Accounting for the Rise in U.S. Mortgage Debt: The Role of Lower Inflation and Mortgage Innovations

James MacGee *

Bank of Canada

Yuxi Yao

University of Nebraska-Lincoln

December 24, 2023

Preliminary and Incomplete

Abstract

U.S. mortgage debt as a share of income rose by roughly 50 percent between the early 1980s and 2001. This rise followed a decline in the level of trend inflation and a corresponding fall in nominal interest rates and wage growth. With fixed amortization and fixed nominal payment mortgage contracts, a decline in nominal interest rates decreases mortgage payments and alleviates payments to income constraints that are more likely to bind for younger homeowners. In addition, a lower growth rate of nominal income slows the decline in the debt to income ratio over a borrower's life. We use a life-cycle housing tenure choice model calibrated to match homeownership rates, loan-to-value ratios, and debt-to-income ratios in 2001 to conduct counterfactual experiments to evaluate the contribution of inflation and a decline in mortgage financing cost to the rise in mortgage debt between the early 1980s and 2001. Our model can account for 57% of the rise in debt-to-income ratio from 1983 to 2001, with the change in inflation accounting for 35% of the rise in mortgage debt and lower mortgage financing costs the remaining 65%. We extend the model to incorporate a decline in the minimum downpayment as well as a cap on payment-to-income ratio on newly originated mortgages, two frequently cited changes to mortgage finance post 2001, and find that the model can largely account for the increase in the debt-to-income ratio from 2001 to 2016. We also show that changes in mortgage financing costs and the cap on payment-to-income ratio have a larger impact on borrowing when inflation is high, while changes in the minimum downpayment matter more when inflation is low.

Keywords: Mortgage Debt, Debt-to-income, Inflation, Homeownership rate, Life-cycle

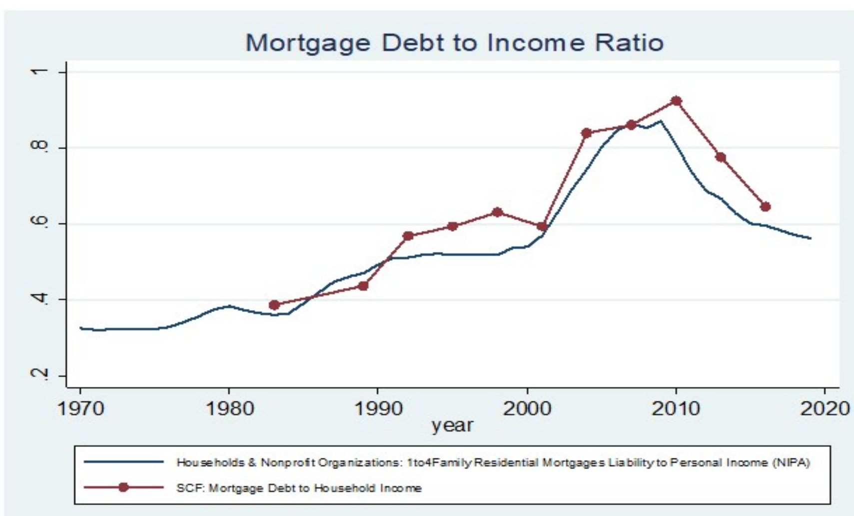
JEL: E21, E60, R21

*The authors would like to thank staff members of the Bank of Canada, as well as seminar participants from for insightful comments. The views expressed in this paper are solely those of the authors and may differ from official Bank of Canada views. No responsibility for them should be attributed to the Bank.

1 Introduction

U.S. mortgage debt rose from less than 40% of household income in the early 1980s to nearly 60% in 2001. Although the housing boom of the early 2002s saw this ratio rise further, following the Great Financial Crisis mortgage debt has stabilized at roughly 60% of income since 2015 (see Figure 1). Although there is no consensus on the key drivers behind this rise in mortgage debt, mortgage innovations that lowered downpayment requirements and financing costs are frequently cited as a key factor (Chambers *et al.*, 2009). However, the 1980s also saw a decline in inflation from an average of 9.7 % over 1980-82 to roughly 2.5% in the late 1990s. As we show, with standard fixed amortization and fixed nominal payment mortgage contracts, a decline in inflation can have a large impact on the life-cycle profile of mortgage debt. This leads us to ask what is the quantitative contribution of the decline in inflation and mortgage market innovations to the rise in U.S. mortgage debt relative to income.

Figure 1: Mortgage Debt to Income Ratio



The National Income and Payment Account (NIPA) measure of mortgage debt is one to four family residential mortgage liability and income is aggregate personal income. In the Survey of Consumer Finance (SCF), mortgage debt is the total households' residential mortgage liability divided by the total households' income.

The intuition for why the level of anticipated (and stable) inflation can impact the mortgage debt to income ratio follows from key features of the typical mortgage contract. Residential mortgages generally specify a fixed amortization period (typically 30 years in the U.S.) at a fixed interest rate (albeit with an option to refinance) with **constant nominal**

payments (typically monthly). For a fixed real interest rate, higher average inflation maps directly into higher nominal interest rates, and thus higher (nominal) monthly mortgage payments. In addition, standard theory implies that changes in average inflation should map into a proportional change in the rate of nominal income growth. This means that varying the level of inflation tilts the hump-shaped life-cycle profile of nominal income.

These forces can interact with borrowing constraints. With constraints on the fraction of income allocated to mortgage payments, higher initial payments limit the level of mortgage debt that young households can take on.[1] In the presence of housing market frictions such as costs associated with buying and selling homes as well as moving costs which discourage households from multiple moves to larger homes over the life-cycle, a tighter constraint on the debt of young households could reduce the average home size and debt levels over the life-cycle.

We document suggestive empirical evidence supporting these key mechanisms by which inflation could impact mortgage debt in Section 2. First, we show that the rise in debt between 1983 and 2001 preceded the rise in real house prices. Second, we illustrate that nominal income grows faster (conditional on age) when inflation is higher by comparing the earning profile of two cohorts: the cohort born in 1956 who were exposed to higher inflation in their 20s and the cohort born in 1986 who experienced stable, lower inflation during their 20s. Faster income growth and constant nominal mortgage payment implies that mortgage payment as a share of income starts at a higher level and decline fast over time. Using data from the Census and American Community Survey, we confirm that the ratio of mortgage payments to income declines faster with a borrower's age in 1980 compared to 2000. This is consistent with the key model mechanism via which inflation impacts the housing market by shifting the timing of real mortgage payments over a borrower's life cycle. Using data from Survey of Consumer Finance (SCF), we document that conditional on mortgage age, the fraction of mortgage of debt paid out is higher in 1983 when the inflation is high than in 2001. This is consistent with our discussion about how inflation affects the path of real debt. Finally, we use the SCF to decompose the contributions of different age groups to the rise in mortgage between 1983 and 2001. We find that middle aged mortgagors account for the majority of the rise in debt.

We use a life-cycle model where households choose whether to rent or purchase a home and

[1] This channel motivated a debate over the potential benefits of alternative mortgage contracts during the high inflation of the 1970s (e.g., see Lessard and Modigliani, 1975).

decide on their level of mortgage debt to quantify the contribution of a decline in trend (i.e., steady-state) inflation and a reduction in mortgage finance costs to the change in mortgage debt between 1983 and 2001. Our model incorporates a standard thirty-year amortization mortgage contract with fixed nominal payments into a standard life-cycle housing tenure choice model. We assume that the only credit contract available is a collateralized thirty-year amortization mortgage.[2] To avoid tracking the change of prices and interest rates due to inflation, we map the nominal budget constraint of a household into real terms. As a result, real mortgage payments depend on inflation and the mortgage age (since origination). We show in Section 2.3 that this implies that real mortgage payments become more front-loaded as inflation rate increases. As a result, in the presence of financial frictions such as a maximum loan-to-value constraint or a cap on the payment-to-income ratio, higher inflation acts to front-load the path of real payments which tightens the credit constraint on young households.

We calibrate the baseline model to match the life-cycle profile of homeownership rates, loan-to-value ratios and debt-to-income ratios in the 2001 SCF.[3] In our baseline, we set inflation to its 2001 value of 2.8% and mortgage origination (finance) cost of 2.48%. In our counterfactual, we use the calibrated model to quantify the impact of changes in inflation and mortgage financing costs on mortgage debt from 1983 to 2001. Specifically, we simulate our calibrated model with an annual inflation rate of 7% and a mortgage financing cost of 2.48%, consistent with the early 1980s data.

Our counterfactual experiments imply a 12 percentage points increase in the debt-to-income ratio, which is 57% of the observed 21 percentage points increase in the aggregate debt-to-income ratio from 1983 to 2001. Our decomposition exercise attributes 35% of the rise in debt-to-income ratio to the inflation decline, and the rest 65% to reduced mortgage finance costs. As a robustness check, we conduct a counterfactual with a 4.19% inflation rate and 1.97% mortgage financing cost, which corresponds to their values in 1989. In this case, our model can account for 88.2% of the rise in debt to income ratio from 1983 to 1989.

[2]Fixed-rate mortgage (FRM) and adjustable-rate mortgages (ARM) are the most common mortgage contracts among U.S. borrowers. Note that in our steady state analysis where inflation and mortgage interest rates are constant, ARM is the same as FRM.

[3]We choose 2001 as the baseline to avoid the housing price swings during the run up to and subsequent to the financial crisis. In addition, the relative stability of the real housing price between 1983 to 2001 is consistent with our partial equilibrium approach to quantifying the impact of changes in inflation and mortgage financing cost.

Our counterfactual produces an increase in the average house size of young and middle-aged households from 1983 to 2001. This is driven both by a relaxation in the credit constraint from lower inflation as well as a lower mortgage finance cost which make it easier for younger households to borrow more so to buy a house closer in size to their preference during their middle age years. This is consistent with the observation that houses built in recent years tend to be larger.[4] We find that this shift to bigger houses accounts for over a fifth of the rise in debt between 1983 and 2001 in our model.

We also use the model to analyze two important changes in housing finance between 2001 and 2016. Specifically, we investigate the impact of a decline in the minimum downpayment observed in the data and the introduction of a cap on the payment-to-income ratio imposed by the Dodd-Frank act on newly originated mortgages. Introducing these changes in our calibrated model leads to a 4.4 percentage point increase in the debt-to-income ratio relative to 2001. This is roughly 85% of the observed 5.2 percentage points increase in the aggregate debt-to-income ratio between 2001 and 2016. We also find that while the introduction of a tighter cap on payment-to-income ratio reduces the debt-to-income ratio, its quantitative effect is modest. Since inflation (and nominal interest rates) remained low during the first two decades of the 2000s, the mortgage payment to income ratio during the early years of homeownership remained relatively low for many borrowers. As a result, the Dodd-Frank act does not have a substantial impact on mortgage demand in our simulations.

We examine the effectiveness of two mortgage-related macroprudential policies, minimum downpayments and cap on payment to income ratio, on mortgage demand and housing demand in high and low inflation environment. We find that adjusting the cap on the payment to income ratio has a larger impact on the demand for housing (and mortgage debt) when inflation is high, while changes in downpayment requirement has a larger impact when inflation is low. Our results thus suggest that the effectiveness of mortgage-related macroprudential policies could vary with the steady state inflation levels.

While a number of recent papers have quantitatively examined the role of changes in the mortgage markets and related policies on household borrowing, ownership decisions, and house prices (see Chambers *et al.*, 2009, Sommer *et al.*, 2013), the impact of inflation has been less studied. Our paper complements this literature by investigating the impact of inflation on steady state levels of mortgage debt as well as the interaction between changes in mortgage

[4]This observation is related to recent media coverage about the decrease in the fraction of smaller, ”starter” homes (e.g., see`https://www.nytimes.com/2022/09/25/upshot/starter-home-prices.html`.

finance and inflation rates on mortgage debt. Our finding suggest that the impact of changes in mortgage finance, such as lower (real) mortgage interest rates and reduced downpayment requirements, on household borrowing are substantially reduced when inflation is high.

Our paper contributes to the long debate over the consequences of high inflation on mortgage borrowing (see i.e. Lessard and Modigliani, 1975 and Garriga *et al.*, 2017). In this paper, we quantitatively evaluate the impact of a decline in inflation on household mortgage debt. We highlight that in the presence of long-term fixed-nominal-payment debt, inflation affects household credit constraint and therefore the effectiveness of mortgage-related policies.

Our work is also related to the literature that examines the causes and consequences of the rise in household debt. Debelle (2004) Dynan and Kohn (2007) examine data from various waves of the Survey of Consumer Finances, and also find that the rise in total household debt is largely due to increased mortgage debt.[5] They also offer some suggestive evidence of an important contribution from house prices to the rise in debt. Bhutta (2015) decomposes the role of inflow and outflows of mortgage payments over 1999 to 2013. However, he does not look at the contributions of inflation to these changes. Mason and Jayadev (2014) also point to the effects of shifts in inflation, income growth and nominal interest rates on household income. Unlike their focus on aggregates, we track how these forces impact different age groups over time. Moreover, we highlight how the impact of frictions in the housing market on borrowing vary with inflation.

Our model is related to recent work which highlights the role of payment-to-income constraint as well as work examining impact of inflation on mortgage borrowing. Greenwald (2018) finds that that changes in a cap on the mortgage payment-to-income ratio is important for understanding boom-bust cycles.[6] Ma and Zubairy (2021) argue that introducing the limit of payment-to-income ratio in structural housing tenure choice models has important implications on the variations in the homeownership rates across age groups. In this paper, we highlight that in the presence of long-term fixed-nominal-payment debt, inflation affects household credit constraint and the effectiveness of mortgage-related policies.

[5]A related literature has focused on the drivers behind the rise in unsecured borrowing, for example see Livshits *et al.* (2010), Livshits *et al.* (2016) and MacGee (2012).

[6]A large literature has examined the implications of household mortgage debt for financial stability. For instance, the empirical studies by Mian and Sufi (2018), Mian and Sufi (2011), and Favara and Imbs (2015) show that mortgage supply has been a major driven force for the boom and bust of house prices.

The rest of this paper is organized as follows. Section 2 examines several key features of the empirical evidence, and uses a simple numerical example to illustrate the implications of inflation for the profile of mortgage payments. Section 3 outlines the model, while Section 4 discusses the calibration strategy. Section 5 conducts several counterfactual analysis evaluating the implication of changing inflation and mortgage innovations on mortgage demand and housing demand from 1980 to 2016. Section 6 discusses the effectiveness of macropodential regulations under different inflation rates. Section 7 concludes.

2 Empirical Evidence

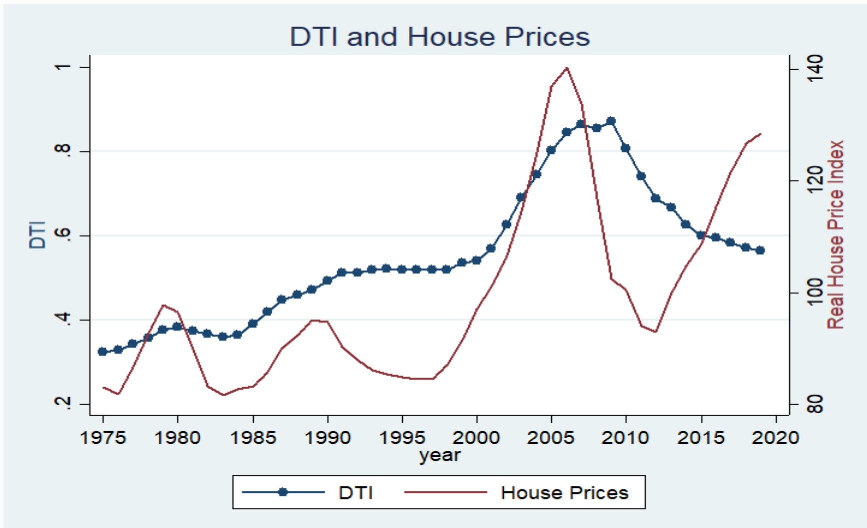
In this section, we document empirical observations which shape key features of our model as well as suggestive evidence consistent with the how changes in trend inflation impacts the steady state ratio of mortgage debt to income. First, the ratio of mortgage debt rose by over 50 % between the late 1970s and early 2000s. Moreover, we document that this rise in mortgage debt relative to personal income precedes the rise in house prices relative to income. Second, we show that sustained shifts in the level of high inflation translate into roughly proportional shifts in nominal borrowing rates and nominal wage growth. We then show that the predictions of standard theory for how a decline in inflation shifts the profile of mortgage payments over a thirty year amortization is qualitatively similar to changes observed in the data. Finally, we use various waves of the SCF to decompose the contribution of different age groups to the rise in mortgage debt between the early 1980s and 2001.

2.1 Mortgage Debt, Inflation, and House Prices

Figure 2 plots the mortgage debt to income ratio, inflation and real house price index since 1975. The mortgage debt to income ratio rose by roughly 20 percentage points between 1980 and 2001 from under 40% to nearly 60%. The rise in debt over this period does not appear to be driven by rising housing prices as real housing prices (while volatile) did not see a sustained rise until after 2001

The early 2000s housing boom saw a rise in both real house prices and mortgage debt. Since the 2008 Global Financial Crisis, the debt to income ratio has returned close to its 2001 level. Unlike the pre-2001 period, real house prices following the GFC have recovered to levels well above the early 1980s.

Figure 2: Mortgage Debt to Income and House Prices



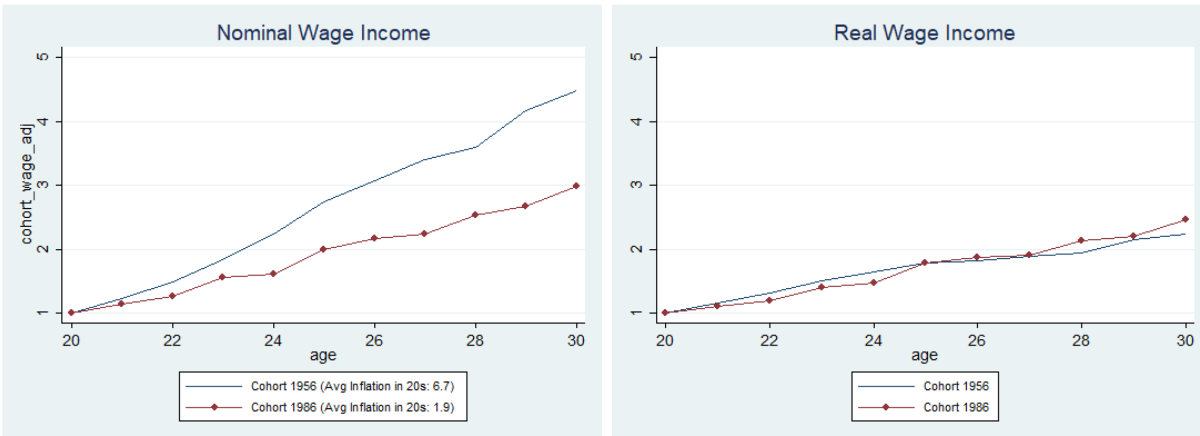
Mortgage debt to income ratio (DTI) is constructed using data from National Income and Product Account (NIPA). Mortgage debt is one to four family residential mortgage liability among households and non-profit organizations. Income is the aggregate personal income. The real house price index is the Federal Housing Finance Agency all-transactions house price index for the United States deflated by CPI.

2.2 Inflation, Nominal Wage Growth and Nominal Borrowing Rates

Standard economic intuition suggests that average nominal wage growth and nominal interest rates should comove with average inflation rates. Indeed, a positive correlation between inflation and nominal wage growth has been documented by Sanchez, 2015. This relationship is important since nominal mortgage payments and nominal wage growth are important components in determining eligible loans and households' borrowing decisions. When inflation affects the nominal wage but not nominal mortgage payments, the path of mortgage payment to income ratio (i.e. share of housing expenditure to income) will be inflation dependent. As a result, changes in inflation may affect mortgage and housing demand.

To illustrate the impact of inflation on wage growth, we compare the wage growth for two cohorts: the first born in 1956 and second in 1986. The 1956 cohort experienced high inflation during the 1970s and 1980s when they started working, with inflation averaging 6.7% during their 20s. In contrast, when the 1986 cohort entered the labour force, inflation rate was stable and low as inflation averaged 1.9% during their 20s. We use the Current Population Survey (CPS) to construct nominal and real wage growth for these two cohorts in Figure 3. Despite the fact that real wage growth of the two cohorts are very similar (right panel), the nominal wage growth for cohort 1956 during the high inflation period was 50% higher compared to cohort 1986 during the low inflation era.

Figure 3: Nominal Wage Growth and Real Wage Growth



Nominal and real wage income are constructed using the Current Population Survey. Nominal income is the average nominal wage of employed workers (relative to age 20) by age born in 1956 and 1986. Real wages are the nominal wage income deflated by the consumer price index.

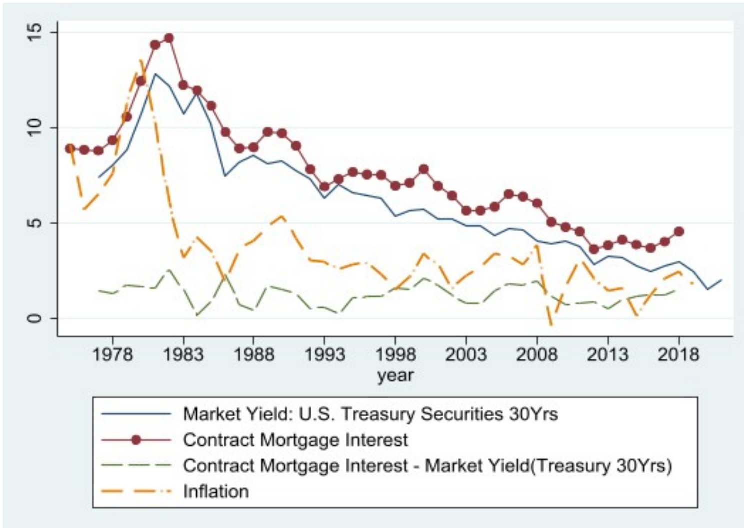
In addition to nominal wage growth rate, standard economic theory implies that nominal interest rates should also vary with inflation. Figure 4 plots U.S. inflation, the contract rate on 30 year mortgages interest and the 30 years treasury yield. Consistent with standard theory, both the mortgage rate and the 30 year treasury yield comove with inflation and the spread between the mortgage rate and treasuries is relatively stable.

2.3 Inflation and Real Mortgage Payments, Debt to Income Ratios and Debt Evolution

We use a simple numerical example to illustrate the key mechanism by which inflation impacts the path of real mortgage payments, payment to income ratios and debt evolution. We use data from multiple waves of the Survey of Consumer Finances and Census to compare the predicted impact of inflation on the profile of mortgage payment to income ratios and a borrower's fraction of debt paid out over the term of a mortgage.

Our illustrative example examines a \$300,000 dollar mortgage with a real interest rate of 2% and a 30 year amortization. Consistent with standard theory and the data presented in Section 2.2 we assume the nominal mortgage interest depends on the real interest rate, the

Figure 4: Mortgage Interest, Nominal Interest and Inflation



The mortgage interest rate is the contract interest rate for conventional single-family mortgages from the Federal Housing Finance Agency (FHFA). The nominal interest rate is the market yield on U.S. Treasury Securities at 30-Year Constant Maturity and inflation is the consumer prices for the U.S., both from Federal Reserve Economic Data.

inflation rate π, and a (constant) mortgage spread of 1%. We compare the path of nominal and real mortgage payments for two alternative inflation rates: 2% and 7%.

The nominal annual mortgage payment, which is usually the annual payment specified in a standard mortgage contract, is calculated using the annuity formula (see Equation 9 and Equation 10 for more details). At 2 % inflation, the nominal annual payment is $19,220 dollars while for 7% inflation the nominal annual mortgage payment is roughly 60% higher at $32,219. To compute the path of real mortgage payments over the 30 year amortization we discount the nominal mortgage payment discounted by inflation (see Figure 5 panel (a)).[7] Since higher rates of inflation imply both a higher mortgage payment and a larger discount factor, real higher rates of inflation result in mortgage payments becoming more front-loaded. In addition, the life-cycle (nominal) earnings profile is steeper at higher rates of inflation. Thus. so long as real income growth is not affected by inflation, this implies that the mortgage payments to income ratio will also be more front-loaded. In other words, when inflation is higher, for any given value of mortgage debt, mortgage payments will account for a larger share of household's income in the initial years of the mortgage. However, the ratio

[7]The reference base period is the year when mortgage contract is signed.

of mortgage payments to income will decline faster over time for higher rates of inflation.

Inflation also affects the evolution of mortgage debt and the accumulation of home equity. Panel b in Figure 5 plots the share of outstanding debt from the year of origination for inflation of 2% and 7%. Debt gets paid out at a faster speed when inflation is higher: It takes about ten years to pay half of the debt at 7% inflation but 17 years at 2% inflation. As can be seen from Panel b, at 2% inflation a mortgagor still has 20% of their mortgage principle to pay over the last five years of the mortgage contract at 2% inflation, while only 10% of the principle would remain at 7% inflation.[8]

We plot the empirical counterparts to the relationship between inflation and the path of mortgage payments in the bottom panels of Figure 5. In the bottom left panel, we use data from Census and American Community Survey (2016) to compare the age profile of the average mortgage payment to income ratio in 1980 and 2000. The inflation rate in the early 1980s was near 10 percent while inflation after 2000 averaged close to 2 percent. Consistent with the front-loading of mortgage payments under higher inflation, the cross-section of mortgage payment to income ratio declines faster with age in 1980 (when inflation rate was high) than in 2000 when inflation had declined.

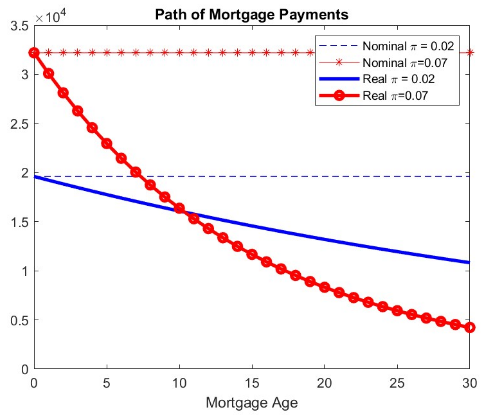
In the bottom right panel of Figure 5 we use data from Survey of Consumer Finance (wave 1983, 2001 and 2016) to examine how inflation affects the evolution of mortgage balances over the life of a mortgage. The SCF reports the year of origination, the value at origination and the outstanding mortgage balance. We deflate by the CPI to compute the real values and the fraction debt outstanding by years since origination. Consistent with evolution of real debt in our illustrative example (Panel b in 5), we find that household pay out their debt faster at the beginning under higher inflation (panel d in 5). For instance, the median fraction of debt outstanding after 10 years is 42% in 1983 when inflation was high and 59% in 2016 when inflation was low.

2.4 Empirical Decomposition of the Rise in Household Debt due to Unexpected Decline in Inflation

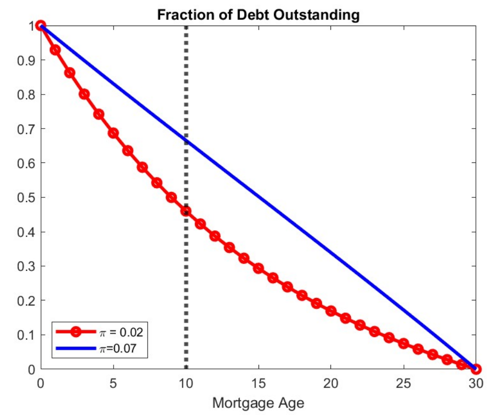
Our quantitative experiments focus on a comparison of mortgage debt to GDP ratio across steady states that differ in the rate of inflation. Later in our discussion, our model results

[8]The decline inflation in the 1980s could be a contributing factor to the rise in the mortgage debt of senior households (see e.g. Li, 2019).

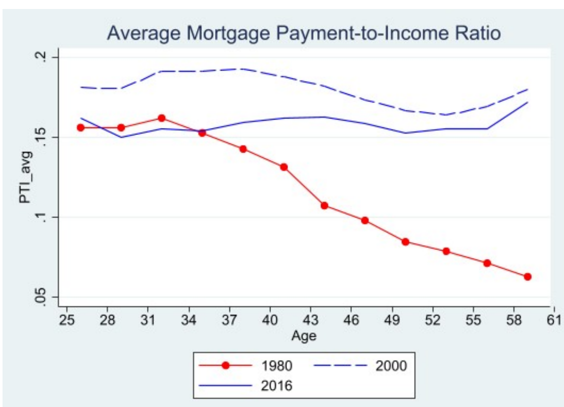
Figure 5: Inflation, Path of Real Mortgage Payments and Debt Evolution



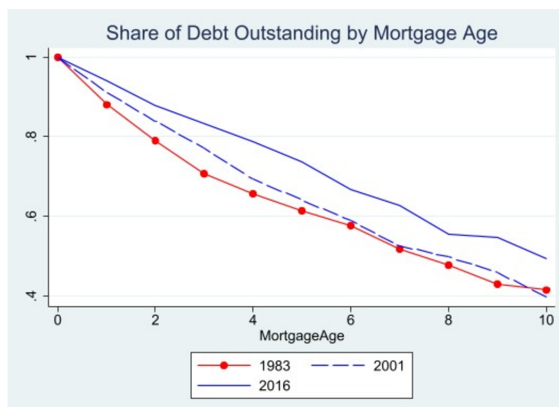
(a) Path of Real Mortgage Payments



(b) Debt Evolution



(c) Payment to Income Ratio



(d) Share of Outstanding Debt

In panel c, average mortgage payment to income by age are constructed using data from the Census (wave 1980 and 2000) and the 2016 American Community Survey. We compute total annual mortgage payments divided by total household wage income for households with at least 5000 dollars annual income. In the bottom right panel (d), the fraction of mortgage debt paid out by mortgage age is constructed using data from the 1983 and 2016 Survey of Consumer Finance. For each household, we compute the real value of the mortgage loan at origination. Then we compute the real value of outstanding loan balance and take the ratio. The mortgage age is calculated using the interview year and the origination year of the mortgage loan.

point to differences across age groups in their contribution to the rise in mortgage debt. We use data from various waves of the Survey of Consumer Finances to decompose the contribution by age of the decline inflation in the early 1980s to the rise in the mortgage debt-to-income ratio.

Before examining the age decomposition, we first look at the direct impact of a one time unexpected decline on inflation on a representative mortgage. This decomposition is similar in spirit to that of Mason and Jayadev, 2014.

Consider a mortgage signed at time t with interest rate $r_{m,t}$ that is determined by the real interest rate, current inflation π_t and a fixed mortgage spread ζ as shown in Equation 9.[9] The evolution of nominal mortgage debt from t to $t+1$ is

$$D_{t+1} = (1 + r_{m,t})D_t - m \tag{1}$$

The change in real mortgage debt due to inflation is simply $\bar{D}_{t+1} = \frac{D_{t+1}}{1+\pi_t}$ We can define the impact of an unexpected decline in the inflation rate $\tilde{\pi}_{t+1} < \pi_t$, the change in real mortgage debt becomes

$$\tilde{D}_{t+1} = \frac{(1 + r_{m,t})D_t - m}{1 + \tilde{\pi}_{t+1}} \tag{2}$$

The increase in real mortgage debt due to an unexpected decrease in inflation is

$$\frac{\tilde{D}_{t+1}}{\bar{D}_{t+1}} = \frac{1 + \pi_t}{1 + \tilde{\pi}_{t+1}} \tag{3}$$

As the nominal mortgage interest and nominal mortgage payments are specified in the mortgage contract and do not frequently adjust with the realized inflation rates, changes in the real mortgage debt is primarily determined by unexpected change in inflation.

As we can see from Figure 2, inflation declined from 9% to 3.7% between 1980 and 2000. A back of envelope calculation using the approach above implies that this would lead to an increase of 5% in real household debt. However, the ratio of mortgage debt to income rose by 50% (from 0.4 to 0.6) between 1980 and 2000. This calculation points to a modest role for the decline in trend inflation, and thus leaves 90% of the rise in household mortgage debt unexplained.

[9] As Figure 4 illustrates, the mortgage interest rate moves closely with the inflation rate and does not seem to reflect changes in future inflation rates.

Decomposing the Contribution of Cohort Effects to the Increase in Mortgage Debt

We now look at the contribution of cohort and effects to the rise in mortgage debt. Our analysis finds that changes in the age distribution of the U.S. population contributed little to the rise in mortgage debt relative to income. Instead, the rise in mortgage debt between 1983 and 2001 is primarily accounted for higher mortgage debts for middle aged homeowners.[10]

We find that the direct effect of shifts in the age distribution of the U.S. population is small and actually works to slightly *lower* the debt to income ratio between 1983 and 2001. We decompose the contribution of shifts in the U.S. age distribution holding fixed the 1983 mortgage debt to income profile and the change in the mortgage debt to income profile at the 2001 age distribution (see Section Appendix for details). Of the 0.21 point rise in debt to income, we find that the change in the profile of debt to income ratio accounts for 0.2129. In contrast, the shift in the age distribution acts to slightly lower the debt to income ratio by 0.0072 points. This finding is consistent with Dynan and Kohn (2007).

Although shifts in the age distribution are not a factor in the rise in debt, the rise in debt to income could vary over the life-cycle. To unpack the contribution of different age groups to the rise in debt we use data from various waves of the Survey of Consumer Finances. For each age group, we further decompose the change in DTI into an extensive margin change in the fraction with a mortgage and an intensive margin change in the DTI conditional on having a mortgage.

Given the modest sample size of the Survey of Consumer Finances, we group households into 5 year age bins from age 20-24 to 70-74, with households over 75 in one bin. Our initial decomposition weights the change in debt compared to 1983 in each age bin by the share of total debt held by that age group. Formally:

$$\frac{\bar{D}_{t+\tau}}{\bar{D}_t} = \frac{\sum_a d^a_{t+\tau}\alpha^a_{t+\tau}}{\bar{D}_t} = \sum_a \underbrace{\frac{d^a_{t+\tau}}{d^a_t}}_{\text{growth in avg debt for age a households}} \overbrace{\frac{d^a_t}{\bar{D}_t}\alpha^a_{t+\tau}}^{\text{share of debt held by age a households}} \tag{4}$$

where $\bar{D}_t$ is average household mortgage debt at time t; $\frac{\bar{D}_{t+\tau}}{\bar{D}_t}$ is the ratio of average household debt in t and $t+\tau$, and d^a_t is average household mortgage debt among age a households at time

[10]However, the contribution of different ages to the rise in mortgage debt to income ratio varies over time. This suggests that there could be cohort effects that reflect the macroeconomic conditions when households entered the housing market.

t. The contribution of each age group a to the rise in mortgage debt is then $Contribution^a = \frac{\frac{d^a_{t+\tau}}{d^a_t}\frac{d^a_t}{D_t}\alpha^a_{t+\tau}}{\frac{D_{t+\tau}}{D_t}}$.

Middle aged homeowners account for the majority of the rise in the mortgage debt to income ratio between 1983 and 2001 (see Figure 6). Indeed, the cohort aged 40-43 in 2001 (who would have aged 22-25 in 1983) alone account for over one-sixth of the rise in total mortgage debt. In contrast, households over 60 years of age (who were more likely to have already owned homes in 1983) combined account for less than a sixth of the total rise.

For comparison we also plot the decomposition by age for the change in mortgage debt between 1983 and 2016 and 2019. This comparison points to larger role for older households in the rise in total mortgage debt. Although the housing boom and bust between 2001 and 2008 raise issues with how to interpret this window, this points to the persistent effect of different cohorts on mortgage debt.

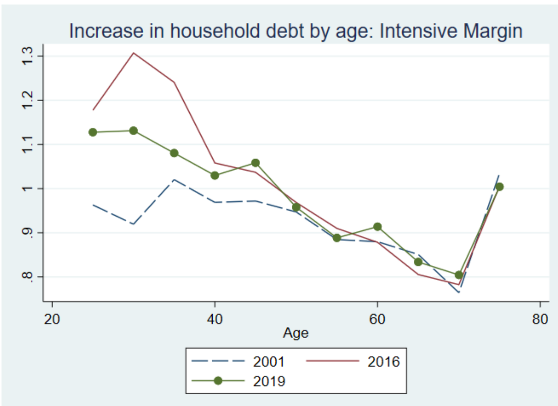
Figure 6: Contribution by Age to Rise in Mortgage Debt

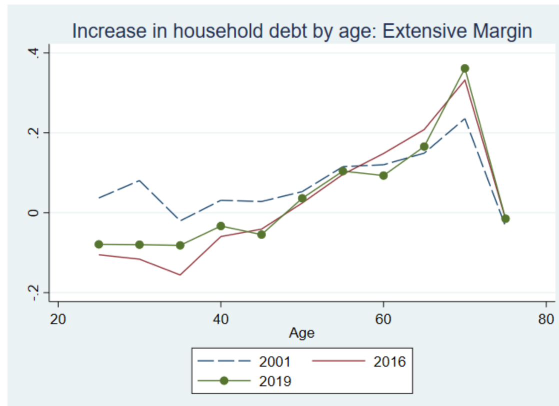
The above decomposition does not distinguish between the change in the average debt of mortgagors x^a_t versus a change in the fraction of households with a mortgage θ^a_t. To quantify the relative importance of these channels, we decompose the change in average mortgage debt into an extensive and intensive margin:

$$d^a_{t+\tau} - d^a_t = \underbrace{\theta^a_{t+\tau}(x^a_{t+\tau} - x^a_t)}_{\text{Intensive Margin}} + \underbrace{x^a_t(\theta^a_{t+\tau} - \theta^a_t)}_{\text{Extensive Margin}} \tag{5}$$

As can be seen from the right panel in Figure 7, the fraction of home ownership by age in 2001 for households under 45 was similar to that of 1983. However, the the fraction with a mortgage over 45 in 2001 was above that of 1983. This points to a slower paydown in mortgages for older households in 2001 than 1983. This is consistent with the left panel of Figure 7 which plots the average debt per mortgagor relative to the level in 1983.

Figure 7: Extensive and Intensive Margins





3 Model

To quantify the impact of trend inflation on household debt and ownership decisions, we develop a small-open economy life-cycle housing tenure choice model. Each period, households choose their consumption of a non-housing good and their consumption of housing services. Consumers can obtain housing services by owning a home or by renting. Compared to renting, owning is attractive for two reasons. First, conditional on house size, owning provides a higher service (utility) flow. This ownership premium is meant to capture that owners can customize their dwellings according to their own taste. Second, owners can choose to use their house asset as collateral for a mortgage. However, while renters can costlessly adjust their level of housing services over time. Buying and selling a house incur transaction costs. In addition households will pay a mortgage closing cost everytime a new mortgage contract is issued (note that this applies to mortgage refinance).

We model trend (steady state) inflation via how it affects the real mortgage payment path in the budget constraint.Specifically, the real mortgage payment depends on inflation as well as the age of the mortgage. Our specification is equivalent to writing the budget constraint in nominal terms when the price of the numeraire good, house prices, rents, and interest rates grow at the same rate as inflation while nominal mortgage payments do not change over time. We assume that the real rate of return on savings r is exogenous and does not depend on inflation.

3.1 Households

The economy is populated by J period lived overlapping generations of ex ante identical households who face mortality risks and labor income uncertainties over their life. Households draw initial wealth from a distribution Γ at birth.

Each household has preferences defined over a non-durable good C and housing services h represented by

$$u(C,h) = \frac{((1-\eta)C^{1-\xi}) + \eta(\theta h)^{1-\xi})^{\frac{(1-\sigma)}{1-\xi}}}{1-\sigma} \tag{6}$$

where the ownership premium θ captures the additional value of owning compared to renting housing services h .[11]. η captures the relative importance of housing compared to regular consumption while ξ measures the substitutability between housing and non-housing consumption. σ is the elasticity of intertemporal substitution.

Each period j, the household objective function is defined by

$$V_j = \frac{((1-\eta)C^{1-\xi}) + \eta(\theta h)^{1-\xi})^{\frac{(1-\sigma)}{1-\xi}}}{1-\sigma} + \beta_j s_j V_{j+1} + \beta_j(1-s_j)B(W_{T+1}). \tag{7}$$

where β_j is the age-specific discount factor that captures the deterministic changes in household size and composition (i.e. McClements scale), s_j is the probability that a household survives from age j to age $j+1$, C is consumption at age j, and h is housing service received at age j. $B(W_{T+1})$ captures the bequest motive, where W_{T+1} is the wealth left by a household, which includes savings and net home equity for owners. Following the literature (see e.g. Guren *et al.*, 2021), we assume the following functional form for bequest motive.

$$B(W_{T+1}) = \frac{B_0(B_1 + W_{T+1})^{1-\sigma}}{1-\sigma} \tag{8}$$

3.2 Assets

There are three assets in this economy: housing, risk-free bonds, and mortgages. Households can save through a risk-free bond which pays a real interest r overtime.

[11] As discussed in Yao (2019), most owners live in detached house while most renters live in apartments. Therefore the price and rent we observe in the data represent the cost of housing for units that are not directly comparable. θ is calibrated to the homeownership rates which captures the utility difference between living in a detached house with a yard and living in an apartment.

Owner occupied housing provides housing consumption and can serves as an investment. Housing assets depreciate with a rate of δ. Additionally, home owners pay property tax proportional to the value of their housing asset $\tau_h Ph$.

Buying and selling house incurs transaction costs. A buyer incurs a total transaction cost of $k_b Ph$ and a seller incurs a total transaction cost of $k_s Ph$. Owners are subject to a minimum house size $\underline{h}$ which means that owners cannot buy a house smaller than $\underline{h}$.

Following the literature, we assume that households can only borrow via collateralized credit.[12] Mortgages are modelled as 30-year fixed-interest mortgage contract.[13] The nominal borrowing interest (i.e., the interest on mortgages) r_m equals the deposit interest (real interest) r adjusted by the inflation rate π plus a spread ζ_m. That is

$$r_m = (1 + r)(1 + \pi)(1 + \zeta_m). \tag{9}$$

The nominal mortgage payment schedule for a L dollar value loan for each year is denoted as

$$m = \frac{r_m L}{1 - (1 + r_m)^{-30}}. \tag{10}$$

Consequently, the real mortgage payment for a loan L issued $n \in \{1, 2, ..., 30\}$ years ago is $\frac{r_m L}{(1-(1+r_m)^{-30})(1+r)^n}$.

The evolution of the nominal debt of a mortgage contract issued n years ago, which specifies a nominal payment m is described by

$$\begin{aligned} D(m, 0) &= \frac{m(1 - (1 + r_m)^{-30})}{r_m} \\ D(m, n) &= (1 + r_m)D(m, n - 1) - m, \quad n \in \{1, 2, ..., 30\} \end{aligned} \tag{11}$$

A proportional closing cost $\tau_m L$ is incurred every time a new mortgage contract is signed.

3.3 Household Income and Income Tax

At the beginning of each period, households receive exogenous real wage income that depends on their age and an idiosyncratic shock ϵ.

$$y(j, \epsilon) = \bar{w_j} \epsilon_i \tag{12}$$

[12] See e.g., Yang (2009) and Sommer *et al.* (2013).

[13] This corresponds to the most popular mortgage contract. In the steady state comparison, what is important is that mortgages have fixed amortization periods.

where $\bar{w_j}$ is the average income of age j households. The idiosyncratic shock ϵ_i follows an AR(1) process:

$$\epsilon_{i,t+1} = \rho\epsilon_{i,t} + \upsilon \tag{13}$$

where $\rho \in [0,1]$ and υ follows a normal probability distribution with mean 0 and standard deviation of σ_υ.

Following (Kaplan *et al.*, 2020), households are subject to a progressive income tax represented by

$$\tau(y) = \tau_0 + \tau_1(log(y) - log(\bar{y})) \tag{14}$$

where $\tau(y)$ is the income tax rate for households whose income is y. $\bar{y}$ is the average income of households in the economy. τ_0 and τ_1 are both positive which implies that the tax rate increases with income.

3.4 Household's Recursive Problem

The state variables of a household are his/her age j, housing asset h, saving a, mortgage contract with a constant nominal mortgage payment m that has lasted for the past n years, and the income shock ϵ . $\Lambda = (a, h, m, n, \epsilon, j)$.

At the beginning of each period j, a household receives their after-tax wage income $y(j, \epsilon)$, chooses housing services, mortgage, saving, housing asset, and consumption of non-durable good. We group households into one of three situations with respect to housing investment and mortgage status.

1. Households choose to be a renter:

   A household who decides to be a renter in the current period chooses the size of rental units d, consumption c, and saving a' to maximize current utility and future values:

$$\begin{aligned} &V^1(a,h,m,n,\epsilon,j) = \max_{c,d,a'} u(c,d) + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',0,0,0,\epsilon',j+1)) + \beta_j(1-s_j)B(a') \\ &s.t. \;\; c + a' + Rd = y(j,\epsilon) + (1+r)a - (\delta+\tau_h)Ph - \frac{m}{(1+\pi)^n} + (1-k_s)Ph - \frac{D(m,n)}{(1+\pi)^n} \end{aligned} \tag{15}$$

   where R is the rental rate and $y(j, \epsilon)$ is the real after-tax household wage income. $(\delta + \tau_h)Ph$ is the depreciation costs and property tax if the household carries the dwelling h and $\frac{m}{(1+\pi)^n}$ is the real mortgage payment. If the household owned a home in the previous period, choosing to be a renter implies they sell their home (i.e., a household cannot own and rent at the same time). In this case, $(1-k_s)Ph - \frac{D(m,n)}{(1+\pi)^n}$ represents the net return from selling the house after paying the selling cost,$(1-k_s)Ph$ and the remaining real value of the outstanding debt $\frac{D(m,n)}{(1+\pi)^n}$.[14] $E(.)$ represents the expected value given current housing and mortgage decisions, taken over the distribution of future income shocks ϵ'. $\beta_j(1-s_j)B(a')$ captures the value of a bequest of value a' as savings are the only asset available to renters.

2. Owners who continue with their current mortgage contract:

   An owner, with a house $h > 0$ and mortgage contract that specifies a nominal mortgage payment m originated n years previously, consumers housing services from their house and makes decisions on consumption c and saving a' to maximize his/her utility and future values.

$$\begin{aligned} V^2(a,h,m,n,\epsilon,j) &= \max_{c,a'} u(c,\theta h) + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',h,m,n+1,\epsilon',j+1)\mathbb{1}_{n<30} \\ &+ V(a',h,0,0,\epsilon',j+1)\mathbb{1}_{n=30}) + \beta_j(1-s_j)B(W_T) \\ s.t.\ \ c+a' &= y(j,\epsilon) + (1+r)a - (\delta+\tau_h)Ph - \frac{m}{(1+\pi)^n}. \end{aligned} \tag{16}$$

   Note that $n = 30$ implies that this is the last period of the mortgage contract and therefore the household will not have any mortgage debt in the following period, i.e. $m' = 0$ and $n' = 0$. W_T is the total wealth left by the household which isthe sum of saving and home equity.

3. A household chooses to own and to sign a new mortgage contract: This case applies when a household decides to start a new mortgage contract. It includes when a renter becomes an owner, an owner decides to change their house size, or an owner decides to refinance their current housing asset. In this case, a household choose housing asset h', new mortgage contract m', saving a', and consumption c to maximize the current

[14] The budget constraints are specified in real terms. Therefore, we convert the nominal mortgage payments m and nominal debt outstanding D to real values by the real interest rate r.

utility and expected future values.

$$V^3(a,h,m,n,\epsilon,j) = \max_{c,h',m',a'} u(c,\theta h') + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',h',m',1,\epsilon,j+1))$$
$$+ \beta_j(1-s_j)B(W_T)$$
$$s.t.\ \ c + a' + Ph' = y(j,\epsilon) + (1+r)a - (\delta+\tau_h)Ph - \frac{m}{(1+\pi)^n} - (k_s Ph + k_b Ph')\mathbb{1}_{h\neq h'}$$
$$+ Ph - \frac{D(m,n)}{(1+\pi)^n} + (1-\tau_m)\frac{m(1-(1+r_m)^{-30})}{r_m} \tag{17}$$

$$\frac{m'(1-(1+r_m)^{-30})}{r_m} \leq (1-\chi)Ph'$$
$$\frac{m'}{w_j\epsilon} \leq \varphi. \tag{18}$$

Equation 17 specifies the budget constraint. Specifically, $(k_s Ph + k_b Ph')\mathbb{1}_{h\neq h'}$ represents the transaction costs for buying and selling a house. For a household refinancing without changing their house size, this term will be 0 as $h = h'$. $Ph - \frac{D(m,n)}{(1+\pi)^n}$ is the real value of home equity for a household who was an owner in the previous period. According to Equation 11, $\frac{m'(1-(1+r_m)^{-30})}{r_m}$ shows the real total amount debt of a standard 30-year fixed-rate mortgage contract with a mortgage payment m' per year. τ_m is the refinancing cost or closing cost of a mortgage contract.

Similar to Greenwald (2018), we have two constraints: one on Loan-to-Value ratio (LTV) and the other one is on Payment-to-Income ratios (PTI) when a new mortgage contract is started. Specifically, the first line in Equation 18 detailed the LTV constraint, which implies that the a χ percent downpayment is required. The second line in Equation 18 shows that mortgage payment has to be lower than φ of the household income.

Finally, we have households choosing among the three options, base on the state variable $\Lambda = (a,h,m,n,\epsilon,j)$. That is

$$V(a,h,m,n,\epsilon,j) = max\{V^1(a,h,m,n,\epsilon,j), V^2(a,h,m,n,\epsilon,j), V^3(a,h,m,n,\epsilon,j)\} \tag{19}$$

4 Parameterization

We calibrate the model to match key moments of the U.S. economy in 2001, including the age profile of homeownership rates, loan-to-value ratios, debt-to-income ratios and payment-to-income ratios.[15] We adopt the generalized method of moments.

4.1 Externally Calibrated Parameters

Households are born at age 22 and live to age 85. Each period in the model corresponds to two years. Households retire at age 64. The survival probabilities are taken from the National Center for Health Statistics, United States Life Tables, 2016.

The age-specific discount factor is calibrated to capture the life-cycle evolution of household size.[16] The intertemporal elasticity of substitution σ is set to 2 as is standard in the related literature (see e.g. Kaplan *et al.*, 2020, Guren *et al.*, 2021). The weight on housing in the utility η function, the substitutability between housing and non-housing consumption ξ and the high ownership premium θ are calibrated.

The risk-free interest r is set to be 2% per year. The average annual inflation rate between 1999 and 2001 is set to $\pi = 2.8\%$ and the mortgage spread to $\zeta_m = 2.5\%$, which is the average difference between the contract mortgage interest rate and the market yield on 30 year treasury bond.

We set the annual property tax and depreciation cost to 1% and 2%, respectively, based on the average property taxes and owner costs reported in the 2016 American Community Survey. Transaction costs for buyers and sellers are set to $k_b = 6\%$ and $k_s = 2\%$ based on estimates in the literature (see e.g. Sommer *et al.*, 2013). Mortgage financing cost is $\tau_m = 0.64\%$, which matches the average initial fees between 1999 and 2001, reported by the Federal Housing and Finance Agency.

For the baseline (2001) calibration, we set the downpayent requirement χ to 20%. The payment to income ratio φ constraint is set to 1, as the Dodd-Frank legislation was introduced in 2010.

[15] We choose 2001 as the baseline year to avoid the boom and bust in the following years. This is a common practice in the literature.

[16] This is quantitatively equivalent to assuming that the discount factor does not vary with age but allowing for the ownership premium to be age-specific which is an alternative approach to capturing the implication of changes in household size over the life cycle on housing demand. See appendix ?? for more details.

The initial wealth distribution is constructed using the 2001 Survey of Consumer Survey. For households aged from 20 to 22, we sum the value of all assets and use this as the initial wealth distribution. We use the 2000 Census to compute the median house value reported by owners and the median gross rent.

We follow Kaplan *et al.* (2020) and set the persistence of the annual income process ρ to 0.97 (biannual 0.941) and the annual standard deviation of earning shocks σ_v to 0.2, so the standard deviation of two years (per period) is $(1 + \rho)\sigma_v$. The standard deviation of initial earning is 0.42 such that the income variation grows with age (see e.g. Heathcote *et al.*, 2010). The income process is approximated by a five-state Markov chain (Tauchen (1986)). We set the income tax parameters, τ_0 to 0.135 and τ_1 to be 0.062, based on Guner *et al.* (2014).

Table 1 summarizes the parameters that are exogenously determined.

4.2 Internally Calibrated Parameters

There are six internally calibrated parameters: the housing share η, substitutability between housing and non-housing consumption ξ, ownership premium θ, minimum house size $\underline{h}$, and the two parameters that shape the bequest motive, B_0 and B_1. We calibrate these parameters using Simulated Method of Moments. We target the age profile of homeownership rate, and Loan-to-Value (LTV) ratios, mortgage Debt-to-Income (DTI), and mortgage Payment to Income (PTI) ratios among owners for 30 age groups. This gives 120 moments in total.

Although the parameters are estimated jointly, several are closely related to a specific moment. Of the six parameters, the ownership premium θ is mainly targeted at the level of homeownership rates. Intuitively, an increase in θ means that owning is more attractive to renting which pushes up the ownership rate. The minimum house size, $\underline{h}$, has the largest impact on the homeownership rates of young and old households with relatively less wealth since they are more likely to be constrained by the minimum house size when considering purchasing a home. The housing share in the utility function, η, and subsitutabiltiy between housing and non-housing consumption ξ are most closely related to the debt to income ratio, which is closely related to the mortgage-to-income ratios among owners. The bequest motive parameters, B_0 and B_1, influence the ownership rates and mortgage debts for senior households. A stronger bequest motive means that older houseowners are more likely to keep their housing asset and less likely to reduce their housing equity via mortgage refinancing.

Table 1: Externally Calibrated Parameters

Parameter	Value	Source
Maximum of life length J	33	
Working life Jr	23	
Annual discount factor β	0.97	Standard in the literature
Equivalence scale e_j		Standard in the literature
Survival Probabilities s_j		National Center for Health Statistic
Annual risk free interest rate	2%	Standard in the literature
Annual inflation rate π	2.8%	Inflation rate in 2001
Mortgage spread ζ_m	2.5%	Federal Housing Finance Agency & Federal Reserve Ban
Annual property tax	1%	American Community Survey
Annual depreciation cost	2%	American Community Survey
Transaction cost for buyers	6%	Sommer *et al.*, 2013
Mortgage closing cost	0.64%	Federal Housing Fiance Agency 2001
Annual auto correlation of earnings ρ	0.97	Kaplan *et al.*, 2020
Standard deviation of earning σ_ϵ	0.2	Kaplan *et al.*, 2020
Downpayment requirement χ	20%	LTV distribution
Cap on PTI φ	1	
Tax schedule τ_0	0.135	Kaplan *et al.* (2020)
Tax schedule τ_1	0.064	Kaplan *et al.* (2020)
Income Profile $\bar{w}_j$		American Community Survey

4.3 Calibration Results

The calibration results are summarized in Table 2.

Table 2: Calibration Results

Parameter		Value	Target
η	Housing Share	0.2	DTI
ξ	Substitutatbility	1.5	DTI and LTV
θ	Ownership Premium	2.2	Homeownership Rate
$\underline{h}$	Minimum House Size	0.8	Homeownership Rate
B_0	Bequest Motive	100	Homeownership Rate & Mortgage Loan
B_1	Bequest Motive	0.5	of Senior Households

Figure 8 presents the performance of our calibration. Our model matches the age profile of homeownership rates, Loan-to-Value ratios, and Debt-to-Income ratios reasonably well.

Given the focus on mortgage borrowing, we also compute the distribution of debt-to-income ratio by age. Figure 9 compares the first, second and third quartiles of DTI by age in the simulated modelwith the data.. Although these moments are not directly targeted in the calibration, our baseline closely matches the distribution of Debt-to-Income ratio among owners in 2001. This illustrates the extent to which our model can successfully replicate key statistics of the U.S. housing market.

5 Counterfactual Experiments

In this section, we use our parameterized model to quantitatively evaluate the contribution of the decline in trend inflation and mortgage financing costs to the rise in household mortgage debt from 1980 to 2001. From 1980 to 2001, the economy saw a significant decrease in inflation and a corresponding fall in nominal mortgage interest rates, as well as a decrease in mortgage financing costs. In our counterfactuals, we set the inflation rate and mortgage financing costs to the early 1980s level. We use the model to decompose the contribution of each of these two factors on household mortgage debt.

We next conduct counterfactual experiments to evaluate the efficiency of two mortgage-related macroprudential policies: a downpayment requirement and cap on payment-to-income ratio, on mortgage demand and housing demand in high inflation and low inflation

Figure 8: Calibration Results

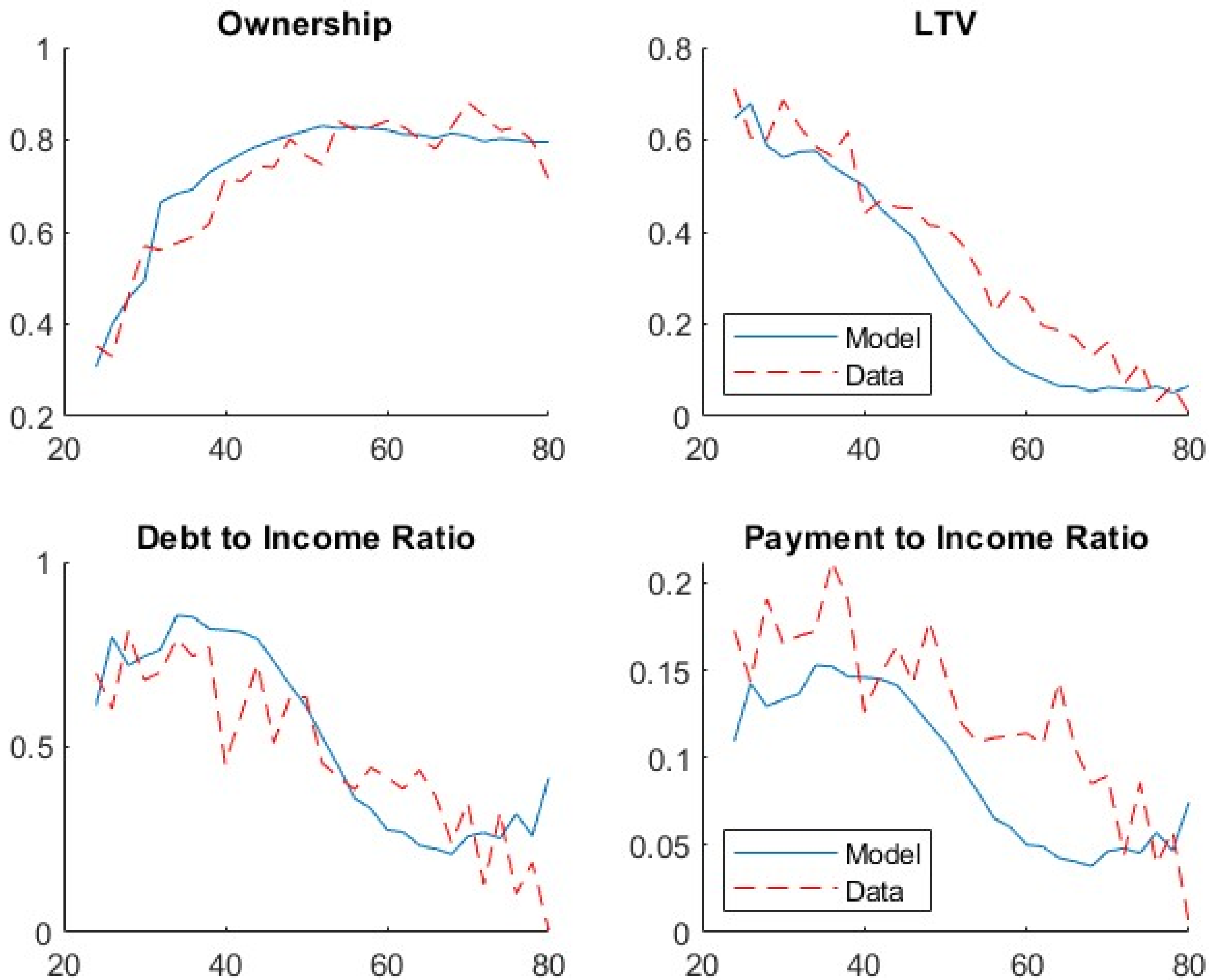
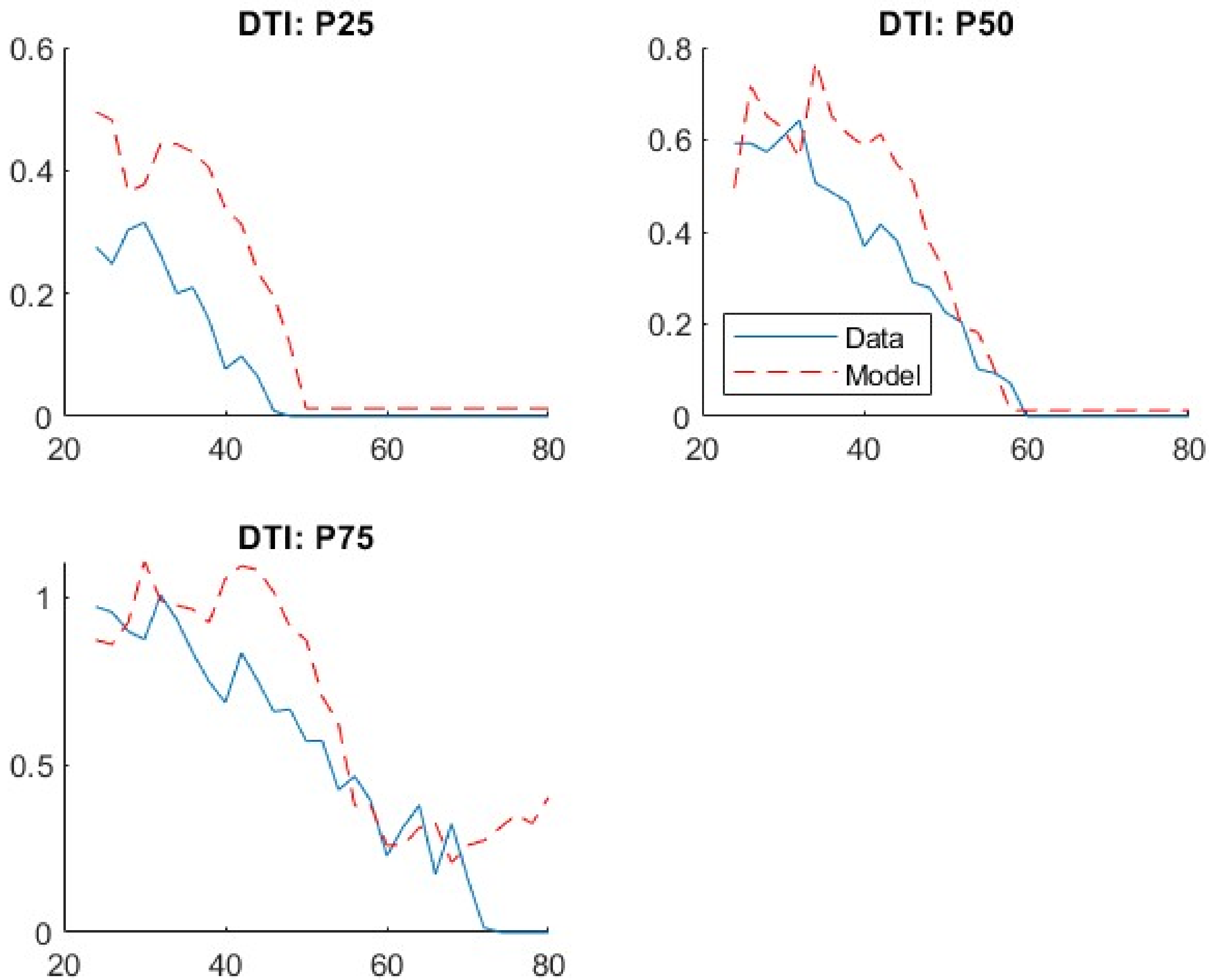


Figure 9: Calibration Results



environment.These experiments are motivated by a decline in the downpayment requirement post 2001 and the introduction of a cap on the payment-to-income ratio after the financial crisis.

5.1 Contribution of Inflation and Mortgage Financing Cost on Mortgage Debt: 1983-2001

We use our model to quantify the contribution of the decline in inflation and mortgage financing cost account to the rise in household debt between 1983 and 2001. In our experiments, we hold fixed the parameters calibrated to match 2001 data but increase the inflation rate from 2.8% to 7%, the inflation rate in 1983. We also adjust the mortgage financing cost from 0.64% to 2.48%, which matches the observed initial fees and charges for new mortgages provided by the Federal Housing and Finance Agency (FHFA) in the early 1980s.

Table 3: Effect of Inflation and Mortgage Financing Cost on Debt

Panel A: Parameters			
Parameters	2001	1983	1989
Inflation	2.80%	7%	4.19%
Mortgage financing cost	0.64%	2.48%	1.97%
Cap-DSR	1	1	1
Maximum LTV	20%	20%	20%
Panel B: Simulation and Data			
Aggregate Debt to Income	2001	1983	1989
Data (NIPA)	57%	36%	47%
Data (SCF)	59.29%	38.65%	43.67%
Model	59.11%	47.3%	51.71%

The model generates a 11.81 percentage points increase in the debt to income ratio between 1983 and 2001 (see Column 1 to 2 in table 3 present the results.). This implies that the decline in inflation and mortgage financing cost account for 57% of the observed 21 percentage points increase in the mortgage debt to income ratio.

As a robustness check, we simulate the model using the observed inflation rate and mortgage financing cost in 1989. As we can see from column 3 Table 3, our model generates a

4.41 percentage points increase in the debt to income ratio from 1983 to 1989, which is about 88% of the observed 5 percentage points increase in the aggregate debt to income ratio. To sum up, declining inflation and mortgage financing cost can account for over half of the rise in mortgage debt from 1980s to 2000s.

To isolate the impact of inflation from mortgage financing cost, we conduct two sequential decomposition exercises (see Table 4). In the first experiment, we reduce the inflation rate from 7% to 2.8% while holding the mortgage financing cost fixed at 2.48%. As we can see from the second column, a 4.2 percentage point decrease in inflation leads to a 4.18 percentage points increase in the debt-to-income ratio, which is about 35% of the rise in debt-to-income ratio generated by the model. Reducing mortgage financing cost generates another 7.7 percentage points increase in the debt-to-income ratio. In the second experiment, we first reduce the mortgage financing cost while holding inflation fixed at 7%. Column 4 in table 4 shows that when inflation is high, lower financing costs generates a 7.6 percentage points increase in the debt-to-income ratio.

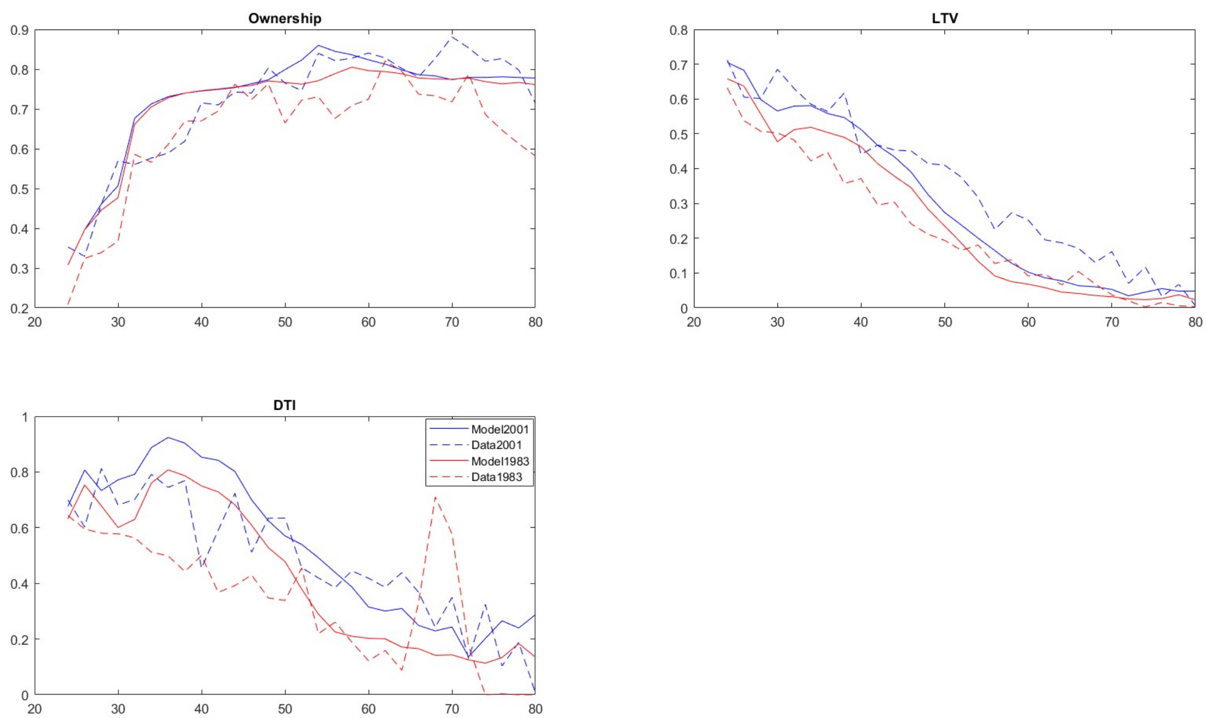
Table 4: Decomposition: Inflation and Mortgage Financing Cost

(1)	(2)	(3)	(4)
Experiment 1	DTI	Experiment 2	DTI
1983 (Model)	47.3%	1983 (Model)	47.3%
Inflation 7->2.8	51.48%	Financing cost 2.48->0.64	54.9%
Financing cost 2.48->0.64	59.11%	Inflation 7->2.8	59.11%

5.1.1 Inflation and Mortgage Innovation: Age Profile of Homeownership, LTV, DTI

In addition to the aggregate debt-to-income ratio, we compare the simulated age profile of homeownership rates, loan to value ratios, and debt to income ratios to the data in 1983 and 2001 in Figure 10. Our model accounts for roughly half of the rise in LTV and DTI for all age groups. Consistent with the data, our model reproduces the observed overlap in homeownership profile between 1983 and 2001. This is because the calibrated substitutability between housing and non-housing consumption in the CES utility function, ξ, is 1.5. This limits the substitution from housing from non-housing consumption. As a result, lower inflation and mortgage financing cost work mainly through the intensive margin and do not significantly affect households' borrowing through the extensive (ownership) margin.

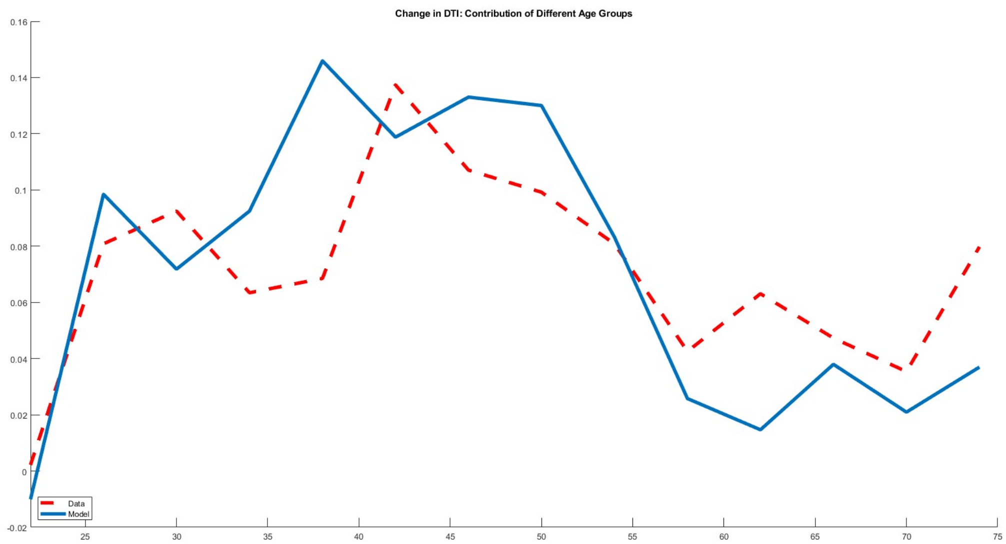
Figure 10: Changes in Homeownership rates, LTV and DTI



5.1.2 Decomposing the Contribution of Different Age Groups to the Rise in Aggregate Mortgage Debt

Motivated by the observation that middle-aged households account for the majority of the rise in the aggregate household debt from 1980s to 2000s, we decompose the contribution of different ages to the rise in mortgage debt in our simulations. As in our data decomposition in Section 2, we compute the ratio of the rise in average mortgage debt for each age group using the corresponding population share as weights to the rise in total mortgage debt between the two steady states. Figure 11 compares the model-simulated decomposition with its data counterparts. The contribution of different age groups our model largely overlaps with what we find in the data. Consistent with the data decomposition, the prime age buyers (from 30-55) contribute to more than half of the rise in the aggregate mortgage debt borrowing in our model. This provides additional support for the validation of our model.

Figure 11: Rise in DTI: Contribution of Different Age Groups



5.1.3 Larger Homes and the Rise in Debt

The decline in nominal interest rates that follows a decline in inflation and lowering mortgage closing cost create space for younger homebuyers to purchase higher priced homes. Since real house prices did not increase over the 1980s and 1990s, this would allow homebuyers to purchase larger homes. This shift towards larger houses would in turn contribute to higher levels of debt to income.

We find this mechanism is at work in our model simulations. We compute the average house size by age for homeowners in the two steady states. As we can see in Figure 12, the 2001 calibration with lower inflation and mortgage financing cost features larger average house sizes for young and middle-aged owners.

While not directly comparable to the average house size of homeowners in our model, the average size of newly constructed homes has also increased. Figure 13 plots the distribution of square footage of new builds in the U.S. By the 1990s, there was a marked rise in the fraction of larger homes being built. Consistent with our simulations, this pushed up the average size of U.S. homes.

Figure 12: Changing House Size: Model and Data

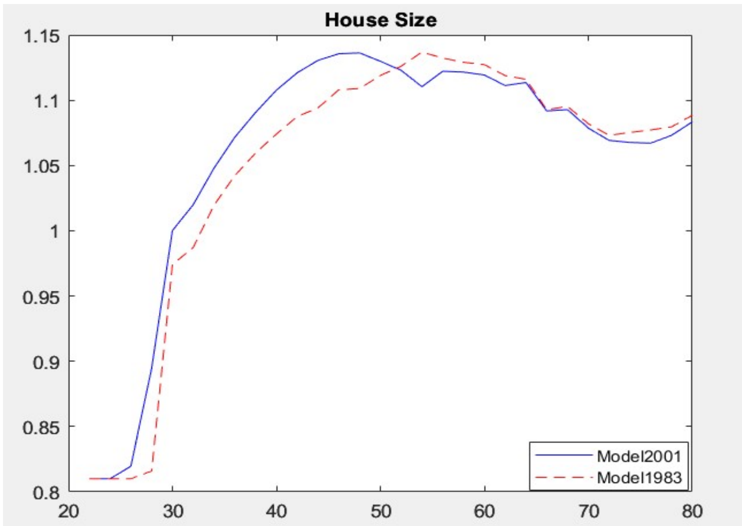
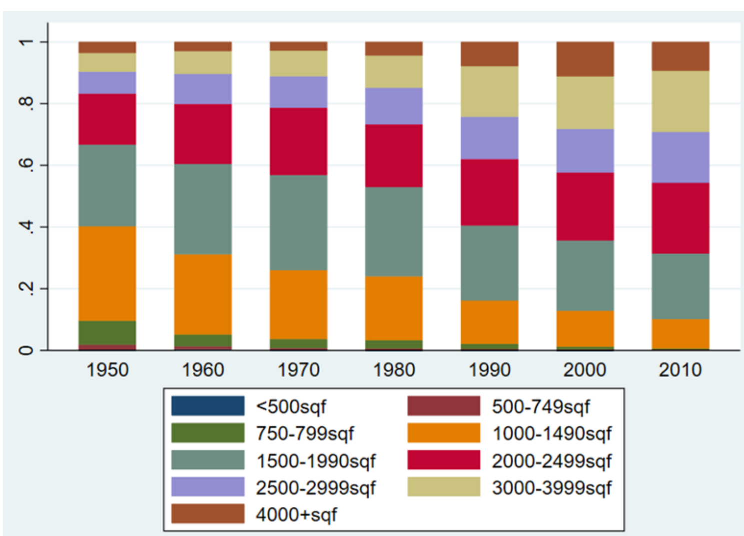


Figure 13: Unit Size by Year of Construction



To estimate the contribution of larger houses to the increase in mortgage debt we apply the following formula to attribute a share of the additional mortgage borrowing to larger homes:

$$ContributionH = \frac{\sum_a \alpha_a LTV_a P(H_{a,2001} - H_{a,1983})}{\sum_a \alpha_a (d_{a,2001} - d_{a,1983})} \quad (20)$$

where α_a is the population share of age group a (which is fixed in our simulations), χ is the downpayment requirement, LTV_a is the average loan to value ratio of age a, P is the house price and $H_{a,2001} - H_{a,1983}$ is the average house size adjustment of age a in the two steady states. The numerator is the overall rise in mortgage debt due to households buying larger homes while the denominator is the total rise in mortgage debt. Equation 20 calculates the fraction of rise in household debt due to the increase in house size under the assumption that households borrow up to the limit (e.g. $(1-\chi)$) to finance additional housing purchase. According to this calculation, changes in house size can account for about 20% of the overall increase in aggregate mortgage debt.[17]

5.2 The Contribution of Maximum LTV Constraint and Cap on Payment-to-Income ratio to Higher Mortgage Debt: 2001-2016

Since 2000, innovations in mortgage lending effectively reduced the maximum Loan-to-Value ratio for many mortgagors. As the first decade of the 2000s saw a boom and bust in the housing market (see e.g. Mian and Sufi, 2009; Kaplan *et al.*, 2020), we compare the model predictions between the pre-boom period and 2016.[18]

To evaluate the impact of relaxing maximum Loan-to-Value constraint on household debt, we reduce the downpayment requirement from 20% to 10% in the economy calibrated to 2001. A 10 percentage point increase in the maximum Loan-to-Value predicts a 6.81 percentage points rise in the Debt-to-Income ratio (see Table 5). The average Debt-to-Income ratio in the 2016 Survey of Consumer Finance is 64.5%, 5.2 percentage points higher than 2001. This is roughly 1.4 percentage points less than the increase in Debt-to-Income Ratio produced by

[17] 21.39% if we apply the LTV in 2001 and 19.23% when we apply the LTV in 1983.

[18] The increase in mortgage defaults following the 2007 housing crash likely limited access to credit for some households and also had a significant impact on lenders. Since 2016 is nearly a decade after the crisis began, it provides a better targets for our steady state analysis of the impact of relaxing maximum loan-to-value ratios on mortgage debt relative to income.

our model simulations.

In addition to a decrease in the downpayment requirement, we introduce a cap on the mortgage payment-to-income ratio. The Dodd-Frank legislation imposed a 43% cap on the total payment-to-income ratio, which includes mortgage and consumer credit. Since this implies a tighter limit on the mortgage payment to income ratio, in counterfactual we impose a mortgage payment to income ratio of 36%.[19] Introducing a cap on the mortgage payment-to-income ratio reduces the debt-to-income ratio by 2.39 percentage points to a level roughly 1 percentage below that of the 2016 SCF.

Table 5: Impact of Relaxing Maximum LTV and Cap on PTI

	Debt-to-Income Ratio
Model 2001	59.11%
Maximum LTV (80%->90%)	65.91%
Max LTV (80%->90%) + Cap on PTI	63.52%

6 Macroprudential Regulations in High and Low Inflation Environments

Our experiments show that changes in the trend inflation rate can impact the level of mortgage debt and house size over the life-cycle. Since a key mechanism via which the level of inflation impacts housing markets is by alleviating borrowing limits on younger homebuyers, this suggests that the efficacy of macroprudential regulations such as downpayment requirements and cap on payment-to-income ratio occurred could vary with the level of inflation.

To explore this, we compare the effect of the downpayment requirement and the 36% cap on the payment to income ratio at 2 and 7 percent inflation. In our experiments, we hold the parameters fixed at our 2001 benchmark calibration. The results are presented in Table 6. Relaxing the downpayment requirement increases the DTI by 5.6 percentage points which is about 82% (5.6/6.8) of its impact when inflation is at 2 percent. Meanwhile, imposing a cap on payment-to-income ratio reduced debt-to-income ratio by 10.3 percentage points, which is twice as big as its impact when inflation is low (see Table 5). Intuitively, when inflation is

[19]This value is similar to that of (Greenwald, 2018).

high, mortgage takers tend to have a higher payment-to-income ratio at the beginning. As a result, a cap on the payment-to-income ratio is more likely to bind and reduce households' borrowing.

Table 6: Impact of Relaxing Maximum LTV and Cap on PTI when Inflation is High

	Debt-to-Income Ratio
Model 2001 + inflation 7%	54.90%
Maximum LTV (80%->90%)	60.5%
Max LTV (80%->90%) + Cap on PTI	50.2%

7 Conclusion

We develop a life-cycle housing tenure choice model to understand the role of changing inflation, declining mortgage financing cost, relaxing downpayment requirement, and the cap on payment-to-income ratio on household debt. We find that declining inflation and reducing mortgage financing cost can account for 57% of the rise in debt-to-income ratio between 1980s to 2001. Looking forward, relaxing downpayment requirement and the introduction of a cap on the payment-to-income ratio can largely account for the observed change in payment-to-income ratio from 2001 to 2016, the post financial crisis period.

We apply the model to discuss the effectiveness of mortgage-related macroprudential policies in high and low inflation environment. We find that relaxing downpayment requirement has a larger impact on the mortgage debt when inflation is low while adjusting the cap on payment-to-income ratio has a larger impact on mortgage debt when inflation is high.

Appendix

Age decomposition

To examine the contribution of shifts in the age distribution of the U.S. population we use a simple decomposition between the contribution of shifts in the U.S. population and divides the rise in mortgage debt between a shift in the age distribution (holding fixed the mortgage debt to income ratio by age groups in 1983) and a change in mortgage debt.

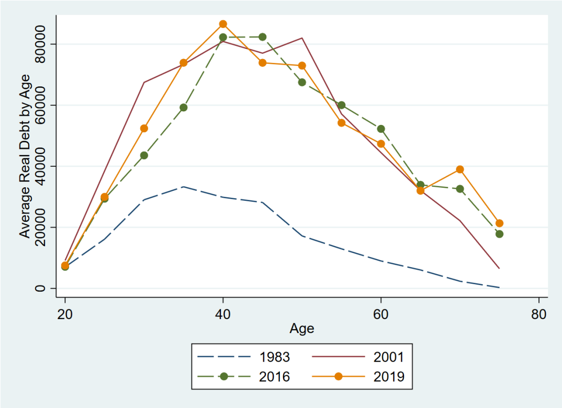
$$\underbrace{D_t}_{\text{Aggregate DTI}} = \sum_a \underbrace{\alpha_{a,t}}_{\text{population share of age a at time t}} \underbrace{d_{a,t}}_{\text{DTI of age a households at time t}} \tag{21}$$

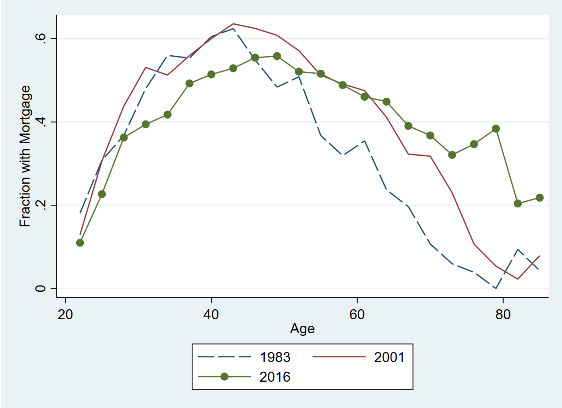
The DTI ratio is defined as the ratio of the total mortgage debt among age a households to the total household income of all age a households: $DTI = \frac{\sum_{i\in a} MortgageDebt_{i,t}}{\sum_{i\in a} Income_{i,t}}$. Our age decomnposition is:

$$D_{2001} - D_{1983} = \underbrace{\sum_a \alpha_{a,2001}(D_{a,2001} - D_{a,1983})}_{\text{Contribution of change in DTI across different age groups}} + \underbrace{\sum_a D_{a,1983}(\alpha_{a,2001} - \alpha_{a,2001})}_{\text{Contribution of change in population structure}} \tag{22}$$

This decomposition implies that the total change in debt $D_{2001} - D_{1983} = 0.21$, and that the contribution from the change in DTI across age groups is 0.2129. The contribution from the change in population structure is small and negative at -0.0072. In our decomposition of DTI across age groups, we attribute: $\frac{\alpha_{a,2001}(D_{a,2001} - D_{a,1983})}{\sum_a \alpha_{a,2001}(D_{a,2001} - D_{a,1983})}$.

Figure 14: Extensive and Intensive Margins





References

[1] N. Bhutta, "The ins and outs of mortgage debt during the housing boom and bust," *Journal of Monetary Economics*, vol. 76, pp. 284–298, 2015.

[2] M. Chambers, C. Garriga, and D. E. Schlagenhauf, "Accounting for changes in the homeownership rate," *International Economic Review*, vol. 50, no. 3, pp. 677–726, 2009.

[3] G. Debelle, "Macroeconomic implications of rising household debt," Bank for International Settlements, Basel, Working Paper 153, 2004.

[4] K. Dynan and D. Kohn, "The rise in u.s. household indebtedness: Causes and consequences," Federal Reserve Board, Washington, Working Paper 37, 2007.

[5] G. Favara and J. Imbs, "Credit supply and the price of housing," *American Economic Review*, vol. 105, no. 3, pp. 958–92, 2015.

[6] C. Garriga, F. E. Kydland, and R. Šustek, "Mortgages and monetary policy," *The Review of Financial Studies*, vol. 30, no. 10, pp. 3337–3375, 2017.

[7] D. Greenwald, "The mortgage credit channel of macroeconomic transmission," 2018.

[8] N. Guner, R. Kaygusuz, and G. Ventura, "Income taxation of us households: Facts and parametric estimates," *Review of Economic Dynamics*, vol. 17, no. 4, pp. 559–581, 2014.

[9] A. M. Guren, A. McKay, E. Nakamura, and J. Steinsson, "Housing wealth effects: The long view," *The Review of Economic Studies*, vol. 88, no. 2, pp. 669–707, 2021.

[10] J. Heathcote, F. Perri, and G. L. Violante, "Unequal we stand: An empirical analysis of economic inequality in the united states, 1967–2006," *Review of Economic dynamics*, vol. 13, no. 1, pp. 15–51, 2010.

[11] G. Kaplan, K. Mitman, and G. L. Violante, "The housing boom and bust: Model meets evidence," *Journal of Political Economy*, vol. 128, no. 9, pp. 3285–3345, 2020.

[12] D. R. Lessard and F. Modigliani, "Inflation and the housing market: Problems and potential solutions," 1975.

[13] Z. Li, "Household debt among older americans, 1989-2016," *Washington, DC: Congressional Research Service*, 2019.

[14] I. Livshits, J. MacGee, and M. Tertilt, “Accounting for the rise in consumer bankruptcies,” *American Economic Journal: Macroeconomics*, vol. 2, pp. 165–193, 2010.

[15] I. Livshits, J. MacGee, and M. Tertilt, “The democratization of credit and the rise in consumer bankruptcies,” *Review of Economic Studies*, no. 3, pp. 1673–1710, Oct. 2016.

[16] E. Ma and S. Zubairy, “Homeownership and housing transitions: Explaining the demographic composition,” *International Economic Review*, vol. 62, no. 2, pp. 599–638, 2021.

[17] J. MacGee, *The rise in consumer bankruptcy and consumer credit: Cause for concern?* Commentary No. 356, C.D. Howe Institute, Apr. 2012.

[18] J. Mason and A. Jayadev, “”fisher dynamics” in us household debt, 1929-2011,” *American Economic Journal: Macroeconomics*, vol. 6, pp. 214–234, 2014.

[19] A. Mian and A. Sufi, “The consequences of mortgage credit expansion: Evidence from the us mortgage default crisis,” *The Quarterly Journal of Economics*, vol. 124, no. 4, pp. 1449–1496, 2009.

[20] A. Mian and A. Sufi, “House prices, home equity-based borrowing, and the us household leverage crisis,” *American Economic Review*, vol. 101, no. 5, pp. 2132–56, 2011.

[21] A. Mian and A. Sufi, “Credit supply and housing speculation,” National Bureau of Economic Research, Tech. Rep., 2018.

[22] J. Sanchez, “The relationship between wage growth and inflation,” *Federal Reserve Bank of ST. Louis: On the Economy Blog*, 2015.

[23] K. Sommer, P. Sullivan, and R. Verbrugge, “The equilibrium effect of fundamentals on house prices and rents,” *Journal of Monetary Economics*, vol. 60, no. 7, pp. 854–870, 2013.

[24] G. Tauchen, “Finite state markov-chain approximations to univariate and vector autoregressions,” *Economics letters*, vol. 20, no. 2, pp. 177–181, 1986.

[25] F. Yang, “Consumption over the life cycle: How different is housing?” *Review of Economic Dynamics*, vol. 12, no. 3, pp. 423–443, 2009.

[26] Y. Yao, “Land and the rise in the dispersion of house prices and rents across u.s. cities,” 2019.