Trend Inflation Matters: The Long-term Effects of Changes in Trend Inflation on Mortgage Debt

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Abstract

Standard mortgage contracts are written in nominal terms. As a result, higher levels of anticipated inflation front-loads real mortgage payments and reduces outstanding debt relative to income more quickly over the mortgage amortization. Using a lifecycle housing tenure choice model with standard nominal mortgage contracts where inflation proportionately shifts nominal income growth and interest rates, we find that the decline in inflation from an average of 8% in the early 1980s to under 3% by 2000 combined with a drop in mortgage financing cost can account for 52% of the rise in US mortgage debt between 1983 and 2001. Following an unanticipated permanent change in inflation, we find that it can take another 20 years for mortgage debt to income and homeownership rates to reach the new steady state. The length and dynamics of the transition depends on how quickly inflation reaches the new steady state level; whether mortgages have fixed or adjustable rate and as well as whether inflation increases or decreases. The option to refinance gives rise to an asymmetry between transitions following a permanent fall versus rise in inflation. We also find that transitions are shorter with adjustable-rate than with fixed-rate mortgages.

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

JEL: E21, E50, G51, R21

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1 Introduction

The 5-year average of annual inflation in the U.S. fell from around 8% in 1980 to near 2 % in the early 2000s. This decline in the level of anticipated (which we refer to as trend) inflation was accompanied by a rise in mortgage debt from around 40% to over 60% of disposable personal income by the early 2000s. A similar pattern of large declines in inflation from close to 10% in the early 1980s to near 2% by the 2000s was followed by a rise in mortgage debt in most developed economies. This raises the question of whether the level of anticipated inflation may have real effects on the mortgage debt-to-income ratio via the housing market.

We show that standard fixed amortization mortgage contracts — which are written in nominal terms — leads to the steady state mortgage debt-to-income ratio decreasing in the level of anticipated (trend) inflation. The model we develop embeds the standard relationship whereby trend inflation proportionately shifts nominal interest rates and income growth into an incomplete markets housing tenure choice model with fixed amortization mortgages. Using the calibrated model we quantify the impact of the anticipated inflation rate on steady state mortgage debt relative to income and households' ownership decisions.

In our analysis, the real effects of anticipated inflation arise due to the interaction between mortgages that specify a constant nominal payment over the amortization period and trend inflation. The typical US residential mortgage specifies constant nominal monthly payments over a fixed amortization period (usually 30 years) at a fixed interest rate (with an option to refinance). For a given real interest rate, higher trend inflation increases the nominal interest rate, leading to higher (nominal) monthly mortgage payments. This implies that the real mortgage payment and real mortgage debt over the amortization period are inflation-dependent. In addition, nominal income growth moves proportionately with trend inflation. As a result, for a given mortgage balance, the higher is trend inflation, the higher the initial payment-to-income and the faster the payment-to-income ratio declines over the amortization period. Higher inflation thus front-loads the mortgage payment-to-income ratio.

We show that these forces, as well as borrowing constraints and costs of buying and selling homes, leads to trend inflation having a significant impact on the steady-state level of mortgage debt and homeownership. With borrowing constraints, higher initial payments limit the level of mortgage debt that young households can take on as higher mortgage payments crowd out non-housing consumption expenditures.[1] As a result, the level of inflation affects the homeownership and borrowing decisions of borrowing-constrained households.

We outline supportive empirical evidence consistent with how inflation affects the amortization schedule in our model (i.e., the path of real mortgage payments and mortgage payment

[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).

to income). In Section 2, we document the strong comovement between nominal mortgage interest rates, nominal income growth, and trend inflation. We also show the rise in US mortgage debt between 1983 and 2001 preceded the rise in real house prices. Using 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 than in 2000. This is consistent with the key model mechanism via which inflation shifts the timing of real mortgage payments and the payment-to-income ratio over a borrower's life cycle. Using the Survey of Consumer Finances (SCF), we document that, conditional on mortgage age, the fraction of mortgage balances paid is higher in 1983 when inflation is high than in 2001. This is consistent with how inflation affects the path of real debt with fixed amortization mortgages. Finally, we use the SCF to document that middle-aged mortgagors account for the majority of the rise in debt between 1983 and 2001.

We use our life-cycle model where households choose whether to rent or purchase a home to quantify the impact of changes in trend inflation on household's housing and life-cycle consumption. Our life-cycle housing tenure choice model assumes that all mortgages have a thirty-year amortization with fixed nominal payments.[2] To avoid tracking the change in prices and interest rates due to inflation, we map the household's nominal budget constraint into real terms so that real mortgage payments depend on inflation and mortgage age. Our baseline model includes a financial friction in the form of a maximum loan-to-value constraint. As a result, higher inflation, which increases mortgage payments, also tightens the credit constraint on younger households.

We calibrate the model to match the life-cycle profile of homeownership rates, loan-to-value ratios, debt-to-income ratios and payment-to-income ratios in the 2001 SCF to avoid the housing price swings during the run up to and subsequent to the financial crisis. In our baseline, we set inflation at its 2001 value of 2.8% and the mortgage origination (finance) cost at 1%.

We find that the level of anticipated and stable inflation has a significant impact on the steady state mortgage debt to income (DTI) ratio. In our calibrated model with a 1% refinance cost, a 1 percentage point increase in inflation leads to a 0.5 percentage point decrease in steady-state DTI as we vary annual inflation from 2 to 16%. With a refinancing cost of 2.5% (similar to the value in the early 1980s), inflation has a larger impact on mortgage debt with each percentage point increase in inflation leading to a decline of roughly 0.9 percentage points in the DTI. The reason is that a higher refinancing cost makes it less attractive for households to refinance to reduce their payments during the early years of the mortgage

[2]Fixed-rate mortgage (FRM) and adjustable-rate mortgages (ARM) are the most common mortgage contracts among U.S. borrowers. In our steady state analysis, where inflation and mortgage interest rates are constant, there is little difference between a sequence of ARMs and an FRM. In the transitional analysis, ARMs may see a change in nominal payments as detailed in 4.2.

term. This reduces the extent to which households undo the tightening of borrowing constraints due to higher inflation at mortgage origination by subsequently refinancing. We also find that trend inflation has a significant impact on homeownership rates, particularly on younger households. These effects of anticipated inflation are significant: the impact of a 5 percentage point difference in anticipated inflation on steady-state mortgage debt relative to income is comparable to that of a 25 bps decline in the risk-free rate.

We use the calibrated model to ask whether the fall in inflation was a significant contributor to the rise in US mortgage debt. In our early 1980s counterfactual, we hold fixed the calibrated parameters except for inflation and the mortgage refinancing cost, which we set to 8% and 2.5%. We find that the fall in inflation and refinancing costs between the early 1980s and early 2000s imply a 14 percentage point increase in the steady state debt-to-income ratio, which is 52% of the observed 26 percentage points increase in the debt-to-disposable income ratio from 1983 to 2001.[3] Our decomposition attributes 60% of the rise in debt-to-income ratio to lower inflation backloading debt payments without changing household borrowing, with the remainder resulting from changes in household borrowing.

Lower inflation and lower mortgage finance cost allow younger households to borrow more, and thus buy a house closer in size to their preference during their middle age years. This results in an increase in the average house size of young and middle-aged homeowners, which accounts for more than a fifth of the rise in debt between 1983 and 2001 in our counterfactual. This increase in house size is qualitatively consistent with the rise in the size of new houses since the 1980s.[4]

What happens along the transition following a large change in trend inflation similar to the early 1980s? To tackle this question, we examine transitions following an unanticipated permanent MIT shock to trend inflation. We show that the duration of the inflation transition and whether mortgages have fixed or variable rates affect the transitional dynamics of homeownership and mortgage debt. We find that it can take a long time – another 15-30 years after the inflation transition ends– for the economy to complete the transition between steady states following an unanticipated permanent change from high (8%) to low trend inflation (2%). This long transition reflects housing choices over the life-cycle. Following a permanent decline in trend inflation, existing mortgagors experience a negative wealth shock as their nominal debt is fixed, while their nominal income grows slower than expected.[5] Combined with the costs of adjusting housing, these wealth effects slow the adjustment of

[3]In our counterfactuals, we hold the real price of housing fixed. This is consistent with the observation that real housing prices did not rise until the early 2000s, well after the decline in inflation. This assumption also highlights the direct impacts of inflation on household housing choices.

[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`).

[5]Doepke and Schneider (2006) document similar effects from unanticipated changes in inflation on the real value of household debt, home equity, and wealth.

mortgagors to the new steady state.

In the steady state, so long as ARMs and FRMs have the same amortization and refinancing cost, trend inflation has the same impact on household decisions.[6] However, along the transition ARM and FRM can have different implications for the wealth effects of changes in inflation since ARMs are indexed to current interest rates (and thus inflation). Surprisingly, we find that the option to refinance FRMs leads to similar transitional dynamics for mortgage interest payments. When the transition in inflation occurs in one period, the rise in homownership and DTI along the transition is gradual and similar in both the FRM and ARM economy. In contrast, we find that a gradual decline in inflation can lead to large differences between an economy with FRM or ARM. In an economy with ARMs, homeownership and DTI converge smoothly to the new steady state, albeit more slowly than following a fast decline in inflation. In a FRM economy, however, following a gradual (announced) decline in inflation from 8 to 2% over 9 periods (18 years), homeownership rates and aggregate DTI initially decline. This is due to our assumption that mortgage interest rates at origination are related to inflation the next period. As a result, the expectation of lower nominal rates as inflation falls leads some households to delay purchasing a house, leading to a fall in homeownership and DTI in the initial years of the transition.

We examine a transitional experiment that captures key features of the US experience over the 1980s and early 1990s. Specifically, we take the 8% inflation steady state and introduce a sudden drop in inflation to 4% followed by an expected gradual decline in inflation and mortgage closing cost to 2.8% and 1% respectively in another 5 periods (10 years). We show that our simulation is roughly consistent with the timing of the rise in mortgage debt and that the transition was largely complete by 2001 which suggests that our steady state experiments provide a reasonable of the long-run impact of fall in inflation.

Motivated by the suggestion of some economists that central banks should increase their inflation targets (e.g., Blanchard *et al.*, 2010), we examine an unanticipated *increase* in inflation from 2% to 5%. This results in a more gradual change in homeownership and debt than in the transition following a fall in inflation. Central to this slower transition is the lock-in effect of mortgages originated in the 2% inflation steady state which leads to a fall in mortgage refinancing as mortgagors benefit from low real rates on existing mortgages. Combined with the wealth effect from a lower real value of mortgage debt, the lower PTIs for existing mortgagors slows the transition from homeownership to renting.

Our paper contributes to a long standing debate on the consequences of inflation for mortgage borrowing (see, e.g., Lessard and Modigliani, 1975 and Garriga *et al.*, 2017). Our paper is most closely related to MacGee and Yao (2024) who examine the welfare costs of

[6]This assumes the same mortgage spread for FRM and ARM, which is natural in our steady state since there is no interest rate risk.

inflation arising from the impact of inflation on housing markets. Although the core mechanism is similar, MacGee and Yao (2024) focus on the interactions between the elasticity of housing supply and the welfare costs of inflation. In this paper, we quantitatively evaluate the impact of the level of trend inflation on household mortgage debt and find that it has a significant impact on the mortgage debt-to-income ratio as well homeownership and we show that transitions following a change in trend inflation can be prolonge and vary with mortgage structure (FRM and ARM). Doepke, Schneier, *et al.* (2019) also argue that with fixed amortization contracts, changes in inflation due to monetary policy can have distributional effects. We differ both in our focus on the relationship between inflation and the level of mortgage debt relative to income as well as well as in highlighting the role of refinancing in shaping transitional dynamics following a permanent change in trend inflation. Our paper is also related to the transmission of monetary policy. Eichenbaum *et al.* (2022) and Berger *et al.* (2021) argue that with long-term mortgage contracts the effectiveness of monetary policy is state dependent in that it depends on the distribution of mortgage rate across borrowers. We show that the history of trend inflation can also give rise to state dependence, and that the level of inflation targeted impacts the DTI and homeownership.

Although recent papers have quantitatively examined the role of changes in mortgage markets and related policies on household borrowing, ownership decisions, and house prices (Chambers *et al.*, 2009; Iacoviello and Pavan, 2013; Sommer *et al.*, 2013; Zhang, 2022), the impact of anticipated inflation has been less studied. Justiniano *et al.* (2019) show that a fall in real mortgage rates in the early 2000s could account for the rapid rise in US mortgage debt and house prices.[7] Our paper complements this literature by showing that anticipated inflation can have a significant impact on steady-state mortgage debt and showing that the fall in inflation can account for the majority of the rise in U.S. mortgage debt in the 1980s and 1990s. This paper is also related to work examining 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 Finance and conclude the rise in household debt is largely due to increased mortgage debt.[8] Bhutta (2015) decomposes the role of inflows and outflows of mortgage payments between 1999 and 2013, but does not consider the contributions of inflation to these changes. [9]

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

[8]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).

[9]Our model is related to work that highlights the role of payment-to-income constraint. Greenwald (2018) finds that that changes in a cap on the mortgage payment-to-income ratio is important for understanding boom-bust cycles. Ma and Zubairy (2021) argue that limiting the payment-to-income ratio in structural housing tenure choice models has implications on homeownership rates across age groups. In this paper, we highlight that with long-term fixed-nominal-payment debt, inflation affects household credit constraints by

The remainder of this paper is organized as follows. Section 2 examines several key features of the empirical evidence. Section 3 uses a simple numerical example to illustrate the implications of inflation for mortgage payments. Section 4 outlines the model, while Section 5 discusses the calibration strategy. Section 6 conducts several counterfactuals examining changes in inflation and interest rates on steady-state mortgage debt and housing consumption. Section 7 discusses the implications of unanticipated transitory and persistent changes in inflation and mortgage rates. Section 8 concludes.

2 Empirical Evidence

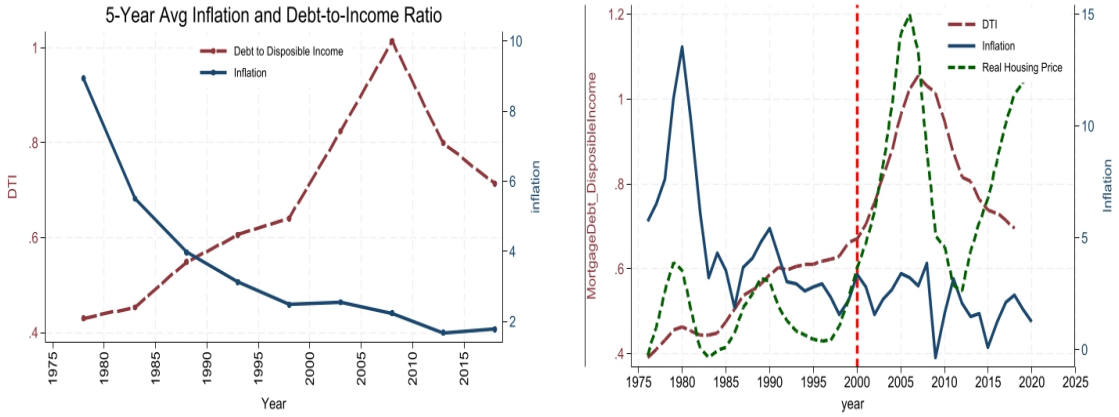
In this section, we document several empirical observations that motivate key features of our model as well as suggestive evidence consistent with how the level of trend inflation affect the mortgage debt-to-income ratio. First, the ratio of mortgage debt to personal disposable income ratio rose by more than 20 % between the late 1970s and early 2000s. Moreover, this rise in mortgage debt relative to personal income precedes the rise in house prices relative to income. We also show that this pattern was not unique to the US, as a similar pattern was observed in other advanced economies. 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. In the next section, we use an example to show that the predictions of standard theory for how a decline in inflation shifts the profile of mortgage payments and outstanding debt 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 1 plots the US mortgage debt to income ratio, inflation, and the real house price index since 1975. The ratio of mortgage debt to income rose by roughly 20 percentage points between 1980 and 2001 from 40% to more than 60%. The rise in debt over this period does not appear to be driven by house 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 (GFC), 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.

shifting the payment to income ratio even in the absence of a binding PTI constraint.

Figure 1: Mortgage Debt to Income Ratio, Inflation and House Prices



(a) Inflation and Debt-to-Income Ratio: 5 Year Average

(b) Inflation, Debt-to-Income Ratio and House Price Index: Annual

Note: Debt is the one to four family residential mortgage liability among households and non-profit organizations. Income is measured by disposable personal income. Annual inflation, debt and income are taken from FRED. We take the five-year average to illustrate the long-run trend for the left panel. 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 Other Developed Economies

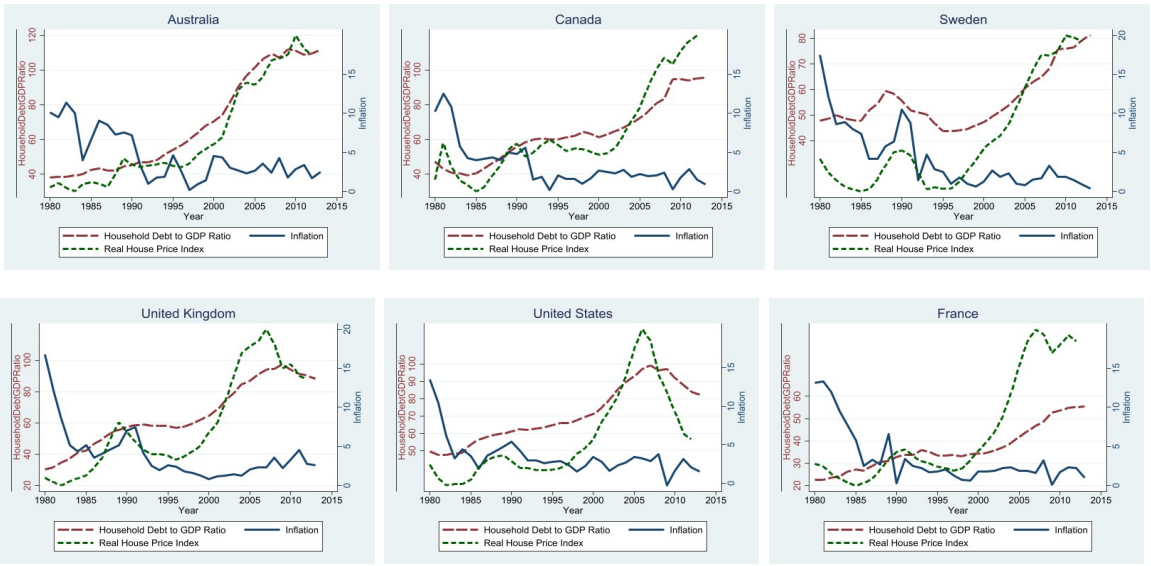
In addition to the United States, other developed countries saw a decline in trend inflation during the 1980s. Although the timing of the inflation decline varies across countries, the fall in inflation was generally followed by a rise in the household debt-to-GDP ratio which preceded the rise in real house prices. Using data from the IMF Global Debt Database, Figure 2 plots inflation, household debt-to-GDP ratio, and house prices in Australia, Canada, France, Norway, the United Kingdom and the United States since 1980.[10] Despite the difference in levels, we see similar trends in both debt-to-GDP ratio and mortgage debt to GDP ratio along the inflation decline. Moreover, all of these countries saw a decline in inflation followed by a rise in debt-to-GDP ratio from 1980 to early 2000.

As noted in the literature (see e.g. Albertazzi *et al.* (2024)) that developed economies vary in the types of popular mortgage contracts, we would like to emphasize that higher trend inflation leads to a higher initial and a faster decline of mortgage payment to income ratios with fixed-rate mortgages, adjustable-rate mortgages, and interest only mortgages. In steady state where inflation is fixed, adjustable-rate mortgages and fixed-rate mortgages have the

[10]Since household debt reported in the IMF Global Debt Database includes both mortgages and debts such as auto loans and credit cards, the household debt to disposable income ratio is higher than the household mortgage debt to GDP ratio in Figure 1. For a discussion of factors behind the rise of unsecured credit card debt, see Livshits *et al.* (2010) and Livshits *et al.* (2016).

same path of payments and debt evolution with the same mortgage interests. With respect to interest-only mortgages, higher trend inflation shifts up nominal mortgage interest and nominal income growth, which implies a front-loaded mortgage interest to payment ratios.

Figure 2: Mortgage Debt to GDP Ratio, Inflation and House Prices



Note: Household debt to GDP Ratio is measured by the household debt, loans and debt securities as percent of GDP. It is taken from the IMF Global Debt Database. Inflation data comes from IMF. Real House Prices are taken from Knoll *et al.* (2017).

2.3 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 (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.

To illustrate the impact of inflation on wage growth, we use the Current Population Survey (CPS) to construct nominal and real wage growth for two cohorts: the first born in 1956 and the second in 1986 (see Figure 3). The 1956 cohort experienced high inflation during the 1970s and 1980s, with inflation averaging 6.7% during their 20s. In contrast, the 1986 cohort experienced inflation that averaged 1.9% during their 20s. Despite the similar **real wage** growth of these cohorts (panel (b)), nominal wage growth for the 1956 cohort during the high inflation period was 50% higher than the 1986 cohort during the low inflation era.

Standard economic theory also implies that nominal interest rates should vary with anticipated inflation. Figure 3 panel (c) plots US inflation, the contract rate on 30-year mortgages,

Figure 3: Nominal Wage Growth, Real Wage Growth, Inflation and Mortgage Rates



(a) Nominal Wage Income (b) Real Wage Income (c) Mortgage Rates and Inflation

Note: 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. Panel (c) is constracted using data from FRED.

and the 30-year Treasury yield. Both the mortgage rate and the 30 year treasury yield co-move with inflation and the spread between the mortgage rate and treasuries is relatively stable.

3 Inflation, Mortgage Payments and Debt to Income

We use a simple numerical example to illustrate the key mechanism by which trend inflation changes the level of nominal mortgage payments and tilts the payment-to-income (PTI) and debt-to-income (DTI) ratios of a borrower. To isolate the direct effect of inflation on payments and debt with fixed-amortization mortgages, we focus on a fixed mortgage and housing choice. Our example illustrates that higher inflation pushes up (lowers) the PTI ratio early (later) in the term of the mortgage which front-loads real mortgage payments when inflation is high. For a given mortgage value and borrower's income at origination, the average DTI of a borrower over the mortgage term is decreasing in trend inflation. Using multiple waves of the Survey of Consumer Finances and Census we show that these predictions are qualitatively consistent with US data.

The example examines a $200,000 dollar mortgage with a real interest rate of 2% and a 30 year amortization. Consistent with standard theory and the data in Section 2.3, the nominal mortgage interest (r_m) depends on the real interest rate and the inflation rate π. For a fixed amortization, higher inflation increases the nominal mortgage payment: the nominal annual payment is $11,428 at 2 % inflation while for 8% inflation the payment nearly doubles to $21,385.[11] The impact of inflation on the payment to income ratio over the amortization

[11]The nominal mortgage payment is calculated using the annuity formula (see Equations 6 and 9).

period is amplified by nominal income growth. In panel (e) of Figure 4 we plot the real wage profile from the calibrated benchmark (see Section 5) and nominal lifecycle earnings for inflation of 2 and 8 %. Even a 6 percentage point difference in inflation has a large impact on the level of nominal income over a working life.

These effects mean that, for a fixed house purchase and mortgage downpayment, higher inflation increases the initial PTI ratio and steepens the slope at which it declines over the mortgage term (see Panel (a) in Figure 4).[12] In other words, when inflation is higher, mortgage payments account for a larger share of household income in the initial years of the mortgage but fall more quickly. Inflation also affects the evolution of (real) mortgage debt and the accumulation of home equity. Debt (in real terms) is paid down faster when inflation is higher: It takes about 8 years to pay half of the real debt at 8% inflation but 17 years at 2% inflation (see Panel b in 4). At the 10-year mark, a household in a 8% inflation environment has 42% of the (real) debt remaining while a household living in a 2% inflation environment has 67% remaining. Thus, when real income is not affected by inflation, the debt-to-income ratio is shifted up by 60% (67/42) when inflation is low 10 years after the mortgage contract is signed.[13]

We plot the empirical relationship between inflation and the path of mortgage payments in panels (c) and (d) of Figure 4. Consistent with the front-loading of mortgage payments under higher inflation, the cross-section of mortgage payment to income declines faster with age in 1980 (when inflation was high) than in 2000 when inflation had declined to under 3% (see panel (c)). In panel (d) we use the 1983 and 2016 Survey of Consumer Finance to plot mortgage balances over the life of a mortgage.[14] As in our illustrative example (see panel b in 4), households pay down their (real) debt faster during the initial years of a mortgage under higher inflation. The median fraction of debt outstanding after 10 years is 40% in 1983 when inflation was high and 65% in 2016 when inflation was low.

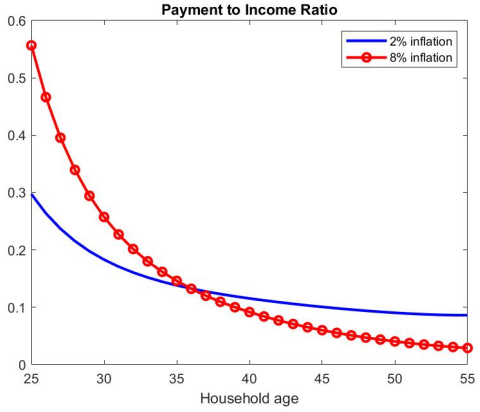
These effects can lead to inflation tilting the profile of life-cycle consumption. This effect is easy to see for a Hand-to-mouth (HTM) borrower as non-housing consumption is simply $1 - PTI$. However, for any borrowing constrained households, holding housing consumption fixed, higher inflation creates a force that tilts non-housing consumption profile to later in life. This mechanism also implies that changes in trend inflation may lead some borrowing constrained households to vary either the timing or the size of the house they purchase. We use our quantitative model to examine these forces in Section 6.

[12]The reference base period refers to the year when the mortgage contract is signed.

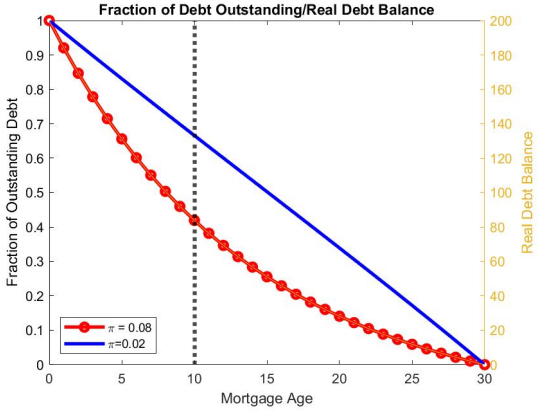
[13]The decline in inflation in the 1980s could be a contributing factor to the rise in the mortgage debt of senior households (see e.g. Li, 2019).

[14]The SCF reports the year of origination, the value at origination and the outstanding mortgage balance. As in panel (b), we deflate by the CPI to compute the real values and the fraction of debt outstanding by years since origination. We use the 2016 wave as by then inflation has been down for near 20 years so that the mortgage contracts signed 20 years ago have mortgage interests reflecting the low inflation.

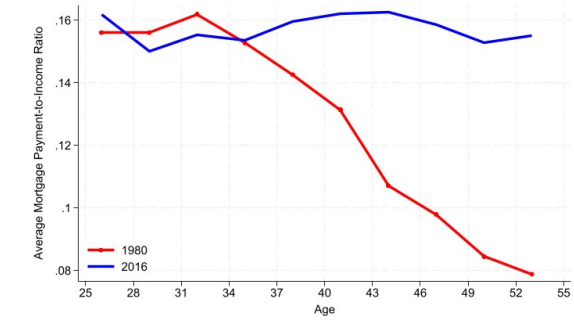
Figure 4: Inflation, Path of Payment-to-Income Ratio and Fraction of Outstanding Debt



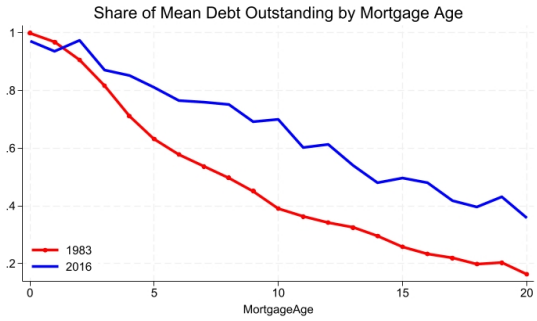
(a) Path of Payment to Income Ratio: Theory



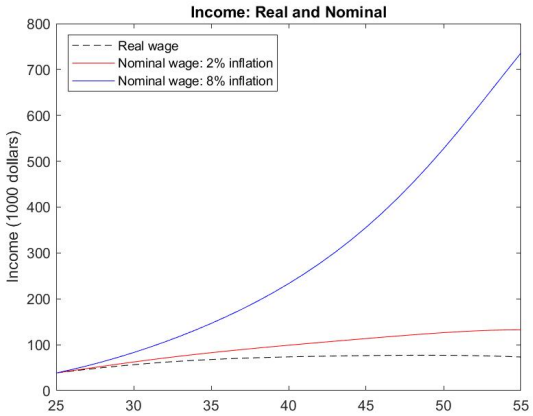
(b) Debt Evolution: Theory



(c) Payment to Income Ratio: Census and ACS



(d) Share of Outstanding Debt: SCF



(e) Nominal Income: Theory

Note: 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. In panel a, The average payment is for a 200,000 mortgage, where $m = \frac{r_m}{1-\frac{1}{(1+r_m)^N}}, 1+r_m = (1+r)(1+\pi)$.

3.1 Empirical Decomposition of the Rise in Household Debt

Our quantitative experiments in Section 6 show that the steady-state mortgage debt to income ratio varies negatively with the level of trend inflation. In addition, our results point to differences across age groups in their contribution to the rise in mortgage debt. We use data from the Survey of Consumer Finances to decompose the contribution by age to the rise in the mortgage debt-to-income ratio since the early 1980s. The rise in mortgage debt between 1983 and 2001 is primarily accounted for by higher mortgage debts of middle-aged homeowners.[15]

The direct effect of shifts in the age distribution of the US population between 1983 and 2001 is small and slightly *lowers* the debt-to-income ratio (see Appendix A for details). To unpack the contribution of different age groups to the rise in debt, we use the SCF to decompose the change in DTI into an extensive margin change in the fraction with a mortgage and an intensive margin change in the DTI for households with a mortgage. Given the modest sample size of the SCF, we group households into 5-year age bins from age 20-24 to 70-74, with households over 75 in one bin. Our decomposition weights the change in debt relative to 1983 in each age j by the share of total debt held by age j. Formally:

$$\frac{\bar{D}_{t+\tau}}{\bar{D}_t} = \frac{\sum_a d^a_{t+\tau}\alpha^a_{t+\tau}}{\bar{D}_t} = \sum_a \underbrace{\frac{d^a_{t+\tau}}{d^a_t}}_{\text{growth in avg debt for age a households}} \overbrace{\frac{d^a_t}{\bar{D}_t}\alpha^a_{t+\tau}}^{\text{share of debt held by age a households}} \tag{1}$$

where $\bar{D}_t$ is the average household mortgage debt at time t; $\frac{\bar{D}_{t+\tau}}{\bar{D}_t}$ is the growth of average household mortgage debt from t to $t+\tau$. d^a_t is the average household mortgage debt among age a households at time t. The contribution of age group a to the rise in mortgage debt is $\frac{\frac{d^a_{t+\tau}}{d^a_t}\frac{d^a_t}{\bar{D}_t}\alpha^a_{t+\tau}}{\frac{\bar{D}_{t+\tau}}{\bar{D}_t}}$.

Middle-aged homeowners account for the majority of the rise in the mortgage debt to income ratio between 1983 and 2001 (see Panel (a) of Figure 5). The cohort aged 40-43 in 2001 (who were 22-25 in 1983) alone account for more than one-sixth of the rise in total mortgage debt. In contrast, households over 60 years of age (who were more likely to own homes in 1983) combined account for less than a sixth of the total rise. Repeating this decomposition by age between 1983 and 2016 and 2019, we find a 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 period, this points to a persistent cohort

[15] 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 macroeconomic conditions when households entered the housing market.

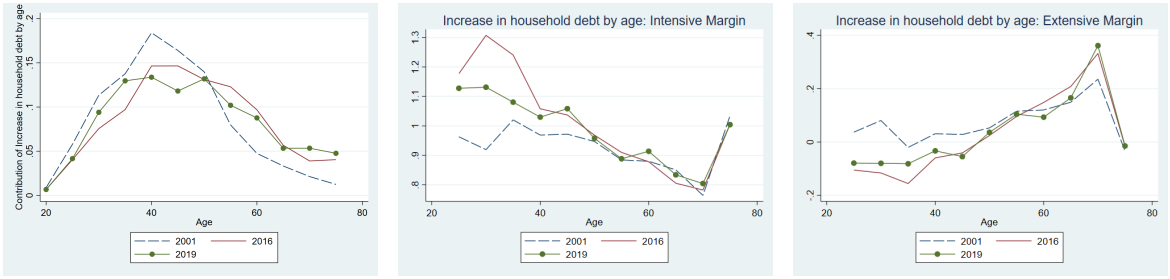
effect on mortgage debt.

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

$$d_{t+\tau}^a - d_t^a = \underbrace{\theta_{t+\tau}^a (x_{t+\tau}^a - x_t^a)}_{\text{Intensive Margin}} + \underbrace{x_t^a (\theta_{t+\tau}^a - \theta_t^a)}_{\text{Extensive Margin}} \tag{2}$$

As can be seen from the rightmost panel of Figure 5, the fraction of homeowners under 45 in 2001 was similar to that of 1983. However, among households over 45, the fraction with a mortgage in 2001 was higher than in 1983. This points to a slower paydown in mortgages for older households in 2001 than in 1983. This is consistent with the middle panel of Figure 5 which plots the average debt per mortgagor relative to the level in 1983.

Figure 5: Decomposition by Age: Extensive and Intensive Margins



(a) By Age (b) Intensive (c) Extensive

4 Model

To quantify the impact of trend inflation on household debt and homeownership, we develop a small-open economy life-cycle housing tenure choice model. Each period, households choose their consumption of a non-housing good and housing services. Consumers can obtain housing services by owning or renting. Compared to renting, owning is attractive since, conditional on house size, owning provides a higher service (utility) flow. This ownership premium captures the ability of owners to customize their homes according to their own taste. Although renters can costlessly adjust their consumption of housing services each period, buying or selling a house incurs transaction costs. In addition, each new mortgage sees households incur a closing cost (including mortgage refinancing).

We model trend (steady-state) inflation via how it affects real mortgage payments and

real debt outstanding in the budget constraint, based on the age of the mortgage. Our specification is equivalent to writing the budget constraint in nominal terms where the numeraire good price, house prices, rents, and nominal interest rates grow at the same rate as inflation while nominal mortgage payments do not change over time. The real rate of return on savings, r, is exogenous and does not depend on inflation.

4.1 Households

The economy is populated by J period lived overlapping generations of ex ante identical households who face mortality risks and uncertain labor income over their life. Households draw initial wealth from a distribution Γ at birth. Households preferences over the non-durable good C and housing services h are represented by

$$u(C,h) = \frac{((1-\eta)C^{1-\xi}) + \eta(\theta h)^{1-\xi})^{\frac{(1-\sigma)}{1-\xi}}}{1-\sigma} \tag{3}$$

where the ownership premium θ captures the additional value of owning compared to renting housing services h .[16] The share η captures the relative importance of housing compared to non-durable consumption while $\frac{1}{\xi}$ measures the substitutability between housing and non-housing consumption, and σ is the elasticity of intertemporal substitution.

Each period j, the household objective function is defined by

$$V_j = \frac{((1-\eta)C_j^{1-\xi}) + \eta(\theta h_j)^{1-\xi})^{\frac{(1-\sigma)}{1-\xi}}}{1-\sigma} + \beta_j s_j V_{j+1} + \beta_j(1-s_j)B(W_{T+1}). \tag{4}$$

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 $j+1$, C_j is consumption at age j, and h_j 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.

$$B(W_{T+1}) = \frac{B_0(B_1 + W_{T+1})^{1-\sigma}}{1-\sigma} \tag{5}$$

There are three assets in this economy: housing, risk-free bonds, and mortgages. House-

[16] 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 and living in an apartment.

holds can save through a risk-free bond that pays real interest r. Owner-occupied housing provides housing consumption and depreciates at rate δ. In addition, home owners pay property tax τ_h proportional to the value of their house Ph.

Buying and selling a house incur transaction costs. A buyer incurs a proportional (to the value of the house Ph) transaction cost of k_b and a seller incurs a total proportional transaction cost of k_s. The minimum size of an owner-occupied house is $\underline{h}$.

Timing: At the beginning of each period t, inflation π_t is realized and mortgage interest $r_{m,t}(n)$ is added to the outstanding nominal debt balance carried from the last period $D_{t-1}(n-1)$. At the end of each period t, households receive labor income and return on their savings, determine whether to adjust housing and mortgage debt borrowing, save and consume.

4.2 Mortgages: Payments and Debt Evolutions

Following the literature, we assume that households can only borrow via collateralized credit.[17] Mortgages are modeled as N-period fixed-amortization mortgage contracts with a financing cost of τ_m that households pay every time they get a new mortgage contract. In other words, the mortgage financing cost applies to new borrowers and existing owners who refinance. We consider both fixed rate mortgages and adjustable rate mortgages but abstract from the choice between these two types of mortgages. Fixed-rate mortgages and adjustable-rate mortgages are identical in the steady state analysis.

A mortgage contract is defined by mortgage interests, nominal mortgage payments, and nominal debt outstanding over amortization.[18] A mortgage contract issued at period t_0 is paid out from period t_0+1 to t_0+N.

4.2.1 Mortgage Interests

Mortgage interest is fixed over amortization for fixed rate mortgages (FRM). As households who originate a fixed rate mortgage at time t_0 start to make payments from the following period, t_0+1, the mortgage interest applied depends on the expected inflation of the following period, $E_{t_0}(\pi_{t_0+1})$.

For adjustable rate mortgages (ARM), the mortgage rate applied in period $t \in \{t_0+1, t_0+2, ...t_0+N\}$ depends on the realized inflation π_t. Equation 6 summarizes the mortgage interest for both ARM and FRM contracts.

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

[18] In the simulation, we convert mortgage payments and debt into real terms evaluated at the period when a mortgage contract is originated.

$$r^i_{m,t}(n) = \begin{cases} (1 + E_{t_0}(\pi_{t_0+1}))(1 + r)(1 + \zeta_m), & \text{if } i \text{ is FRM} \\ (1 + \pi_t)(1 + r)(1 + \zeta_m), & \text{if } i \text{ is ARM} \end{cases} \tag{6}$$

where $t_0 = t - n$ is the period when the mortgage contract is signed, r is the real risk free rate and ζ_m is a spread. Note that $E_{t_0}(\pi_{t_0}) = \pi_t = \bar{\pi}$ in steady state. Meanwhile, an unexpected in inflation leads to a change in the real mortgage interest.

4.2.2 Debt Evolutions and Mortgage Payments:

Nominal: In the period t_0 when a D amount of loan is issued, the total amount of outstanding loan is

$$D^i(0) = D \tag{7}$$

In all of the following periods $n \in \{1, 2, .., N\}$, the amount of outstanding loan in nominal terms is

$$D^i(n) = (1 + r^i_{m,t}(n))D^i(n - 1) - m^i_t(D(n - 1)) \tag{8}$$

where $D^i(n-1)$ is the loan carried from the previous period, $r^i_{m,t}(n)$ is the mortgage interest and $m^i_t(D(n-1))$ is the nominal mortgage payments specified as

$$m^i_t(D(n - 1)) = \frac{r^i_{m,t}(n)D^i(n - 1)}{1 - (1 + r^i_{m,t}(n))^{-(N+1-n)}} \tag{9}$$

Note that for fixed rate mortgages, mortgage interest is a constant. Denote $r^i_{m,t}(n) = r_{m,t_0}$, $m^i_t(n) = \frac{r_{m,t_0}D(0)}{1-(1+r_{m,t_0})^{-N}}$, which is also a constant over the amorization.

Real: Real mortgage payments $\tilde{m}^i$ and debt outstanding after making the mortgage payment $\tilde{D}^i(n)$ at period t using period t_0 as the reference period is given by

$$\begin{aligned} \tilde{D}^i(0) &= D \\ \tilde{D}^i(n) &= \frac{D^i(n)}{\prod_{k=0}^{n-1}(1 + \pi_{t-k})} \\ \tilde{m}^i_t(D(n - 1)) &= \frac{m^i_t(D(n - 1))}{\prod_{k=0}^{n-1}(1 + \pi_{t-k})} \end{aligned} \tag{10}$$

where n is the mortgage age, and $\prod_{k=0}^{n-1}(1 + \pi_{t-k})$ is the product of realized inflation since the mortgage is originated.

Equation 9 indicates that both nominal and real mortgage payments increase with the mortgage interest, which depends on the inflation level of the first period when borrowers start to make payments for FRM, and current inflation level for ARM. As a result, when

inflation goes down (up), the mortgage interest for FRM loans will be higher (lower) than ARM loans, as mortgage interest on ARM loans gets updated with current inflation. Mortgage payments on FRM loans will be higher (lower) than FRM loans, conditional on the outstanding loan carried from the previous period.

4.3 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.

$$y(j, \epsilon) = \bar{w_j}\epsilon_i \tag{11}$$

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

$$\epsilon_{i,j+1} = \rho\epsilon_{i,j} + \upsilon \tag{12}$$

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

$$\tau(y) = \tau_0 + \tau_1(log(y) - log(\bar{y})) \tag{13}$$

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.

4.4 Household's Recursive Problem

The state variables of a household, $\Lambda = (a, h, D, n, \epsilon, j)$, are their age j, house h, savings a, the amount of outstanding loans carried from previous period, mortgage age n, and the income shock ϵ.

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

1. *Households choose to be a renter*: A household who decides to be a renter chooses the

size of rental units x, consumption c, and saving a' to maximize:

$$V^1(a,h,D,n,\epsilon,j) = \max_{c,x,a'} u(c,x) + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',0,0,0,\epsilon',j+1)) + \beta_j(1-s_j)B(a')$$
$$s.t.\ \ c + a' + Rx = y(j,\epsilon) + (1+r)a + (1-k_s)Ph - \frac{(1+r^i_{m,t})D}{\prod_{k=0}^{n-1}(1+\pi_{t-k})} \tag{14}$$

where R is the real rental rate and $y(j,\epsilon)$ is the real after-tax household labor income. If the household owned a home in the previous period, choosing to be a renter requires them to sell their home (a household cannot own and rent at the same time). In this case, $(1-k_s)Ph$ is the profit from selling the house net of the selling cost. $\frac{(1+r^i_{m,t})D}{\prod_{k=0}^{n-1}(1+\pi_{t-k})}$ the real value of the debt. [19] $E(.)$ represents the expected value given current housing and mortgage decisions, taken over the distribution of future income shocks ϵ'. Note that renters start the next period with no housing asset ($h' = 0$) or mortgage debt ($D' = 0$). $\beta_j(1-s_j)B(a')$ captures the value of a bequest of value a'.

2. *Owners continue with their current mortgage contract*: An owner with a house $h > 0$ and outstanding mortgage loan D originated n years previously consumes housing services and chooses consumption c and savings a' to maximize her utility:

$$\begin{aligned} &V^2(a,h,D,n,\epsilon,j) = \max_{c,a'} u(c,\theta h) + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',h,D',n+1,\epsilon',j+1)\mathbb{1}_{n<N} \\ &+ V(a',h,0,0,\epsilon',j+1)\mathbb{1}_{n=N}) + \beta_j(1-s_j)B(W_T) \\ &s.t.\ \ c + a' = y(j,\epsilon) + (1+r)a - (\delta+\tau_h)Ph - \tilde{m}(D) \\ &D' = (1+r^i_{m,t}(n))D - m(D) \end{aligned} \tag{15}$$

$\tilde{m}(D)$ is the real mortgage payment (see Equation 10), and $(\delta+\tau_h)Ph$ is the maintenance cost and property tax of the house. $n = N$ represents the last period of the mortage so the balance in the following period is reset to zero, i.e. $D' = 0$ and $n' = 0$. W_T is the total wealth left by the household (savings plus home equity).

3. *Households choose to sign a new mortgage contract*: This case includes when a renter becomes an owner, an owner changes their house size, or an owner refinances while keep living in the current house. A household chooses their new housing asset h', mortgage contract D', savings a', and consumption c to maximize their current and

[19] The budget constraints are specified in real terms. Therefore, we convert the nominal mortgage payments m and the outstanding nominal debt D.

future expected utility.

$$
\begin{aligned}
&V^3(a,h,D,n,\epsilon,j) = \max_{c,h',D',a'} u(c,\theta h') + \beta_j s_j E_{\epsilon'|\epsilon}(V(a',h',D',1,\epsilon,j+1)) \\
&+ \beta_j(1-s_j)B(W_T) \\
&s.t.\ \ c + a' + Ph' = y(j,\epsilon) + (1+r)a - (\delta+\tau_h)Ph' - (k_s Ph + k_b Ph')\mathbb{1}_{h\neq h'} \\
&+ Ph - \frac{(1+r^i_{m,t})D}{\prod_{k=0}^{n-1}(1+\pi_{t-k})} + (1-\tau_m)D'
\end{aligned}
\tag{16}
$$

$$
\begin{aligned}
&D' \leq (1-\chi)Ph' \\
&\frac{r^i_{m,t}(n)D'}{(1-(1+r^i_{m,t})^{-N})(w_j\epsilon)} \leq \varphi.
\end{aligned}
\tag{17}
$$

Equation 16 specifies the budget constraint. Specifically, $(k_s Ph + k_b Ph')\mathbb{1}_{h\neq h'}$ represents the transaction costs of buying and selling a house when households adjust their house $h \neq h'$. For a household refinancing without changing their house size, this term is 0 as $h = h'$. $Ph - \frac{(1+r^i_{m,t})D}{\prod_{k=0}^{n-1}(1+\pi_{t-k})}$ is the real value of home equity for a household who was an owner in the previous period. τ_m is the closing (refinancing) cost of a mortgage.

Similarly to Greenwald (2018), we include a maximum Loan-to-Value ratio (LTV) and a Payment-to-Income ratio (PTI) on new mortgages. The first line in Equation 17 specifies the LTV constraint of a minimum downpayment of χ percent and the second line requires that the mortgage payment be less than φ of household income.

Households with state variable $\Lambda = (a,h,D,n,\epsilon,j)$ choose among the three options:

$$
V(a,h,D,n,\epsilon,j) = max\{V^1(a,h,D,n,\epsilon,j), V^2(a,h,D,n,\epsilon,j), V^3(a,h,D,n,\epsilon,j)\} \tag{18}
$$

5 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.[20] We adopt the generalized method of moments.

[20] As is common in the literature, we choose 2001 to avoid the boom and bust in the following years.

5.1 Externally Calibrated Parameters

Households are born at age 23, retire at 64 and live up to 81. Each period corresponds to two years. 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 the life-cycle evolution of household size.[21] Following the related literature (see, e.g. Kaplan *et al.*, 2020, Guren *et al.*, 2021), the intertemporal elasticity of substitution σ is set to 2. The common discount factor β, weight on housing in the utility function η, the substitutability between housing and non-housing consumption ξ, minimum house size $\underline{h}$ and the high ownership premium θ are calibrated.

The annual risk-free interest r is set to 2%. In the baseline analysis, we set inflation to $\pi = 2.8\%$, which is the average annual inflation between 1999 and 2001, and the mortgage spread $\zeta_m = 1.5\%$, which is the average difference between the contract mortgage interest rate in 2001 and the market yield on a 30-year Treasury bond. We set the annual property tax and depreciation cost at 1% and 1.5%, respectively, based on the average property taxes and owner costs reported in the 2016 American Community Survey. Transaction costs for buyers and sellers are $k_b = 6\%$ and $k_s = 2\%$ based on estimates in the literature (see, e.g., Sommer *et al.*, 2013). The mortgage financing cost is $\tau_m = 1\%$, which matches the average initial fees between 1999 and 2001 reported by the Federal Housing and Finance Agency.

For the calibration of the baseline (year 2001), we set the minimum downpayment χ to 20% and the payment-to-income constraint φ to 1.[22] The initial wealth distribution is constructed using the 2001 SCF. We allow for initial wealth to be correlated with first period income. For households aged 20 to 22, we sum the value of all assets for households whose income is higher than the average and households whose income is lower than the average and use it as the initial wealth distribution conditional on income. We use the 2000 Census to compute the median house value of owners and median gross rent.

We follow Kaplan *et al.* (2020) and approximate the life-cycle income profile with a fourth order polynomial 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_υ to 0.2, and the standard deviation of two years (per period) is $(1+\rho)\sigma_\upsilon$. The standard deviation of initial earnings 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 seven-state Markov chain (Tauchen (1986)). We set the income tax parameters τ_0 at 0.135 and τ_1 to 0.062, based on Guner *et al.* (2014).

Table 1 summarizes the externally calibrated parameters.

[21] 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.

[22] The Dodd-Frank legislation was introduced in 2010.

Table 1: Externally Calibrated Parameters

Parameter	Value	Source
Maximum of life length J	33	
Working life Jr	23	
Equivalence scale e_j		Standard in the literature
Survival Probabilities s_j		National Center for Health Statistics
Annual risk free interest rate	2%	Standard in the literature
Annual inflation rate π	2.8%	Inflation rate in 2001
Mortgage spread ζ_m	1.8%	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	1%	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

5.2 Internally Calibrated Parameters

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

Although the parameters are estimated jointly, several are closely related to specific moments. The ownership premium θ mainly targets the level of homeownership rates. Higher θ makes owning more attractive relative to renting, which increases 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 $\underline{h}$ when purchasing a home. The housing share in the utility function, η, and the substitutability between housing and non-housing consumption ξ are most closely related to the debt-to-income ratio and thus the mortgage payment-to-income ratios of owners. The bequest motive parameters, B_0 and B_1, influence the ownership rates and mortgage debts of senior households. A stronger bequest motive means that older homeowners are less likely

to reduce their housing equity through mortgage refinancing.

5.3 Calibration Results

The internally calibrated parameters values are similar to those of related work (see Table 2). The calibrated model matches the targeted age profile of homeownership rates, Loan-to-Value ratios, Debt-to-Income, and Payment-to-Income ratios reasonably well (see Figure 6).

Table 2: Calibration Results (updated)

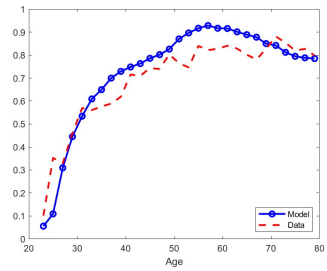
Parameter		Value	Target
β	Discount Factor	0.9	life-cycle LTV and DTI
η	Housing Share	0.27	DTI
ξ	Substitutability	1.2	DTI and LTV
θ	Ownership Premium	1.8	Homeownership Rate
$\underline{h}$	Minimum House Size	0.9	Homeownership Rate
B_0	Bequest Motive	13	Homeownership Rate & Mortgage Loan
B_1	Bequest Motive	0.1	of Senior Households

We also compare the model predictions for several non-targeted moments: the rent to income ratio, the level of average mortgages and average housing value. As we can see from Figure 6, our model successfully replicates key statistics of the US housing market. The fraction of owners who do not move while increase their loan balance (i.e. refinance) is 14.3% per period which is 7.15% per year. This is close to the estimates by Boar *et al.* (2022).

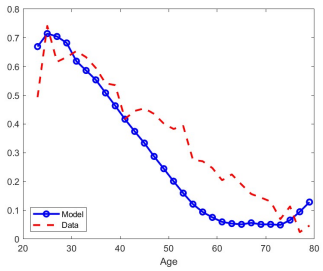
Although we do not directly target non-housing consumption, the calibration delivers a standard hump shaped consumption profile (see panel (h) of Figure 6). Consistent with US non-housing expenditure reported by Foster (2015), non-housing consumption in our benchmark peaks between age 45 to 50 at a level about twice as high as the consumption of 20-25-year olds and the over 75.

Behind this average profile are different profiles for the cross-section of homeowners and renters. In panel (i) of Figure 6 we plot the lifetime non-housing consumption profile of homeowners and renters. As in the data, homeowners have higher average income compared to renters which results in the non-housing consumption of owners being roughly three times as high that of renters. The hump in non housing consumption is also more pronounced for homeowners. In part, this reflects selection as the rise in the homeownership rate results in the mean income of renters falling for younger households.

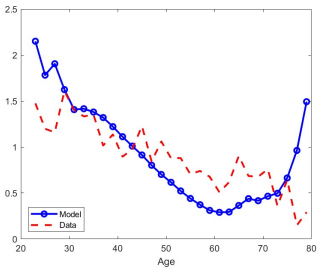
Figure 6: Benchmark Calibration



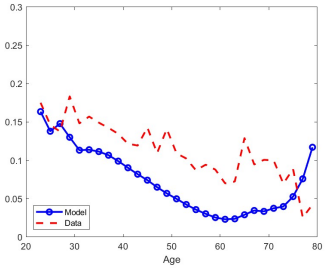
(a) Ownership Rates (Target)



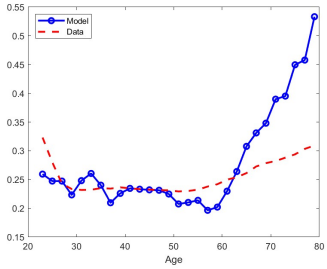
(b) Loan-to-Value (Target)



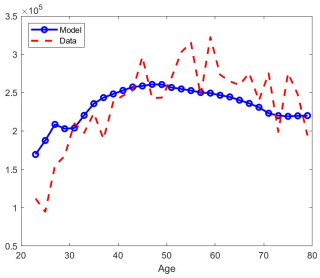
(c) Debt-to-Income (Target)



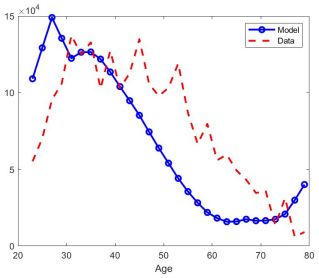
(d) Payment-to-Income (Target)



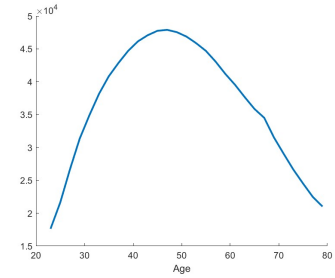
(e) Rent-to-Income



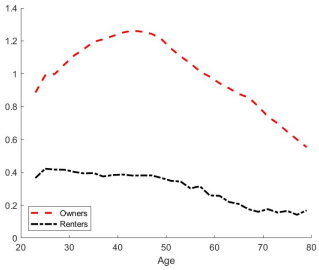
(f) House Value: Owners



(g) Mortgage Debt: Owners



(h) Average Non-housing Consumption



(i) Average Non-housing Consumption by Tenure

Note: The model period is 2 years. Data moments are from the Survey of Consumer Finances 2001. The Loan-to-Value ratio is the ratio of total outstanding mortgage debt to total house value of all owners. Debt-to-Income is the ratio of total mortgage debt to total household labor income of owners. Payment-to-Income is the ratio of total mortgage payment to total household labor income of owners. Consumption is the annualized average non-housing consumption measured in 2001 dollars.

6 Counterfactual Experiments: Steady-state analysis

We use our parameterized model to quantify the effect of the level of trend inflation on mortgage debt to income. In our experiments we vary steady state annual inflation between 2 and 20 %. We find that higher levels of anticipated inflation lower the steady state mortgage debt to income ratio. We also find that higher mortgage refinance costs lead to a larger impact of inflation on debt. This result is intuitive, since higher mortgage refinance costs make it more costly for younger honeowners to refinance so as to reduce borrwowing and their PTI ratios.

Between 1980 to 2001, the US 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. We find that the decline in inflation and mortgage finance costs can account for roughly a 15 percentage point increase in the mortgage debt to income ratio, which is about two-thirds of the rise observed in the data.

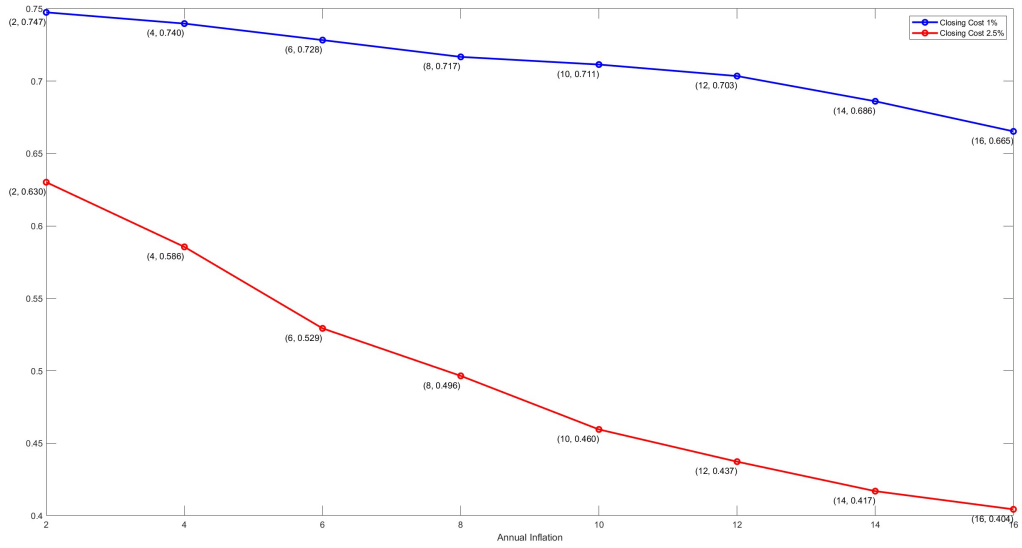
6.1 Inflation and Mortgage Debt in Steady State

We use our calibrated model to examine the steady state implications of trend inflation rates ranging from 2% to 20% for refinancing (closing) costs of 1 and 2.5%. The 1 percent refinancing cost is in line with estimates for the US in the early 2000s, while the 2.5 percent cost is in line with Federal Housing and Finance Agency estimates from the early 1980s.

The steady state DTI in the economy is decreasing in the level of inflation (see Figure 7). However, both the slope (i.e., the change in DTI for a percentage point change in inflation) and the level of DTI are impacted by refinancing costs. For a refinancing cost of 1 percent, a percentage point increase in inflation is associated with a roughly half of a percentage point drop in the debt-to-income ratio (see Figure 7). At a 2.5 percent refinance cost, DTI falls by roughly 0.9 percentage points in response to a percentage point increase in inflation.

The change in steady state debt levels are driven by higher trend inflation tightening the credit constraints of homebuyers. As discussed in Section 3, higher inflation acts to more heavily front-load mortgage payments, which tightens the credit constraint of younger households. In addition, more front-loaded mortgage payments implies faster accumulation of home equity. These forces mean that at higher levels of inflation, the initial PTI (for a given mortgage) rise which depresses the non-housing consumption of borrowing constrained homebuyers and thus shifts their non-housing consumption of constrained borrowers to later in life. In our experiments, on average, non-housing consumption of younger households falls at higher inflation rates compared to 2 % steady state inflation (see panel d and h of Figure 8).

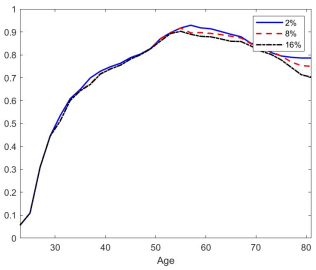
Figure 7: Steady State DTI by Inflation



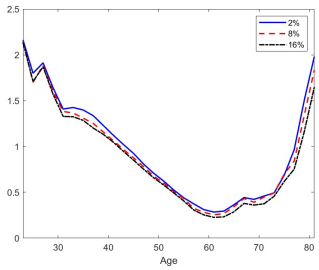
Households can respond to the tighter constraints imposed by higher inflation by postponing when they purchase, buying a smaller home or refinancing more often so as to extract equity for consumption and extend the maturity of their mortgage. In our experiments, all three of these forces are at work. As trend inflation increases, the homeownership rate declines moderately due to the complementarity between housing and non-housing consumption. The fraction who refinance – especially of younger homeowners – substantially increases at higher inflation levels (see Figure 8). By refinancing, a homeowner can extract equity for non-housing consumption or extend the maturity to reduce payments. The difference between a refinancing cost of 1 and 2.5 percentage points is substantial in terms of both the responsiveness of refinancing to the level of inflation and the impact of inflation on mortgage debt. The larger rise in refinancing at a low refinancing cost by younger homeowners as inflation rises contributes to the smaller fall in non-housing consumption at higher rates of inflation when refinancing costs 1 percent compared to 2.5 percent. This results in higher average debt levels for lower refinancing costs, and reduces the impact of higher inflation on the DTI.

These steady state forces illustrate how the level of trend inflation can have a significant impact on the level of debt (and housing consumption) over the life cycle. As we explore in Section 7 these life cycle patterns can give rise to prolonged transitions between steady states following an unexpected change in the level of trend inflation.

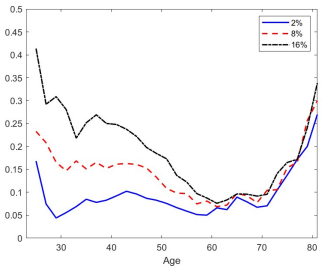
Figure 8: Steady State Comparison by Refinance costs



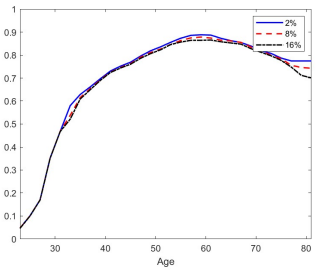
(a) Ownership: 1% Cost



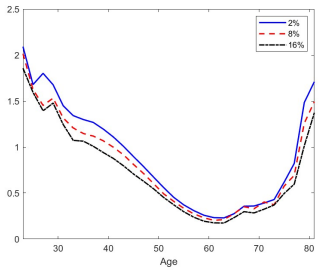
(b) DTI: 1% Cost



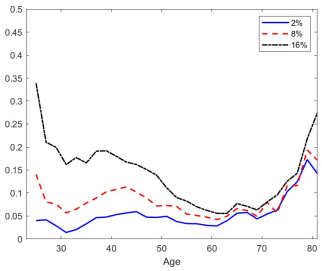
(c) Owners Refinancing: 1% Cost



(d) Ownership: 2.5% Cost



(e) DTI: 2.5% Cost



(f) Refinance Share of Owners: 2.5% Cost

Note: Refinance share of owners is defined as the annualized fraction of owners who get a new mortgage with a balance higher than the mortgage loan without changing house size.

6.2 The Contribution of Lower Inflation and Mortgage Financing Cost to the Rise in Mortgage Debt: 1983-2001

We use our calibrated model to quantify the contribution of the decline in inflation and the cost of mortgage financing to the increase in household debt between 1983 and 2001. This is an interesting episode both because it spans a large decline of over 5 percentage points in inflation and also since mortgage debt relative to disposable income rose by nearly 25 percentage points. Moreover, this rise in debt took place while real house prices were roughly flat. We find that the fall in trend inflation and refinancing costs can account for about two-thirds of the rise in mortgage debt relative to income.

In our counterfactual experiments, we compare our steady state economy calibrated to 2001 to the steady state of an economy where we hold fixed all of the parameters except for trend inflation and the mortgage refinancing cost. We set the inflation rate to 8% (from 2.8% in our 2001 benchmark) and the mortgage financing cost to 2.5% (from 1% in our 2001 baseline) to match the initial fees and charges for new mortgages reported 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	↑ 1983 r 25 bps	No Δ Refi Cost
Inflation	2.80%	8%	8%	2.8%
Mortgage finance cost	1%	2.5%	2.5%	2.5%
Risk free rate	2%	2%	2.5%	2%
Panel B: Simulation and Data				
Aggregate DTI	2001	1983		
Data (SCF)	75%			
Data (Debt to Disposable Income)	68.5%	42.5%	42.5%	%
Model	75%	61%	51%	67%
Ownership (Data)	68%	65%	65%	%
Model	71.5%	68.6%	66.2%	68.06%

Note: In the steady state simulations, the maximum LTV is 80% and the cap on payment-to-income ratio is 1. The SCF data moments are total mortgage debt divided by total household labour income.

The counterfactual experiment generates an 14 percentage point increase in the debt-to-income ratio between 1983 and 2001 (see columns 1 to 2 in Table 3). Thus, the decline in inflation and mortgage financing cost can account for 54% of the observed 26 percentage points increase in ratio of mortgage debt to disposable income.[23]

[23]We chose to use data from NIPA instead of SCF 1983 due to concern about the limited sample size of

To quantify how much of the rise in DTI is due to lower inflation backloading mortgage debt payments (mechanically increasing outstanding debt) without changing initial borrowing decisions we conduct a simple decomposition exercise. Specifically, we take the 8% inflation steady state simulation and apply the hypothetical real debt balance under 2.8% inflation based on a household's initial mortgage loan and amortization and calculate the total amount of debt. This calculation implies an aggregate debt-to-income ratio of 70.6%, which implies that about 69% ($\frac{70.6\%-61\%}{75\%-61\%}$) of the rise in aggregate debt-to-income ratio across our experiments can be attributed to the backloading of mortgage debt due to lower trend inflation.

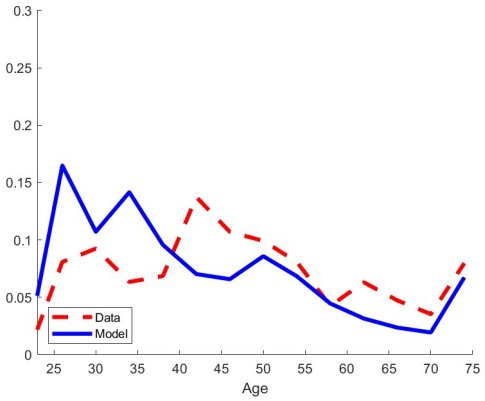
We decompose the contribution of different ages to the rise in mortgage debt in our simulations and compare this to data from the 1983 and 2001 SCF. As in our decomposition in Section 3.1, we compute the ratio of the rise in average mortgage debt for each age group using the population share as weights to the rise in total mortgage debt between the two steady states. Figure 9 panel (a) compares the model-simulated decomposition with its data counterparts. The contribution of different age groups in our model largely overlaps with what we find in the data. Consistent with the data decomposition, 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.

The comparison of steady states in Section 6.1 illustrated that the effect of different levels of trend inflation varied with the level of refinancing costs. Our counterfactual comparing 1983 and 2001 varies both steady state inflation and refinancing costs. This gives rise to larger impacts on the profile of life-cycle consumption and also shifts the profile of debt to income over the lifecycle. The counterfactual implies a steeper lifecycle consumption profile in 1983 than in 2001 as higher inflation and mortgage closing costs tighten the borrowing constraints of younger homeowners. In Panel (b) of Figure 9 we plot the difference between non-housing consumption in the 1983 counterfactual and our 2001 benchmark.The combination of 5.2 percentage point difference in inflation and a 1.5 percentage point difference in mortgage financing cost results in non-housing consumption for younger households in our 1983 steady state being 1 to 2.5 percentage points lower than in the 2001 benchmark. The counterpart to the lower consumption of the young is higher non-housing consumption for households close to retirement.

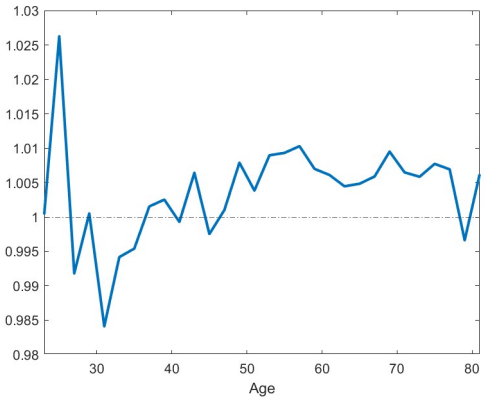
To provide a metric of how substantive are the effects of inflation on household mortgage debt and homeownership, we use our benchmark model to quantify the impact of a 25 basis point change in the steady state risk free rate. In column 3 of Table 3 we repeat our 1983

SCF 1983. Normally, disposable income is higher than labor income as it counts investment income but not tax. As a result, mortgage debt to labor income ratio should be higher than the debt to disposable income ratio. This is true in 2001 but the relationship reverses in 1983.

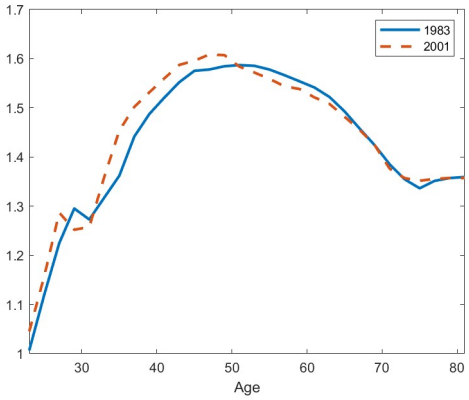
Figure 9: Steady State Comparison: 1983 vs 2001



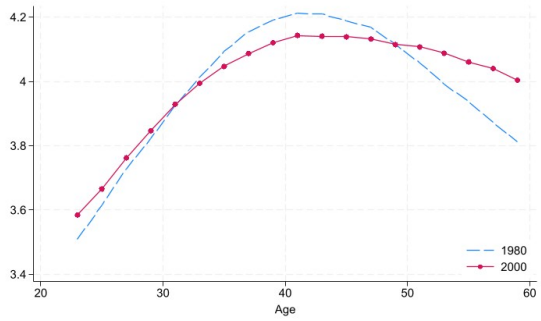
(a) Contribution by Age to Increase in DTI (Model and Data)



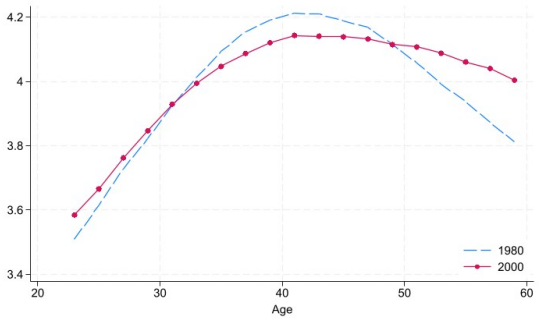
(b) Consumption Difference (Model)



(c) House Size by Age (Model)



(d) Average Number of Rooms by Age (Data)



(e) Average Number of Bedrooms by age (Data)

Panel (a) compares the contribution of different age group to the rise in DTI in the model and in the data. Panel (b) plots the ratio of mean non-housing consumption in the steady state 1983 steady state counterfactual to the mean non-housing consumption in the steady state calibrated to 2001. Panel (c) compares house size by age of the simulated 1983 high inflation steady state with simulated 2001 low inflation steady state. Panel (d) and (e) plots the average number of rooms and bedrooms among owners by age using data from Census 1980 and Census 2000.

benchmark experiment but with a higher risk free rate. The impact of a 25 bps change in real rates (which changes both mortgage rates and the return on savings) is similar to a 5.2 percentage change in trend inflation. The change in the mortgage debt to income ratio is 12 percentage points, which is close to the effect of a 5.2 percentage point change in inflation holding fixed mortgage finance costs (column 4 of Table 3). This reinforces our finding that anticipated inflation can have substantial real effects via the housing market.

6.2.1 Larger Homes and the Rise in Debt

The decline in nominal interest rates that follows a decline in inflation as well as lower mortgage closing cost create space for younger homebuyers to purchase larger (and thus more expensive) homes. We find that this mechanism is at work in our model simulations. The 2001 calibration with lower inflation and mortgage financing cost features larger average house sizes for young and middle-aged owners than our 1983 experiment (see Figure 9, panel (c)). This shift towards larger houses financed by increased borrowing contributes to higher mortgage debt levels.

Similar to the model simulations, real house prices did not systematically increase during the 1980s and 1990s. As a proxy for house size, we use data from the 1980 and 2000 Census on the average number of rooms and bedrooms to approximate the average size (and thus housing consumption) of households over the lifcecycle. Consistent with our model simulations, we find that the average number of rooms and bedrooms among 20-30-year-old owners in 2000 when inflation was low is higher than in 1980 when inflation was high (see Figure 9, panel (d) and (e)).

To quantify the contribution of larger houses to the increase in mortgage debt, we apply the following formula to attribute a share of the increase in mortgage borrowing between our 1983 and 2001 simulations to larger homes:

$$ContributionH = \frac{\sum_a \alpha_a LTV_a P(H_{a,2001} - H_{a,1983})}{\sum_a \alpha_a (d_{a,2001} - d_{a,1983})} \tag{19}$$

where α_a is the population share of age group a (which is fixed in our simulations), 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. This calculation attributes about 34% of the overall increase in aggregate mortgage debt to the purchase of larger houses.[24]

[24]Specifically: 37% if we apply the LTV in 2001 and 34% when we apply the LTV in 1983.

7 Transitional Dynamics following Unanticipated Permanent Change in Inflation

We use the model to examine transitions between steady states following an unanticipated permanent change in trend inflation. We first show that the transitional dynamics depend on both how fast (and anticipated) the transition in inflation takes place. We also show that whether mortgages are FRM or ARM impacts the transitional dynamics (but not the steady state). Finally, we show that the option to refinance FRMs leads to differences in the transitional dynamics between a decrease and increase in inflation.

Unlike in our steady state analysis, unanticipated changes can result in existing borrowers experiencing capital gains (losses) which impact their decisions along the transition. In addition, unlike in the steady state, whether the mortgage contract has a fixed or adjustable rate is important since adjustable rate mortgages payments adjust with inflation. For fixed rate mortgages, the option to refinance (at a fixed cost) offers existing mortgagors an option of either continuing with their current mortgage (at the existing interest rate) or refinancing at a new rate. As a result, an unanticipated rise in inflation benefits existing borrowers with fixed rate mortgages by reducing the real value of their debt (i.e., the real interest rate on their mortgage declines) and offers them an option to borrow at lower rate specified before the shock (lock-in). However, when inflation unexpectedly declines, households with fixed rate mortgages can refinance at a new lower interest rate. As we show, this can lead to asymmetric effects following unanticipated changes to inflation.

Our analysis yields several surprising insights. First, we find that the transition following a permanent change in trend inflation can take up to twenty five years. Behind this prolonged transition is the life-cycle nature of housing decisions. Since adjusting housing is costly, following a permanent change in trend inflation, many mortgagors are slow to adjust. Second, expectations around the path of inflation and mortgage rates along the transition can further slow the transition if some prospective homebuyers anticipated lower rates in the future. We also find that an increase in central banks target inflation rate – advocated by some economists as a low cost way of reducing the risk of ELB episodes – would impact housing markets. Our experiments also suggest that a transition to a higher inflation level takes longer with FRMs, compared to a transition to lower inflation level, due to the asymmetric response of mortgage lock-in. Whereas when inflation and mortgage rates fall, existing mortgagors refinance at lower rates, when inflation rises existing owners have an incentive to keep their low-interest loans.

7.1 An Unanticipated Permanent Fall in Inflation

We begin by examining the housing market dynamics of a transition from high to low inflation of over 6 percentage points, similar in magnitude to the US experience during the 1980s. Motivated by cross-country differences in the timing and speed of inflation and mortgage markets changes, we compare transitions along how quickly inflation converges to the new steady state level as well as whether mortgages have fixed or adjustable rates. We find that both the speed with which inflation reaches the new steady state as well as the mortgage structure effects the speed and dynamics of homeownership and mortgage debt.

The transition experiments begin with the economy in the 8% inflation steady state when an unexpected and permanent fall in inflation is announced. We compare two inflation transition paths: a *sudden* transition where inflation falls to 2% in the first period and a *gradual* transition in which inflation declines linearly from 8% to 2% in 9 periods. We conduct these experiments in an economy where all mortgages have fixed rates and one where all mortgages have adjustable rates. For households who originate a fixed rate mortgage at time t (and payments begin in $t+1$), the mortgage rate is based on expected inflation in $t+1$ while the interest rate on an ARM varies with inflation each period.[25] In all experiments, the mortgage amortization period is 30 years and the refinancing cost is 2.5%.

The transitions between steady states take a long time: for the sudden transition it takes 10 periods (20 years) for the homeownership rate and mortgage debt-to-income ratio to fully converge to the new steady state (see panel (e) and (f) in Figure 11). The gradual transition in inflation is even more prolonged as it takes another 5 periods (10 years) following the 9 period transition in inflation (see panel (a) and (b) in Figure 11). This reflects the slow adjustment of debt levels for existing homeowners when the change in inflation is announced.

A key force along the transition is the wealth effect for mortgagors of the unanticipated change in inflation. The unexpected drop in inflation results in slower than expected nominal income growth and an unanticipated increase in real mortgage payments (payment-to-income ratio) and real debt (nominal mortgage balances divided by the price level) for existing mortgagors. The negative wealth effects with FRMs are shaped by the option to refinance at lower interest rates and the speed of the inflation transition. In the gradual inflation transition, the initial negative wealth effect is smaller as inflation adjusts slowly from 8% to 2%. However, the fixed cost of mortgage refinancing means that existing mortgage holders face a trade-off about when to refinance. On the one hand, the longer mortgagors stay with the old higher rate contract (based on 8% trend inflation), the more they pay in high real interest rates. On the other hand, households know that inflation and mortgage rates will

[25] Along the transition we hold fixed the relative (real) price of housing in terms of the non-housing good. The assumption of fixed real housing prices makes solving for the transition analytically tractable. It also corresponds to what we observe in the US data for the 1980s and 1990s.

fall further in the future and have an incentive to wait as refinancing is costly. These forces drive the differences in the timing of refinancing in panels (c) and (g) of Figure 11.

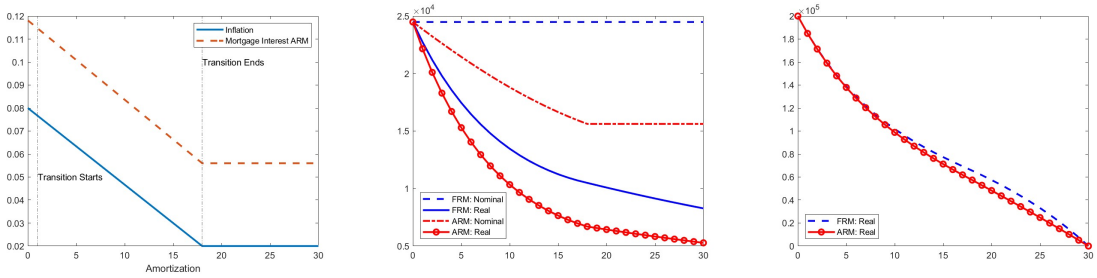
The refinance option plays a key role in understanding the differences and similarities between the ARM and FRM economy transitions. In an ARM economy, the mortgage rate comoves with realized inflation. This results in mortgage interest payments falling with inflation (see panels (d) and (h) in Figure 11), and nominal principal payments rising slightly as the amortization period is fixed. What may seem surprising is that the debt-balance weighted average mortgage interest on outstanding loans in the FRM environment closely track the ARM payments. This is driven by refinancing: in the sudden transition, the high-balanced loans get refinanced which brings down the average mortgage rate to the new steady state level. Since the net benefits of refinancing are larger for those with larger debts (and longer remaining amortizations), this has a large impact on average (debt-weighted) interest payments. In the gradual transition, while the spike in refinancing is less pronounced it remains high throughout the transition in inflation. However, since refinancing is costly, in the FRM world, some homeowners decide to sell and transition to renting. This effect is quantitatively modest in the sudden inflation transition, and as a result the sudden inflation transition features similar paths for homeownership, debt and interest payments in both the FRM and ARM economies.

To highlight the large impact of refinancing, we use our simple numerical example of a $\$200,000$ mortgage from Section 3.[26] We compare the path of payments for a FRM that is *not* refinanced with an ARM originated the period prior to a transition of inflation from 8% to 2% over 18 years (see Figure 10). If the FRM is not refinanced, the rate and (fixed) nominal payments are higher than that of an ARM whose rate and payments decline with inflation. By the end of the transition (year 18), the FRM payment is 55% higher than that of the ARM. Despite the higher payments, the outstanding FRM loan balance is higher as a result of higher interest payments (Figure 10 panel (c)). However, due to FRM mortgagors choosing to refinance, the path of mortgage interest payments in the FRM and ARM economies (see panels (d) and (h) of Figure 11) closely track one another.

In the gradual transition there are significant differences between homeownership and DTI between the FRM and ARM economies. The main driver of these differences are renters delaying their purchases of homes. In the FRM world, the mortgage rate is based on period ahead inflation. As a result, households anticipate that rates will decline once the transition is announced. Since refinancing is costly, this leads some renters to wait until inflation falls closer to 2% before purchasing. In addition, the expectation that rates will decline leads some homeowners to transition to renting until rates have fallen. The combination of the negative wealth effect and postponed homebuying results in a larger

[26] In this example, the real interest rate is 2%, the mortgage spread is 1.5% and amortization is 30 years.

Figure 10: Downward Inflation Transition: FRM and ARM



(a) Inflation and Mortgage Rates along Transition

(b) Nominal and Real Mortgage Payments along Transition

(c) Real outstanding Debt along the Transition

Note: All real values are evaluated at the period when the mortgage contract is signed (i.e. amortization 0)

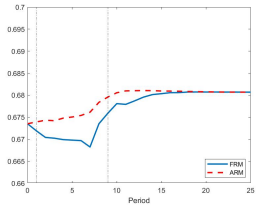
initial drop in homeownership and DTI in the gradual transition with FRM. In contrast, in the ARM economy, the dynamics of homeownership and DTI is only slightly slower than that observed in the sudden transition.

The effect of the level of inflation on aggregate steady state non-housing consumption is small (less than .2%). The deviations along the transitions can be larger, particularly in the FRM economy. Along the transition, non-housing consumption initially falls (see Panel (i) and (j) of Figure 11) as the negative wealth shock for mortgagors drives a small decline in non-housing consumption. This decline is initially deeper for the one-period transition than for the gradual transition, although the gradual transition features a slower recovery in consumption over the transition. Behind the aggregate lie larger shifts in consumption across age cohorts with young and middle-aged people seeing larger declines, particularly in the gradual transition with FRMs.[27] This reflects both the negative wealth effects from the unexpected decline in inflation on mortgagors and the expenditures on the refinance cost (2.5% of the new loan balance) that households incur to obtain a lower rate. The third force comes from the complementarity between housing and non-housing consumption. This contributes to the drop in consumption among young households who postpone buying a home (anticipating rates will decline) and lower their non-housing consumption. This contributes to higher savings which supports higher consumption following the end of the transition to lower inflation.

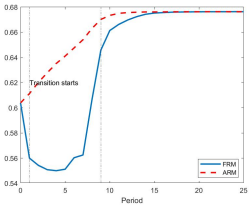
These experiments show that the transition dynamics following an unanticipated and permanent change in inflation are surprisingly prolonged and dependent upon the structure of mortgage markets. Our experiment also offer two other important insights. First, the option to refinance FRMs can significantly reduce the redistribution of wealth from borrowers to lenders following an unanticipated decline in inflation. Second, the speed and credibility of

[27]See the supplementary appendix.

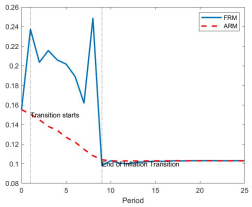
Figure 11: Permanent Drop in Inflation from 8% to 2%



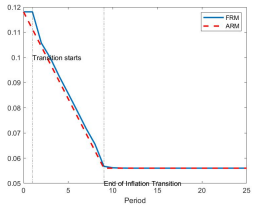
(a) Gradual: Ownership rate



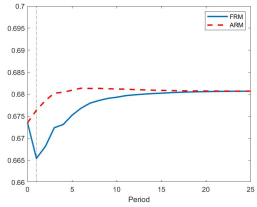
(b) Gradual: DTI



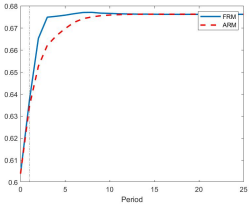
(c) Gradual : Refinance



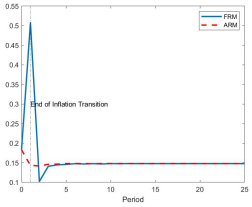
(d) Gradual :Avg Mortgage Interest



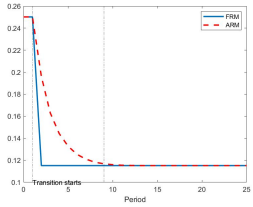
(e) Sudden: Ownership rate



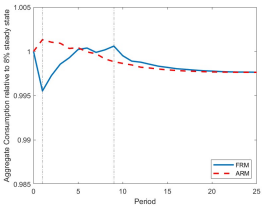
(f) Sudden: DTI



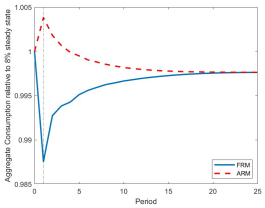
(g) Sudden : Refinance



(h) Sudden : Avg Mortgage Interest



(i) Gradual: Aggregate Non-housing Consumption



(j) Sudden: Aggregate Non-housing Consumption

Note: Each period is 2 years. Debt to Income is the ratio of total outstanding mortgage debt to total household labor income. Refinance rate is the fraction of owners who end their current mortgage and originate a new one with a higher balance. Average mortgage interest is the debt-weighted average mortgage interest on outstanding loans. Consumption deviation is relative to consumption at the 8% old steady state. Inflation falls from 8% to 2% linearly in 9 periods for the gradual transition. Inflation drops to 2% in period 1 for the sudden transition. 2.5% refinancing cost is applied.

the inflation transition are important. To the extent that a gradual transition is less credible than a sudden transition, one would expect mortgage rates to track the path of inflation as assumed in our gradual transition case. Compared to the sudden transition, this results in lower homeownership along the transition to the steady state.

7.2 A Permanent Rise in Inflation

Some economists have suggested that central banks should increase their inflation targets 4 or 5 % (e.g., Blanchard *et al.*, 2010). Although these proposals raise many practical questions around the credibility of inflation targeting, here we focus on the implications for housing markets if a central bank were to increase their target from 2 to 5 %. Our experiment begins in the 2 % inflation steady state when we introduce an unanticipated, permanent increase in inflation to 5% in one model period (i.e., over 2 years).

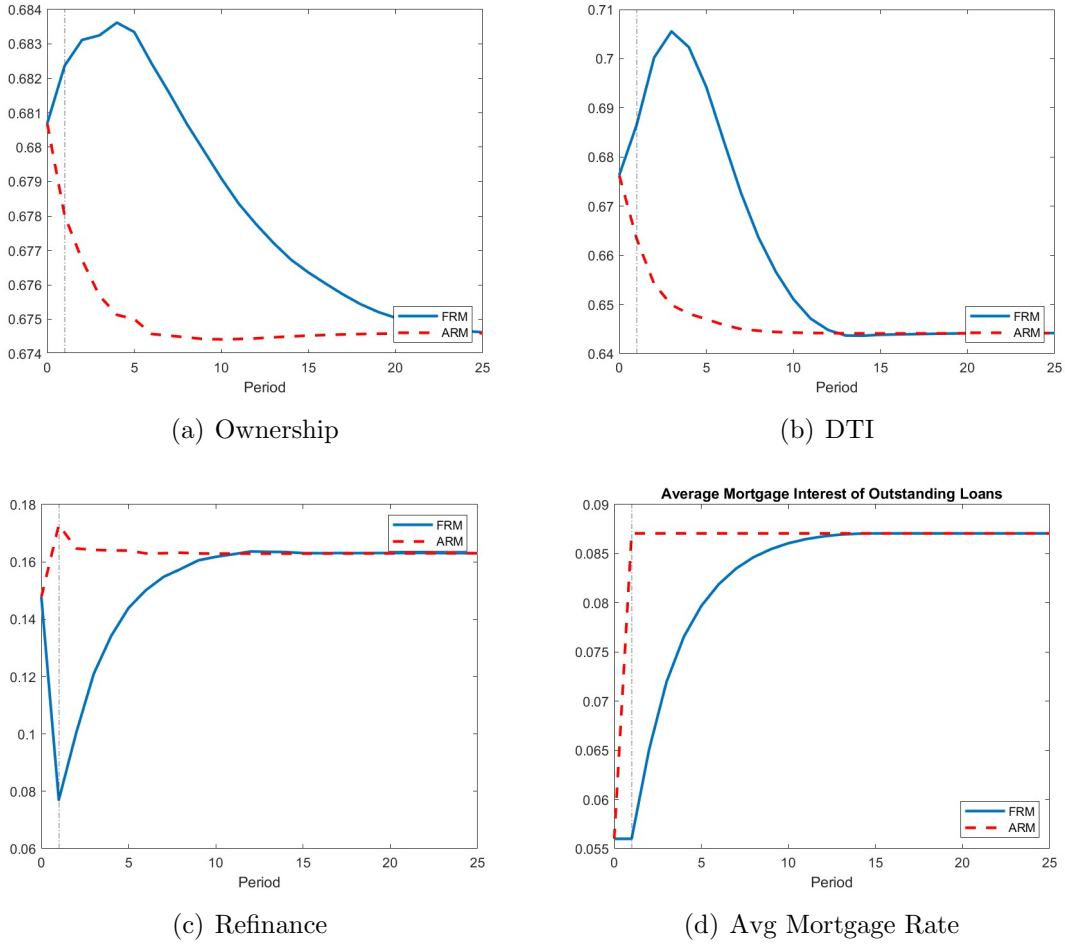
Our counterfactual experiment delivers two insights. First, a change in change in central bank's the inflation target would likely significantly impact housing markets. Our experiment implies a nearly 2 percentage point decline in homeownership and a five percentage point fall in DTI (see panels (a) and (b) in Figure). Second, whether mortgages are primarily fixed or adjustable rates significantly impacts the transitional dynamics. With fixed rate mortgages, the transition in homeownership rates and DTI is much slower than with ARMs. The significant asymmetry between a downward and an upward change in trend inflation.

With fixed rate mortgages, an unexpected increase in inflation effectively transfers wealth to existing mortgagors as the real interest rate on existing mortgages declines and lowers the value of mortgage debt relative to income due to the faster growth in nominal income (see Figure 12, panel (b)). However, the decline in DTI with FRMs is prolonged since the mortgage lock-in effect (Fonseca and Liu, 2024; Gerardi *et al.*, 2024; Liebersohn and Rothstein, 2024) creates an incentive for existing mortgagors to remain as home owners rather than becoming renters following negative income shocks. These forces also result in a decline in refinancing. These forces mean that the average mortgage rate on outstanding mortgage balance rise slowly, and takes nearly 25 years (12 model periods) to converge to the new steady state (see Figure 12, panel (b)). Combined with the initial positive wealth effect for mortgagors, this contributes to the slow decline in homeownership rates with FRMs (see Figure 11, panel (a)). Compared with a decline in inflation (see Figure 11), the transition following an increase in inflation takes much longer.

The transition in a mortgage environment based on ARMs is significantly faster than with FRMs. With ARMs, the mortgage rates jump to the new steady state (panel (d)). Higher rates on existing mortgages increase the number of existing homeowners who transition to renting, which accelerates the fall in debt relative to income (panel (b)). Despite these forces

speeding up the transition, it still takes nearly twenty years for ownership to reach the steady state.

Figure 12: Permanent Increase in Inflation: 2% to 5%



(a) Ownership (b) DTI

(c) Refinance (d) Avg Mortgage Rate

Note: Each model period is equivalent to 2 years. Inflation rises from 2% to 5% in 1 period. The refinancing cost is 2.5%.

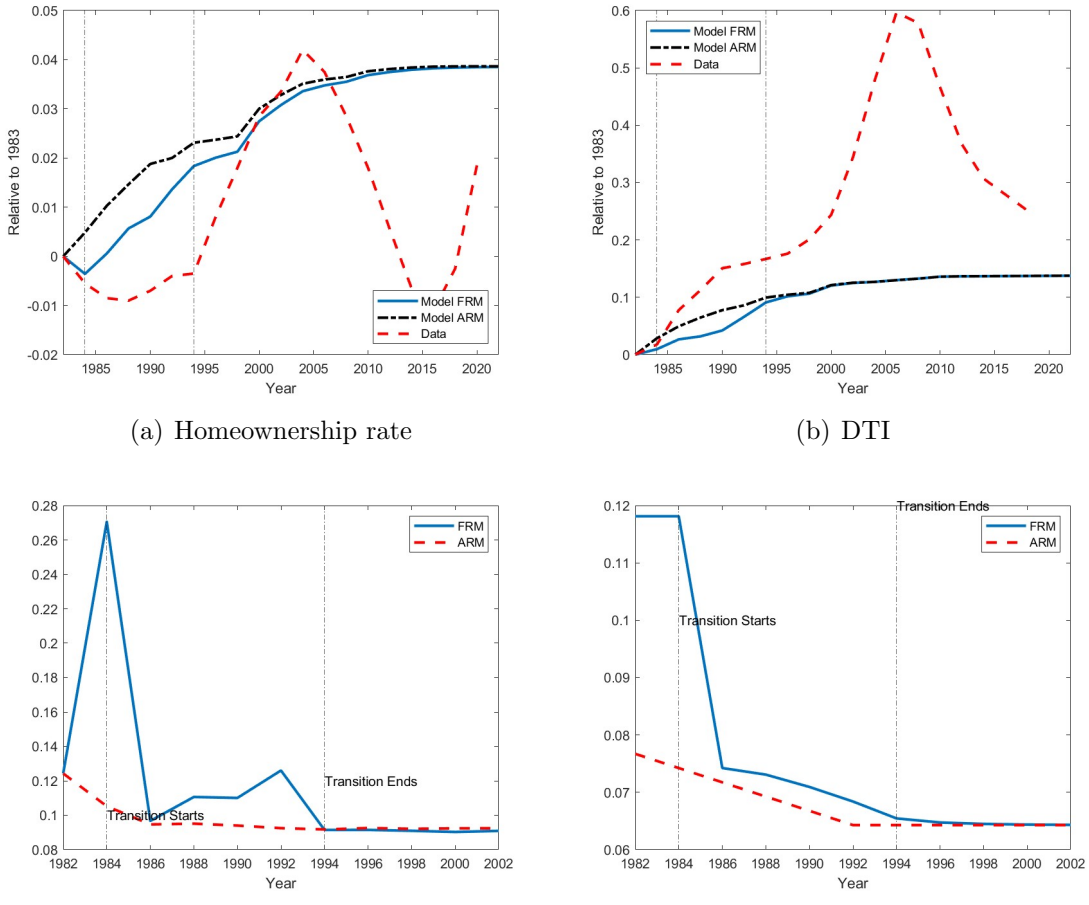
7.3 The 1980s Inflation Decline and the Rise in US Mortgage Debt

The steady state experiments in Section 6.1 indicated that the decline in inflation and mortgage refinance could account for roughly two-thirds of the rise in US mortgage debt DTI ratio during the 1980s and 1990s. In this section we ask whether the inflation dynamics observed in the US during the 1980s are roughly consistent with the timing of the rise in debt. In designing our counterfactual, we build on the insights from Section 7.1 and take into account both the timing of the decline in inflation and the mix of FRM and ARMs. US inflation fell sharply in the early 1980s, and was followed by a further decline to roughly

2.8% by early 1990s. The inflation path we input involves an unexpected decline in inflation from 8 to 4 % in the first period, followed by a linear decline from 4 to 2.8% over 5 periods. Since ARMs in 1982 accounted for approximately a fifth of US mortgages, our counterfactual assumes four-fifths of mortgages are FRM and the remainder ARMs.

Our experiments yields two key insights (see Figure 13). First, the impact of the fall in inflation on debt and homeownership rates was largely complete by 2001, which suggests that our steady state experiments provides a reasonable estimate of the long run impact of the fall in inflation. Second, we find that the timing of the rise in debt and homeownership rates is roughly in line with the US experience.

Figure 13: 1980s Inflation Decline in U.S.



(a) Homeownership rate

(b) DTI

(c) Refinance Owners

(d) Avg Mortgage Interest

Note: One model period is equivalent to 2 years. Debt to Income ratio is the ratio of total outstanding mortgage debt to the total household labor income in the economy. Inflation falls from 8% to 4% in the first period of transition and gradually drops to 2.8% in 5 periods 2.5% refinancing cost is applied. Debt to Income ratio is computed using aggregate mortgage debt to disposable income ratio in the data.

8 Conclusion

We develop a life-cycle housing tenure choice model to understand the impact of changes in the level of trend inflation on homeownership and mortgage borrowing. We show that typical nominal fixed amortization mortgage contracts (both ARM and FRM) result in lower anticipated inflation backloading real mortgage payments and real debt. Using our calibrated lifecycle housing tenure choice model, we find that a 1 percentage point increase in inflation leads to a 0.5 to 0.9 percentage point drop in the steady-state aggregate debt-to-income ratio, depending on the cost of refinancing. We also find that the observed decline in inflation from 8% to 2.8% combined with a decline in mortgage refinancing cost from 2.5% to 1% can account for over 52% of the rise in the aggregate US debt-to-income ratio between 1983 and 2001.

Our analysis with respect to the transitions between steady states following an unanticipated permanent change in trend inflation shows that it can take another 20 years for homeownership and mortgage debt to reach their steady state values. Interestingly, we find that the option to refinance fixed rate mortgages results in a similar path for mortgage interest payments with FRMs and ARMs along the transition following an unanticipated decline in inflation. In contrast, an increase in inflation results in a faster rise in mortgage interest payments with ARMs than FRMs as borrowers with FRMs delay refinancing. As a result, transitions are more protracted following ain increase in inflation with FRMs.

Our analysis points to several promising directions for future research. Our analysis in this paper assumed that there are no changes in the relative price in housing in response to shifts in demand for housing as a result of changes in inflation. Although this corresponds to the US experience during the 1980s and 1990s, the relative price of housing has risen since then. In addition, there are substantial cross-country differences in the term of mortgage rates. Although we document similar aggregate increases in debt across countries, work that systematically compares changes in the distribution of household mortgage debt over time across countries with what we document for the U.S. using the SCF could be informative.

Appendix

A Age decomposition

To examine the contribution of shifts in the age distribution of the US population, we use a simple decomposition between the contribution of shifts in the US 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.

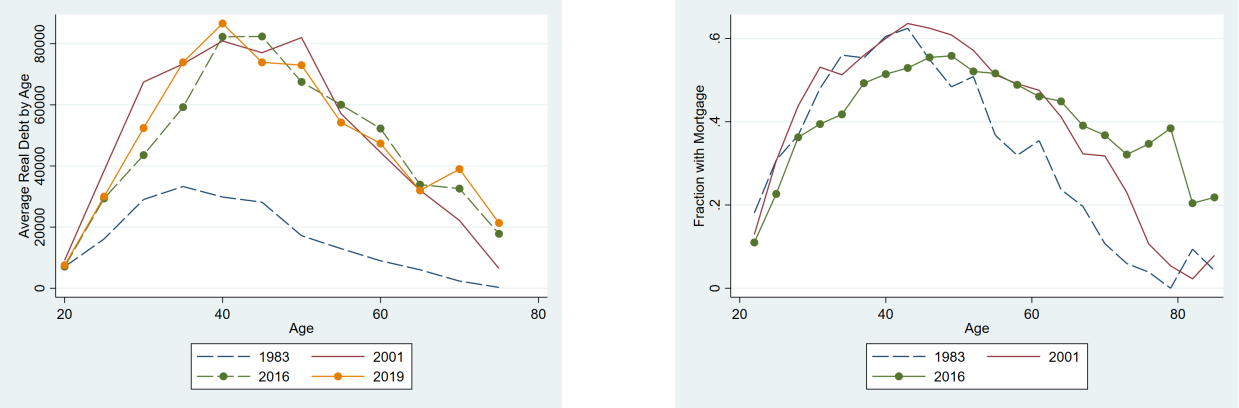
$$\underbrace{D_t}_{\text{Aggregate DTI}} = \sum_a \underbrace{\alpha_{a,t}}_{\text{population share of age a at time t}} \underbrace{d_{a,t}}_{\text{DTI of age a households at time t}} \tag{20}$$

The DTI ratio is 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:

$$D_{2001} - D_{1983} = \underbrace{\sum_a \alpha_{a,2001}(D_{a,2001} - D_{a,1983})}_{\text{Contribution of change in DTI across different age groups}} + \underbrace{\sum_a D_{a,1983}(\alpha_{a,2001} - \alpha_{a,2001})}_{\text{Contribution of change in population structure}} \tag{21}$$

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: $\frac{\alpha_{a,2001}(D_{a,2001} - D_{a,1983})}{\sum_a \alpha_{a,2001}(D_{a,2001} - D_{a,1983})}$.

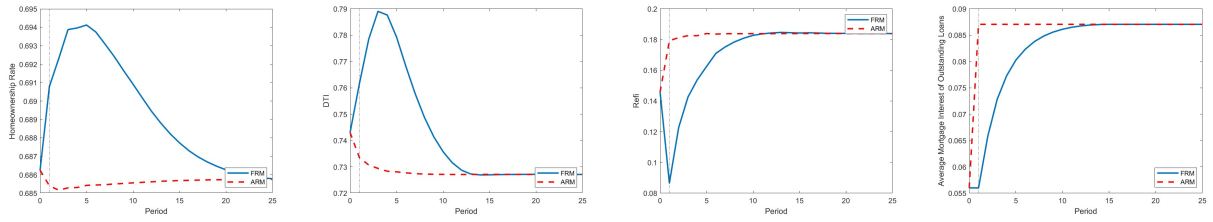
Figure 14: Extensive and Intensive Margins



B Upward Transition under Low Refinance Cost

We conduct a robustness check for the upward transition where we set refinance cost to 1%. We start with the 2% inflation initial steady state and increase the inflation to 5% all of a sudden. Consistent with the finding the steady state analysis that refinance cost plays an important role in determining the implications of trend inflation, we find larger responses in homeownership rate and DTI for a sudden upward transition. Compared to the simulation where 2.5% is applied, we see a temporary rise in homeownership rate and DTI, although the magnitude of ownership increase is small (less than one percentage point). Fraction of owners who refinance drops more as the level is higher at the initial steady state with lower refinance cost. Comparing the average mortgage rates on outstanding loans under high and low refinance cost reveals that low refinance costs marginally speed up the transition. It takes 3 periods to reach the middle point of the transition for 1% refinance cost and 4 periods for the 2.5% refinance cost. This is because that lower refinance cost marginally increases households' incentive to refinance when they experience negative income shocks and therefore update their mortgage rates.

Figure 15: Permanent Increase in Inflation: 2% to 5%



(a) Ownership (b) DTI (c) Refinance (d) Avg Mortgage Rates on Outstanding Loans

Note: Each model period is equivalent to 2 years. Inflation rises from 2% to 5% in 1 period. The refinancing cost is 1%.

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