeted moments in the calibration

Moments	Data	Model
Overall homeownership rate	0.86	0.86
Homeownership rate under age 30	0.66	0.69
Share of mortgage origination amount for secondary houses	0.05	0.03
Share of mortgage origination number for secondary houses	0.05	0.04
Homeownership rate for secondary houses	0.15	0.06
Aggregate wealth-to-income ratio	10.21	8.54
Ratio of outstanding mortgage amount to income	3.09	3.12
Ratio of owner income to renter income under age 30	2.80	3.10
Ratio of purchased house value to income	7.30	8.11
Ratio of net worth of households with age 75 to that of those with age 55	0.82	0.81
Share of mortgage origination number for middle-aged households	0.58	0.57
Share of mortgage origination number for old households	0.06	0.07
Ratio of net housing wealth to net worth: 10^{th} percentile	0.61	0.68
Ratio of net housing wealth to net worth: median	0.93	0.95
Ratio of net housing wealth to net worth: 90^{th} percentile	1.00	1.00

Notes: We construct housing wealth as the sum of the values of both primary 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 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. The data moments for the share of mortgage origination amount for secondary houses, the share of mortgage origination number for secondary houses, and the share of mortgage origination number for middle-aged and old households 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.

TABLE 11. Cross-sectional moments: the model predictions

Moments	Data	Model
Gini coefficient: net worth	0.61	0.46
Gini coefficient: housing wealth	0.56	0.50
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	0.51
Ratio of homeowners' housing wealth to their incomes: 10 percentile	1.78	4.46
Ratio of homeowners' housing wealth to their incomes: median	8.18	9.04
Ratio of homeowners' housing wealth to their incomes: 90 percentile	40.19	15.13

Notes: See the notes in Table 10 for the definitions of housing wealth and net worth. The data moments are calculated from the CHFS.

TABLE 12. Benchmark policy experiment: an increase in the maximum LTV ratio for secondary houses

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

	Model	Data
House price	3.97	5.94
Mortgage origination amount	91.19	91.78
Mortgage origination number	30.65	46.51
Mortgage origination amount (primary houses)	53.08	78.98
Mortgage origination number (primary houses)	19.07	42.21

(B) Changes in mortgage shares by age-income groups

	Mortgage share change (%)			
	Origination amount		Origination number	
	Low income	High income	Low income	High income
Young	-4.27 (-4.13)	1.56 (-2.58)	-8.69 (-2.66)	2.63 (-0.09)
Middle-aged	-6.39 (-6.45)	11.73 (13.32)	-1.54 (-5.45)	8.79 (8.07)
Old	-0.41 (-1.11)	-2.22 (0.95)	-0.27 (-0.52)	-0.92 (0.65)

(C) Changes in mortgage shares for primary houses by age-income groups

	Mortgage share change (%)			
	Origination amount		Origination number	
	Low income	High income	Low income	High income
Young	-3.06 (-3.79)	-1.06 (-1.17)	-8.21 (-2.46)	2.00 (0.52)
Middle-aged	-1.69 (-6.26)	8.03 (11.78)	1.00 (-5.22)	5.82 (7.26)
Old	-0.37 (-1.19)	-1.84 (0.64)	-0.16 (-0.57)	-0.45 (0.46)

Notes: Values in parentheses in Tables (B) and (C) are actual data across age-education groups in Table 4, which correspond to age-income groups in the model.

TABLE 13. Contributions (%) from the increase of households who trade up their existing homes

(A) Contributions to the increase in aggregate mortgage and housing demands

	Origination amount	Origination number	Housing demands
Primary houses	49.58	91.90	54.24

(B) Contributions by age-income groups

	Origination amount		Origination number		Housing demands	
	Low income	High income	Low income	High income	Low income	High income
Young	7.95	12.16	7.49	19.83	8.02	12.14
Middle-aged	27.96	51.94	30.55	42.14	27.92	51.92
Old	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Contributions across age-income groups in table (B) sum up to 100 for each variable.

TABLE 14. The effects (%) of increasing the maximum LTV ratio for secondary houses on the mortgage market: a counterfactual exercise with the 100% capital gains tax rate

	Counterfactual (1)	Benchmark (2)	Data (3)
House price	1.53	3.97	5.94
Origination amount	25.56	91.19	91.78
Origination number	-0.13	30.65	46.51
Origination amount (primary houses)	3.66	53.08	78.98
Origination number (primary houses)	-6.97	19.07	42.21

Notes: Values reported in the table are annualized percentage changes of respective variables.

TABLE 15. A relaxation of LTV policy for secondary houses: its effects on the mortgage market for primary houses among households who trade up their existing homes

(A) Difference (%) between the counterfactual exercise with the 100% capital gains tax rate and the (benchmark) model

	Origination amount	Origination number	Housing demands
Primary houses	-85.47	-84.10	-84.86

(B) Contributions (%) by age-income groups

	Origination amount		Origination number		Housing demands	
	Low income	High income	Low income	High income	Low income	Hight income
Young	6.87	14.22	6.14	23.57	6.91	14.30
Middle-aged	32.39	46.52	35.96	34.32	32.57	46.22
Old	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

Notes: Contributions across age-income groups in table (B) sum up to 100 for each variable.

TABLE 16. Welfare effects (%) of a change in the MDR for secondary houses in the (benchmark) model

(A) By age and homeownership

	All households	Renters	Homeowners
All	-0.56	-4.40	0.24
Young	-1.95	-4.18	0.18
Middle-aged	0.21	-3.24	0.42
Old	-0.67	-5.05	0.08

(B) Across age-income groups of households

	All households		Renters		Homeowners	
	Low income	High income	Low income	High income	Low income	High income
Young	-2.89	-0.52	-4.71	-2.69	-0.17	0.49
Middle-aged	0.08	0.42	-3.42	-2.49	0.37	0.50
Old	-1.19	0.11	-5.31	-1.23	0.03	0.15

Notes: MDR stands for the "minimum downpayment ratio" required by LTV policy.

TABLE 17. Welfare effects (%) of a change in the MDR for secondary houses in the model with the house price held constant

(A) By age and homeownership

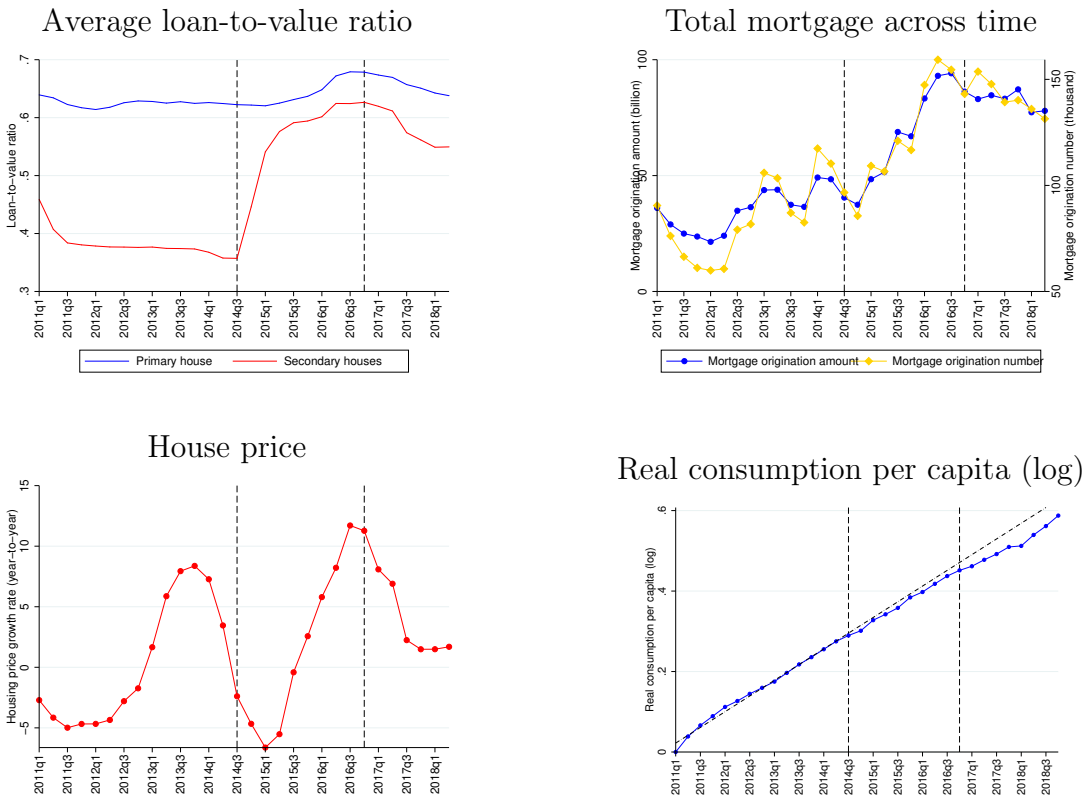
	All households	Renters	Homeowners
All	0.08	-0.00	0.09
Young	0.07	-0.00	0.14
Middle-aged	0.17	-0.00	0.18
Old	0.00	0.00	0.00

(B) Across age-income groups of households

	All households		Renters		Homeowners	
	Low income	High income	Low income	High income	Low income	High income
Young	-0.00	0.18	-0.00	-0.00	-0.00	0.26
Middle-aged	0.01	0.40	-0.00	-0.00	0.01	0.41
Old	-0.00	0.01	0.00	0.00	-0.00	0.01

Notes: MDR stands for the "minimum downpayment ratio" required by LTV policy.

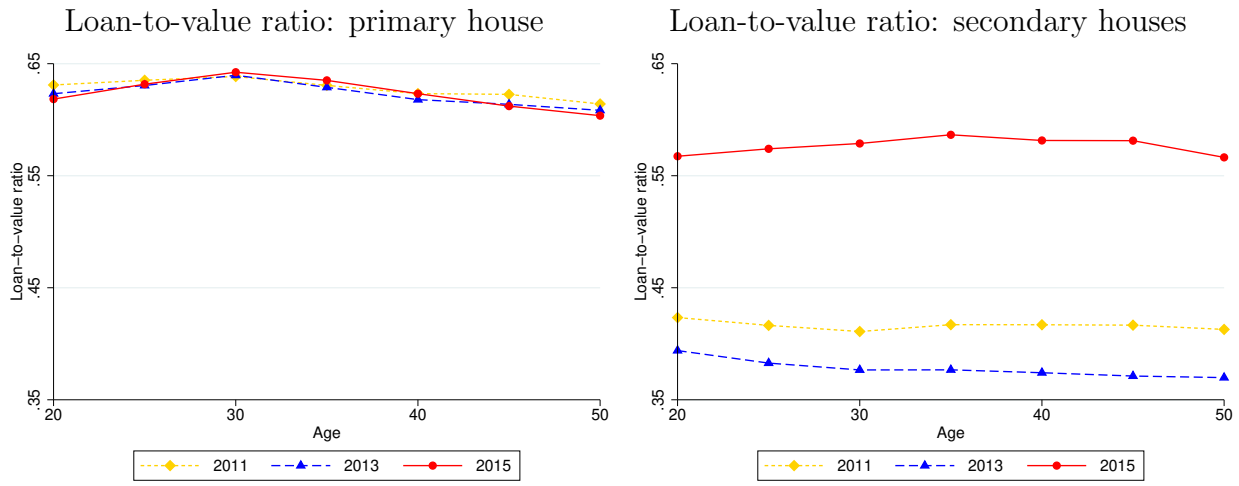
FIGURE 1. Time series of aggregate variables



Notes: The four panels are organized as follows. The top left panel: the LTV ratios for primary and secondary houses across 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 (the value in 2011Q1 normalized to one). For a given city, the real house price is the house price divided by the GDP deflator. We aggregate city-level real house prices to obtain the national average real house price using each city's population in 2011 as a weight.

Sources: The Bank Loan Data, the NBS, and China's macroeconomy time series on the website of the Federal Reserve Bank of Atlanta.

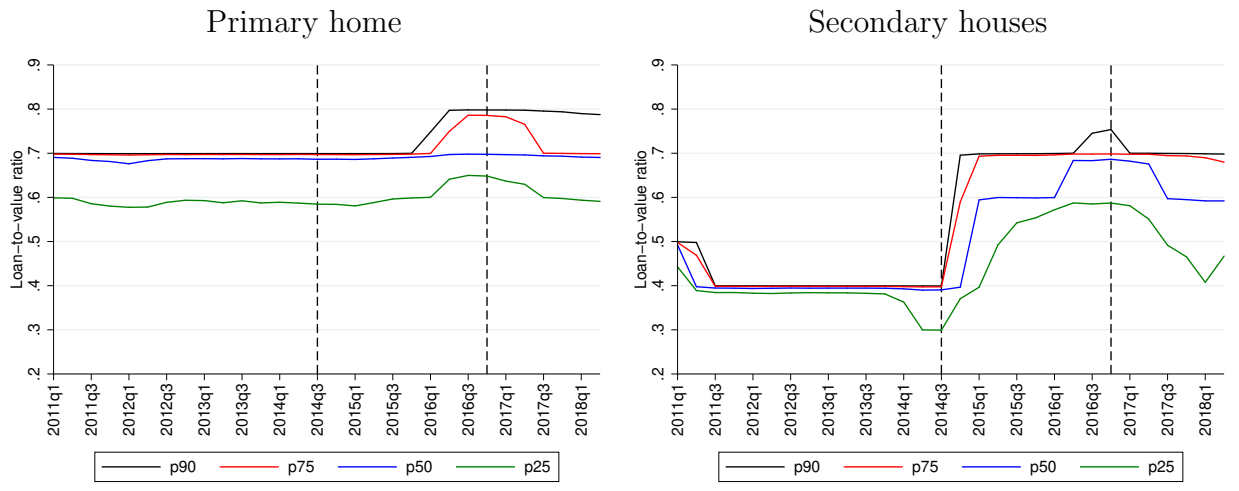
FIGURE 2. Loan-to-value ratio at origination



Notes: The left panel plots the average LTV ratios for primary homes in 2011, 2013 and 2015 across ages. The right panel plots the average LTV ratios for secondary houses in 2011, 2013 and 2015 across ages. The average LTV ratio is computed for each of five-year age bins (e.g., 23-27 and 28-32).

Source: The Bank Loan Data.

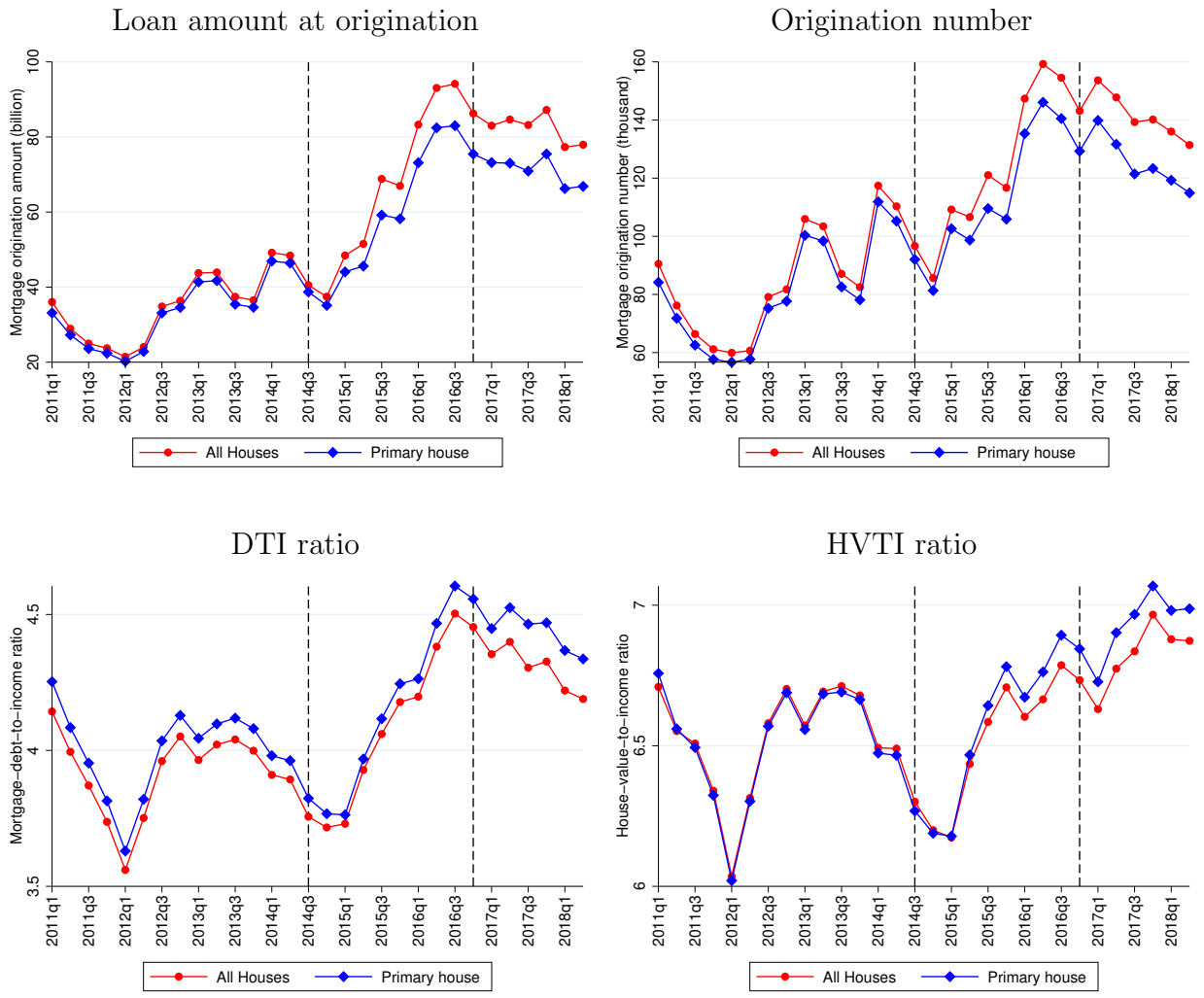
FIGURE 3. Distribution of loan-to-value ratios



Notes: The first vertical dashed line in each panel marks the time when LTV policy was relaxed. The second vertical dashed line in each panel marks the time when LTV policy was tightened. The most significant change in LTV policy was applied to secondary houses.

Source: The Bank Loan Data.

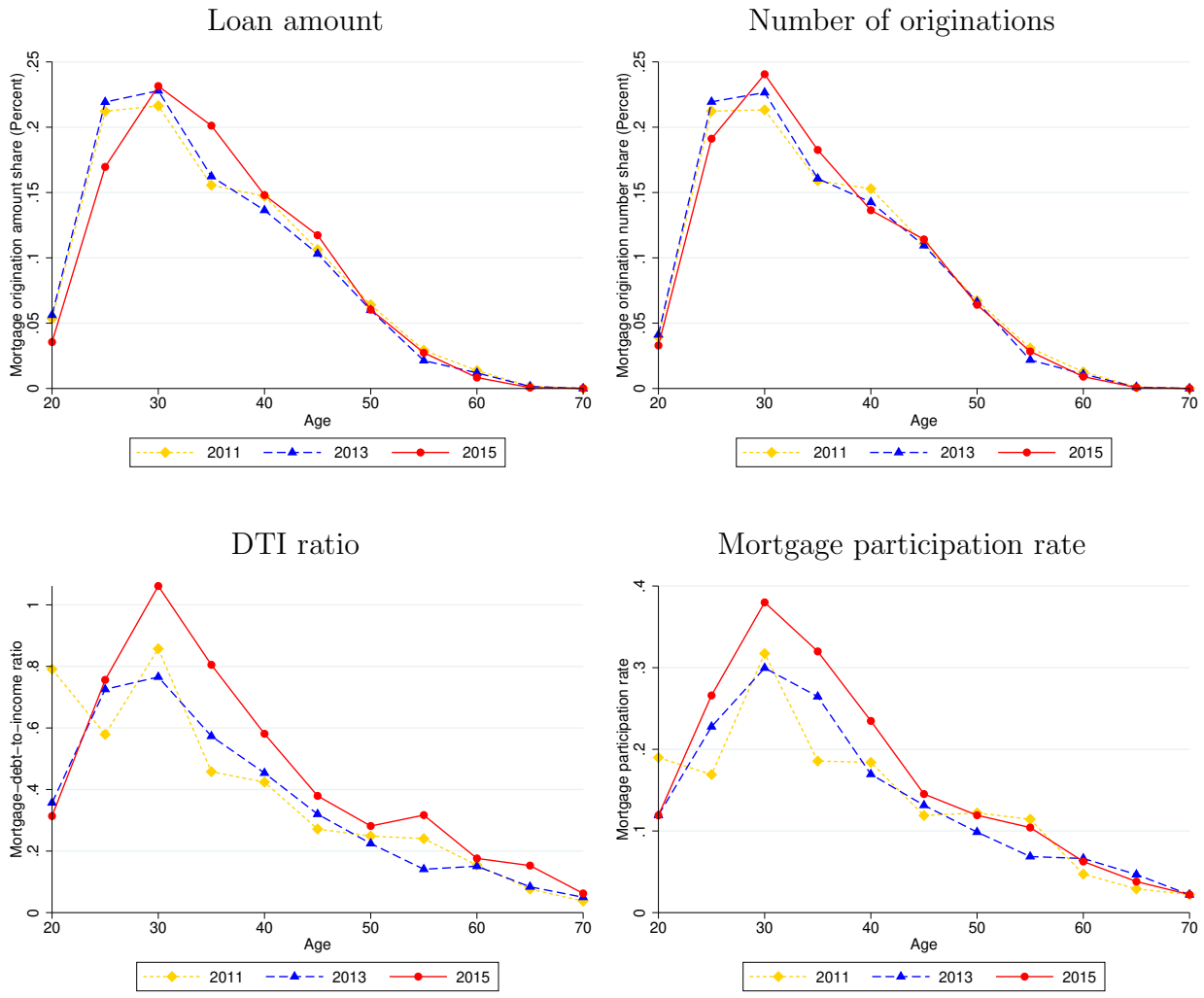
FIGURE 4. Mortgage debt and house value



Notes: DTI stands for debt to income (debt in this paper is mortgage debt) and HVTI stands for house value to income. Top left panel: the amount of mortgage loans at origination for all houses and primary houses across time. Top right panel: the number of mortgage originations for all houses and primary houses across time. Bottom left panel: the average DTI ratio at origination for all houses and primary houses across time. Bottom right panel: the average HVTI ratio for all houses and primary houses across time. The first vertical dashed line in each panel marks the time when LTV policy was relaxed. The second vertical dashed line in each panel marks the time when LTV policy was tightened.

Source: The Bank Loan Data.

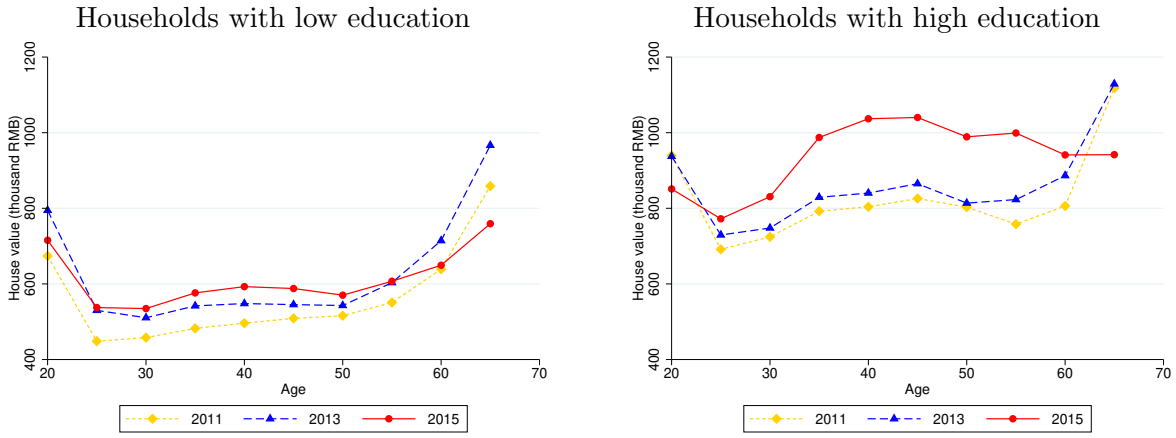
FIGURE 5. Mortgage loans across age groups



Notes: DTI stands for debt to income. Top left panel: the share of loan amount 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 2011, 2013 and 2015. Bottom left panel: the average DTI ratio for each age group in 2011, 2013 and 2015. Bottom right panel: the average share of households with positive mortgage debts in all households across age groups in 2011, 2013 and 2015.

Sources: The Bank Loan Data and the CHFS.

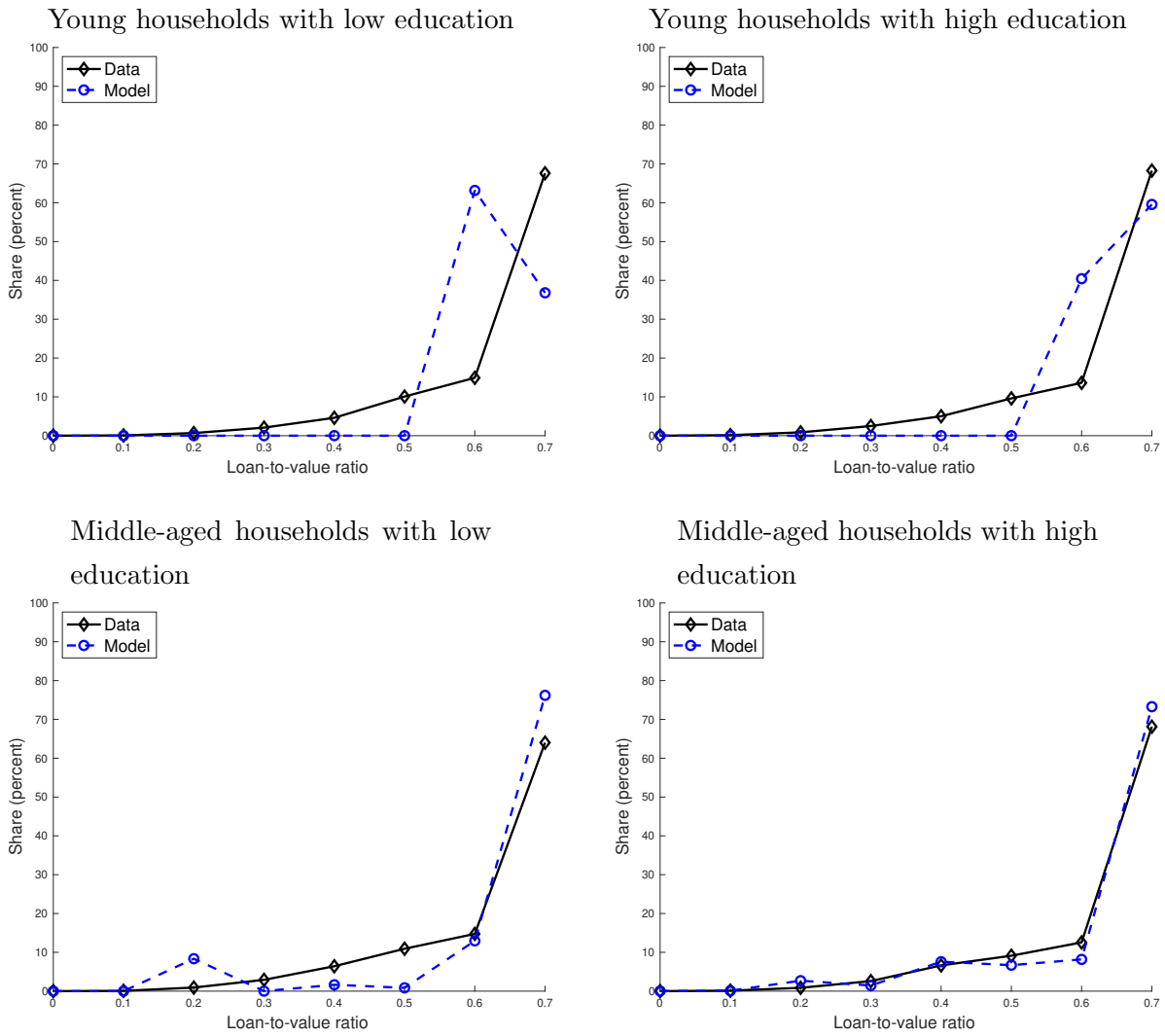
FIGURE 6. Average house value: primary homes



Notes: The house value for each household in a certain year is deflated by the monthly NBS index of house price of the city in which the household resided during the month of that year when the mortgage was originated.

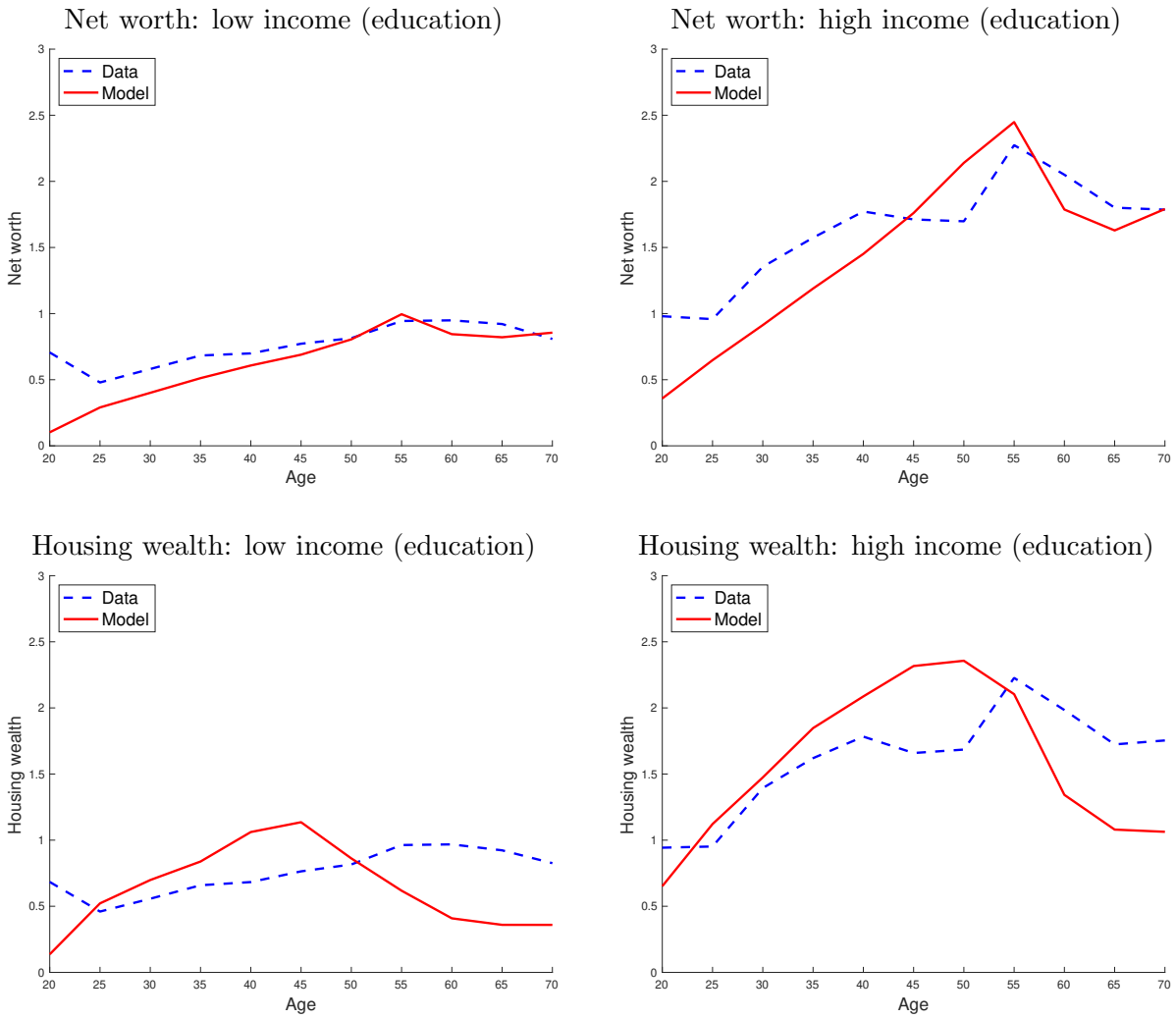
Sources: The Bank Loan Data and the NBS.

FIGURE 7. LTV distribution at origination for primary houses: model versus data



Notes: The top panels display the LTV distribution at origination for young households; the bottom panels display the LTV distribution at origination for middle-aged households. The empirical LTV distributions are based on the 2013 data from the Bank Loan Data.

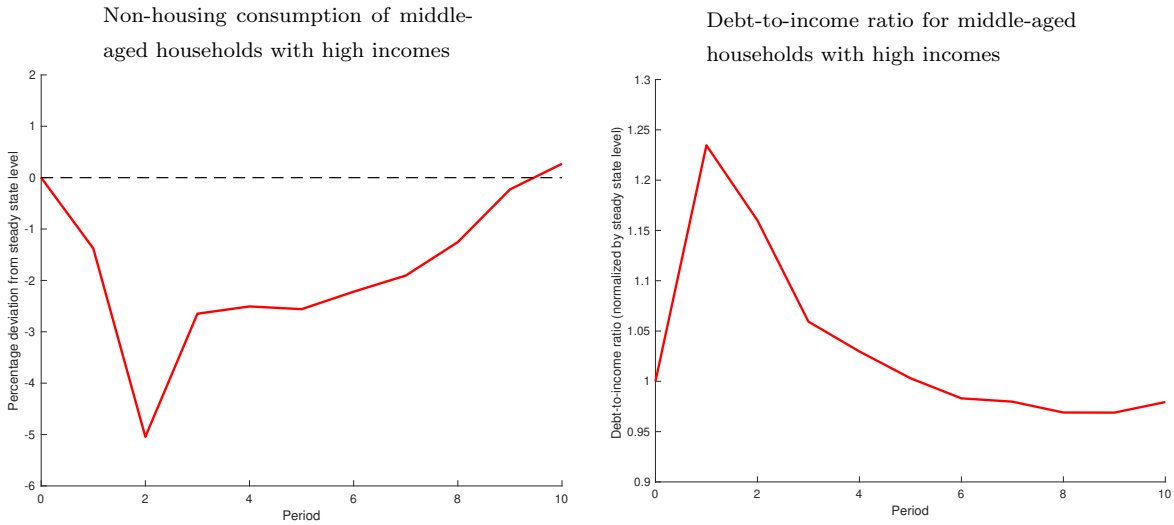
FIGURE 8. Life-cycle profile of wealth



Notes: See the notes in Table 10 for the definitions of housing wealth and net worth. 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. The empirical profiles are based on the 2013 survey data. Education in the survey data is used as a proxy for income in the data.

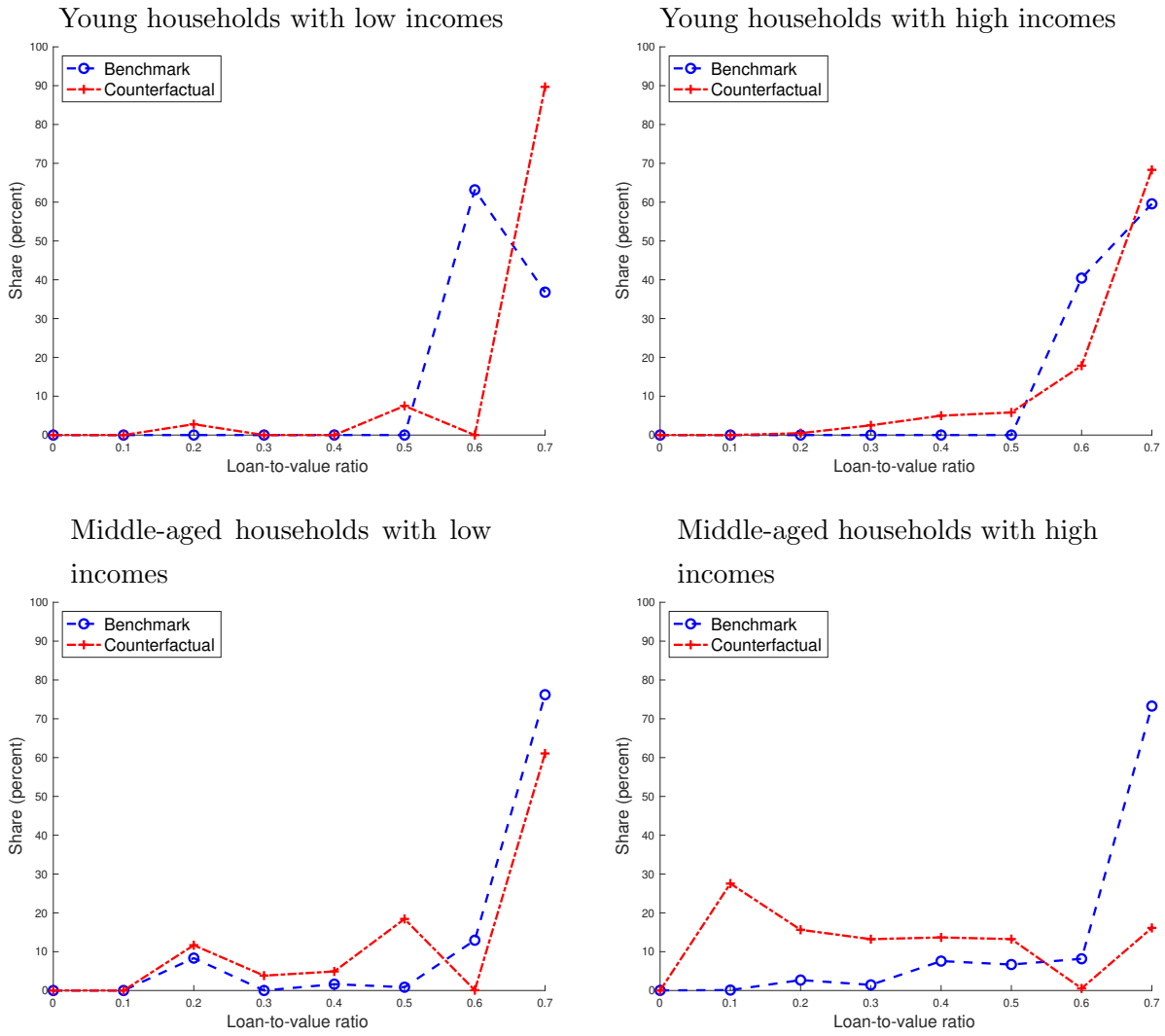
Source: The CHFS.

FIGURE 9. A relaxation of LTV policy for secondary houses: long-run impacts on consumption and debt burden



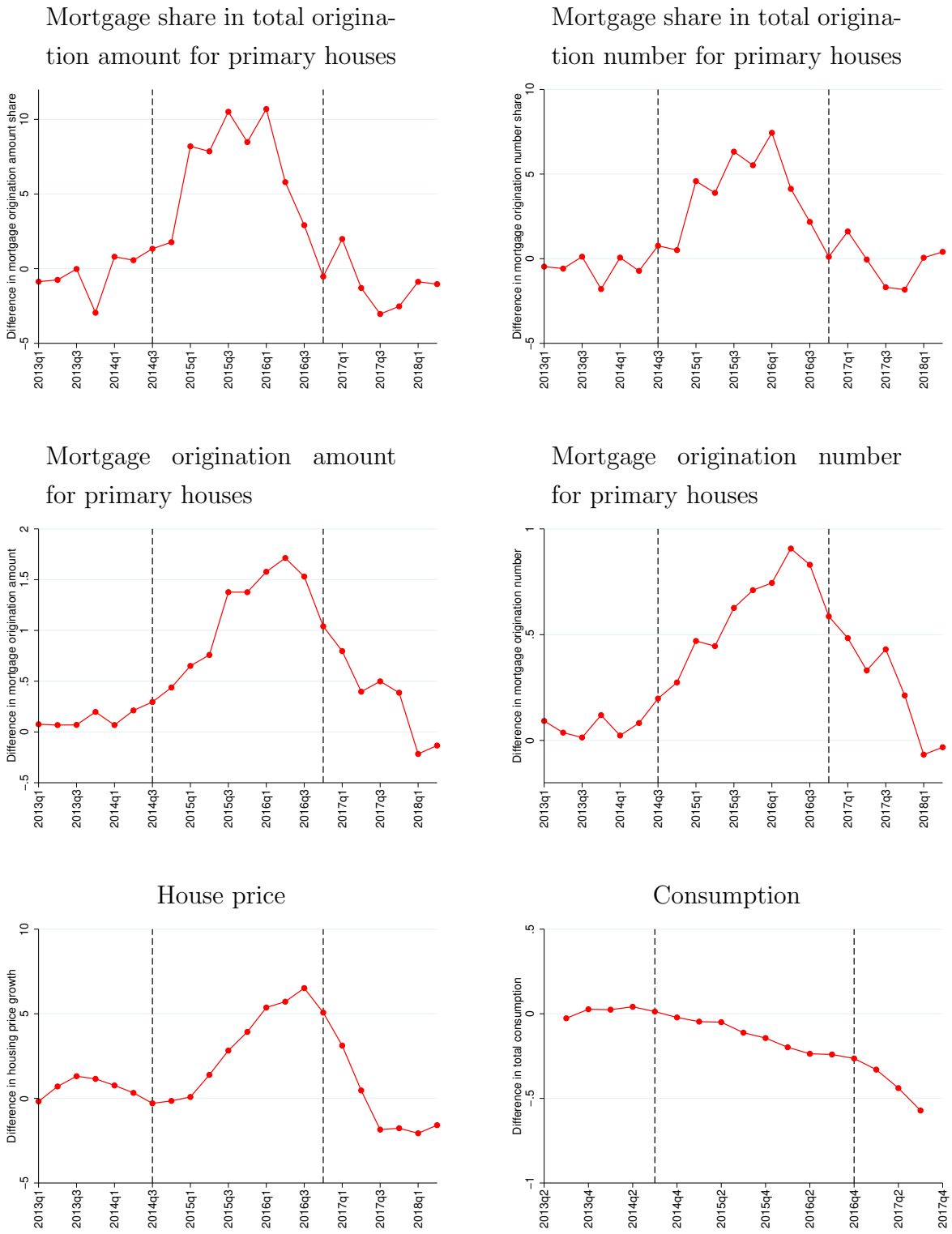
Notes: The debt-to-income ratio is the ratio of the average outstanding mortgage debt to the average income for middle-aged households with high incomes.

FIGURE 10. Distribution of LTV ratios at origination for primary houses in the steady state: counterfactual versus benchmark economies



Notes: The benchmark economy is our model with a stochastic regime for utility of housing services. The counterfactual economy turns off this stochastic regime while keeping all other parts of the model intact.

FIGURE 11. Difference between high and low exposure groups of cities



Notes: The NBS's 70 cities are divided into two groups, one with a high exposure to housing speculations and the other with a low exposure. The mortgage share in each group of cities is for middle-aged households with high education. The mortgage origination amount and number in each group of cities are normalized by their respective 2011 levels. Total consumption in each group is normalized by its 2013 level.

Sources: The Bank Loan Data, the NBS, and China UnionPay.

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Appendix A. Household problem

We now describe a household's problem in recursive forms. Each period, a household's idiosyncratic state vector $\chi = (b, m, h, y)$. Denote $\mu(\chi)$ as the measure of households across individual states and the aggregate states vector as $\Omega = (\phi, \mu)$. We solve the problem of a household in two steps. First, the household chooses the intermediate housing status as described above. Conditional on its housing status, it then chooses the size of housing to either rent or purchase, together with the choice of consumption and saving in financial assets.

At the beginning of each period, a household without a house solves the following problem by choosing between renting or buying a house.

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

where V_j^N, V_j^r, and V_j^b denotes the value functions for a household without a house, value function of the renter and value function of the homebuyer, respectively.

In the case of changing their housing position, the household needs to sell the house first.[47] 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^H, and V_j^s, denote the value functions for a household with a house, value function of keeping the house and value function of selling the house, respectively. If a household chooses to sell the house, it needs to pay all the outstanding mortgage debt associated with the sold house. Accordingly, the financial wealth after selling the house is

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

After the household sells the house, it can then choose whether to rent or buy a new house 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 (A.1). V_j^{sr} is the value function for a household who sells its house and chooses to rent and V_j^{sb} is the function for a household who sells its house and chooses to buy a new house.

Now we switch to the choice of housing size. Since a household dies after age J, we first describe the problem of a household with age $j < J$. For a renter, it solves the following problem.

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

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

subject to

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

A homebuyer solves the following utility maximization problem

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

subject to

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

A homeowner who chooses to keep its house and pay mortgage solves the following problem:

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

subject to

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

Similar to a renter's problem, a household who sells its house and chooses to rent solves

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

subject to

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

Finally, similar to the homebuyer's problem, a household who sells its house and chooses to buy a new house solves

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

subject to

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

Appendix B. Equilibrium

Denote $\chi^H = (b, m, h, y)$ and $\chi^N = (b, y)$ as the idiosyncratic state vectors for homeowners and non-homeowners, respectively. Also, let μ_j^H and μ_j^N be the measure of these two types of households at age j. A recursive competitive equilibrium consists of household value functions $\{V_j^N\left(\chi^N; \Omega\right), V_j^H\left(\chi^H; \Omega\right), V_j^r\left(\chi^N; \Omega\right), V_j^b\left(\chi^H; \Omega\right), V_j^p\left(\chi^H; \Omega\right), V_j^s\left(\chi^H; \Omega\right)\}$, household decision rules, aggregate functions for construction labor $N_h(\Omega)$, rental units stock $\tilde{H}'(\tilde{H}; \Omega)$, 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 the aggregate states:

(1) Households optimize with value functions and associated decision rules;
(2) Construction sector firms maximize profits with associated labor demand and housing investment functions $\{N_h, I_h\}$;
(3) The labor market clears at the wage rate $w = \Theta$;
(4) The rental market clears at price ρ_h;
(5) The housing market clears at price p_h;

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

(6) The aggregate law of motion is induced by the exogenous stochastic processes and all the decision rules, and it is consistent with individual behavior.

Appendix C. Numerical Computation

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[48]:

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.

[48]Since there is potential housing preference state switching and high preference state is an absorbing one, the stationary equilibrium in the high housing preference state is solved first by searching for the market clearing house price following the same algorithm. In this case, there is no state switching in the future, so the house price will always stay the same.

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 D. Alternative mortgage policies

This section explores the implications of two alternative policies: a reduction of the MDR for primary houses and a reduction of the interest rate. Since both policies were used in China during its mortgage boom period 2014Q4-2016Q3, the purpose is to use our model as an identification tool to quantify the effects on the mortgage market of these policies relative to those of LTV policy for secondary houses.

In the first alternative experiment, we change the MDR for primary houses by increasing λ_1 from 0.7 to 0.8 for one period during which all households expect that such a policy change would last forever. After one period, λ_1 returns to its initial steady state level. This experiment replicates the practical change in LTV policy for primary houses during 2014Q4-2016Q3. When stimulating the transitional dynamics, we keep all other parameters unchanged.

Table D.1a reports the distributional impacts of this alternative policy across age-income groups of households. There are two notable differences from our benchmark results. First, the share of young high income households in the total mortgage amount increases by 4.41% and is the highest among all age-income groups, while the share declines or stays the same in the data as well as in our benchmark model. The reason for this counterfactual difference is

straightforward: young high income households are the group that is constrained for housing services. An increase in the maximum LTV ratio for primary houses relaxes this borrowing constraint and increases their leverage against the house value. This standard channel for a change in the maximum LTV ratio to have an impact on housing demands, however, cannot explain our empirical findings for the Chinese mortgage market documented in Section III.

Second, non-housing consumption of middle-aged households with high incomes increases in this counterfactual policy experiment on impact, while it falls in our benchmark model. An increase in the maximum LTV ratio for primary houses relaxes the borrowing constraint of middle-aged households with high income for housing services and non-housing consumption. By contrast, an increase in the maximum LTV ratio for secondary houses does not allow existing homeowners to increase their leverages when they trade up their primary houses. Consequently, these households must reduce their consumption as in the data and shown in our benchmark model.

In the second alternative experiment, we reduce the deposit rate by 1.5% for one period (the mortgage rate is also reduced proportionately). This policy change replicates the loosening of monetary policy since 2014Q4 when the People's Bank of China (PBC) lowers the deposit rate in the banking system. Following this alternative policy change, an increase of the share of middle-aged high income households in the total mortgage amount is substantially smaller than that in the benchmark model (cf. Tables D.1b and 12b), and non-housing consumption of these households does not decline but rather increases over time because a lower interest rate reduces the price of current consumption relative to future consumption.

In summary, changes in these two alternative policies have a positive aggregate impact on housing demands but exert distributional impacts on mortgage demands and consumption over age-income groups of households that are at odds with our empirical findings. A reduction in the MDR for secondary houses, therefore, is the main factor in explaining the mortgage boom during 2014Q4-2016Q3 in China, as shown in our benchmark model.

TABLE D.1. Effects of two alternative policies on the mortgage market

(A) Increasing λ_1

	Change (%) of the mortgage share			
	Origination amount		Origination number	
	Low income	High income	Low income	High income
Young	0.02	4.41	-0.59	0.78
Middle-aged	-4.31	3.65	-1.57	3.68
Old	-0.56	-3.21	-0.29	-2.01

(B) Reducing the interest rate

	Change (%) of the mortgage share			
	Origination amount		Origination number	
	Low income	High income	Low income	High income
Young	-1.35	-1.21	-6.28	0.44
Middle-aged	0.06	2.25	0.32	4.90
Old	0.39	-0.14	0.27	0.34

Notes: λ_1 is the MDR for primary houses.

APPENDIX E. ESTIMATION OF MORTGAGE SHARE AGAINST EXPOSURE

Since our housing speculation exposure measure might be related to other city-level characteristics, we regress the mortgage share changes by the middle-aged high-educated households in a city against the city's speculative exposure measure.

$$MortgageShare_c^1 - MortgageShare_c^0 = \alpha + \beta * EXP_c + \Gamma * controls_c + \varepsilon_c \tag{E.1}$$

We estimate equation (E.1) first using the eight quarters during which the LTV limits were relaxed (2014Q4-2016Q3). The left side variable represents the average mortgage share of the middle-aged high educated households during this period in city c ($MortgageShare_{c1}$) relative to the average mortgage share during the year 2013 in the same city ($MortgageShare_{c0}$).[49] EXP_c, the housing speculation exposure measure, is city c's fraction of mortgage by secondary homes in its total mortgage in 2013 divided by the standard deviation of the same variable. We then estimate equation (E.1) for the period of 2016Q4-2018Q2, again using the

[49]We also run similar regressions with the difference between the average mortgage shares during 2014Q4-2016Q3 and that during 2013Q4-2014Q3 as the left side variable. The results are quantitatively very similar.

TABLE E.1. The Effect of Housing Policy on Middle-aged High-educated Mortgage Share Change

	Mortgage Amount			Mortgage Number		
	Coefficient	S.E.	P Value	Coefficient	S.E.	P Value
2014Q4-2016Q3	2.529	0.952	0.010	2.111	0.909	0.024
2016Q4-2018Q2	-0.294	1.117	0.793	-0.548	1.058	0.606

average mortgage share of the middle-aged high educated households during these quarters relative to that during the year 2013. The control variables include, for each city, the population growth rate between 2011 and 2013, per capita income growth between 2011 and 2013, log of population in 2013 and log of income in 2013.

Table E.1 presents the estimated coefficients on the housing speculation exposure variable, along with the standard errors. For both mortgage amount and mortgage numbers, the estimate coefficients for exposure are significantly positive during the policy period (first row), suggesting that upon relaxation of LTV limits, the mortgage share of middle-aged high educated households increased faster for cities with higher exposure. The estimated coefficients for 2014Q4-2016Q3 imply that a one-standard-deviation increase in the speculation exposure leads to a 2.53% (2.11%) increase in mortgage amount (number) share of the middle-aged high-educated households relative to the average level in 2013. However, the estimates for the post-policy period (second row) are insignificant for both mortgage amount and number shares of the middle-aged high educated households. Our results suggest that an important channel for the relaxation of LTV limits to influence the mortgage demand of middle-aged high-educated households is via their housing speculation.