A Dynamic Economic and Monetary Union

ADEMU WORKING PAPER SERIES

Failure to Launch: Housing, Debt Overhang, and the Inflation Option

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April 2018

WP 2018/098

www.ademu-project.eu/publications/working-papers

Abstract

Can inflating away nominal mortgage liabilities effectively combat recessions? I address this question using a model of illiquid housing, endogenous credit supply, and equilibrium default. I show that, in an ordinary recession, temporarily raising the inflation target has only modest or even counterproductive effects. However, during episodes like the Great Recession, inflation effectively boosts house prices, consumption, and dramatically cuts foreclosures, but only when fixed rate mortgages are the dominant instrument. The quantitative implications of inflation also vary if other nominal rigidities or demand externalities are present. In the cross section, inflation delivers especially large gains to highly leveraged homeowners.

Keywords: Housing; Liquidity; Mortgage Debt; Foreclosure; Inflation
JEL codes: D31, D83, E21, E22, G11, G12, G21, R21, R31

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Horizon 2020
The Framework Programme for Research and Innovation

Acknowledgments

I thank Grey Gordon, Carlos Garriga, Joe Haslag, Chris Otrok, Todd Walker, Juan Carlos Hatchondo, Kurt Mitman, Fatih Karahan, Serdar Ozkan, Morris Davis, Allen Head, Victor Rios-Rull, Gianluca Violante, Michele Tertilt, Virgiliu Midrigan, Athanasios Orphanides, Harold Cole, two anonymous referees, and participants at the spring 2015 Midwest Macroeconomic Conference, the 2015 NBER Summer Institute, the 2015 World Society of the Econometric Society, the 2016 Bank of England \Housing: Micro Data, Macro Problems" conference, and the 2018 ADEMU "Risk Sharing, Macroeconomic Interdependencies, and Imbalances" conference for their useful comments. This paper is related to the research agenda of the ADEMU project, "A Dynamic Economic and Monetary Union", funded by the European Union's Horizon 2020 Program under grant agreement 649396 (ADEMU). Any errors are my own.

The ADEMU Working Paper Series is being supported by the European Commission Horizon 2020 European Union funding for Research & Innovation, grant agreement No 649396.

1 Introduction

In response to the unprecedented collapse in the housing market and macroeconomy during the Great Recession, the U.S. government undertook dramatic interventions to pull the economy out of its slump. However, the Federal Reserve assiduously avoided any attempt to push inflation above its usual two percent target.[1] Even when signaling its discontent with the low level of inflation and its willingness to take additional action, the Fed continually re-invoked its long-run target. In October 2014, the Federal Open Market Committee even explicitly affirmed that it "would be concerned if inflation were running consistently above or below" its 2% objective.

On the one hand, these actions demonstrate an understandable reluctance by the Fed to put its hard-won inflation-fighting credibility at risk. On the other hand, household debt throttled the economy for several years, with economic growth only recently demonstrating signs of durable strength. Although foreclosures have subsided, real house prices and existing house sales still remain below their peaks.

The protracted recession and sluggish recovery have led to repeated calls for a temporary regime of higher inflation to battle debt's long shadow. For example, Robert Engle and Paul Krugman both make the point that, in episodes like the Great Recession, inflation can boost house prices, reduce foreclosure activity, and accelerate the macroeconomic recovery.

"If we had just a little bit of inflation and house prices went up, all the sudden they would be above the mortgages." –Robert Engle

"If we could manage 4 or 5 percent inflation...so that prices were 25 percent higher, the real value of mortgage debt would be substantially lower than it looks on current prospect – and the economy would therefore be substantially farther along the road to sustained recovery." –Paul Krugman

[1] See http://www.federalreserve.gov/faqs/economy_14400.htm.

Ken Rogoff emphasizes another benefit of inflationary policies, which is that they circumvent some of the political barriers that have limited the scope and effectiveness of many direct legislative attempts at debt-relief.

> *"If direct approaches to debt reduction are ruled out by political obstacles, there is still the option of trying to achieve some modest de-leveraging through moderate inflation of, say, 4 to 6 percent for several years." –Ken Rogoff*

In this paper, I address whether such an outside-the-box measure of explicitly inflating away mortgage debt can effectively improve economic performance during a deep recession. To do so, I construct a macroeconomic model along the lines of Hedlund (2016) that features endogenously illiquid housing and equilibrium default.

In the model, households value consumption and housing services, which they receive either by owning a house or by renting an apartment. Households face uninsurable individual income risk and can accumulate buffer savings. Illiquidity arises in the housing market because of search frictions that create delays in the process of matching willing buyers and sellers. Lastly, lenders in the mortgage market issue long-term, *fixed rate*, *nominal* mortgages that price inflation expectations and individual default risk at origination.

In this analysis, I focus on three channels of inflation. First, inflation erodes the real value of debt and relaxes household budget constraints. However, by eroding the burden of debt to borrowers, inflation simultaneously diminishes the value of repayments to banks. This dimension of inflation acts as a source of ex-post redistribution between borrowers and lenders, but it also impacts lending behavior ex-ante by reducing the supply of credit. In the case of either one-period debt or adjustable rate contracts, the mortgage supply response completely cancels out the debt erosion benefits of inflation, and only the real interest rate matters.

By contrast, long-term *fixed rate* mortgages (FRMs) act as a significant nominal rigidity. For existing borrowers whose rates were set prior to the intervention, temporary higher inflation delivers a boon by *permanently* reducing outstanding debt.

Furthermore, because long-term rates do not adjust one-for-one to short-run nominal interest rate fluctuations, new borrowers also experience accelerated debt reduction in the early years of repayment.

Illiquidity in the housing market generates a third channel of inflation. In a frictional, decentralized housing market, homeowners face a trade-off between list price and selling time, and mortgage debt impinges on that decision because of the requirement to settle all obligations upon sale. Highly indebted homeowners in particular are unable to price their houses competitively, which leads to long selling delays and elevated foreclosure risk. Inflation provides additional pricing flexibility to these sellers by eroding their debt and creating equity. The resulting lower time on the market proves especially key for distressed homeowners, as it gives them an escape other than default from the burdensome consequences of debt.

On balance, these channels roughly wash out for permanent inflation changes. However, if implemented during a run-of-the-mill productivity-driven recession, a temporary burst of inflation has real but mixed effects. Inflation in this scenario boosts house prices (both nominal *and* real) and reduces foreclosures, but the contraction in mortgage supply causes consumption to initially fall before recovering. If nominal income responds seamlessly to inflation—the best-case scenario in this environment—inflation delivers a modest increase in welfare. However, if nominal income exhibits sluggishness, higher inflation erodes purchasing power, thereby erasing the gains to real house prices, depressing consumption, and *reducing* welfare. Overall, the case for regularly using high inflation to combat recessions proves weak.

However, the main question in this paper involves whether inflation helps or harms an economy in crisis. To provide an answer, I first replicate the dynamics of the Great Recession in the model using the insights of Garriga and Hedlund (2017). They find that an increase in downside income risk and a tightening of downpayment constraints in the mortgage market act as the main drivers of the crash. As these shocks propagate through the economy, they are amplified by balance sheet effects

that increase in strength with the amount of leverage in the economy. Because of the importance of this heterogeneity for any policy analysis, this paper demonstrates that the model matches not only the aggregate response of consumption during the Great Recession but also its cross-sectional behavior.

Having established the validity of the model as a laboratory for counterfactual policy analysis, I proceed to consider several inflationary interventions. First, I assess the impact of temporarily raising the inflation target at the onset of the crisis—which, like the crisis itself, is unanticipated. I analyze variants of this policy that involve different magnitudes and durations of higher inflation. In every case, surprise inflation boosts nominal *and real* house prices, thereby quickly restoring equity to the housing market. This equity injection significantly attenuates the rise in foreclosures, bolsters consumption, and accelerates the recovery. Because each of these policies permanently increase the nominal price level in the presence of long-term, fixed-rate mortgages, the effects are also quite persistent.

As an alternative, I study price-level targeting policies that increase inflation during the crisis before shifting to a period of disinflation that returns prices to their original trajectory. It turns out that such a policy is almost as effective at boosting consumption and reducing foreclosures, which is consistent with the finding in Ganong and Noel (2017) that short-term debt relief—which occurs both with inflation targeting and price-level targeting—plays the dominant role in shaping the dynamics of consumption and default. However, inflation targeting still proves more potent, especially for restoring real house prices to their pre-crisis level.

To understand why inflation is relatively ineffective at fighting typical recessions but potent when implemented during a crisis, note that the stimulative impact of inflation depends nonlinearly on the degree of leverage in the economy. At a business cycle frequency, real house prices do not exhibit large swings, and leverage remains stable. Thus, most homeowners can still fairly easily smooth consumption in the face of shocks by either refinancing or selling with minimal delay. However, dramatic

crisis-induced house price declines drive up leverage and create a hole in household balance sheets. Owing to higher default risk, banks restrict the ability of homeowners to extract equity through refinancing, and because of debt overhang, selling delays in the housing market become severe. Higher inflation packs a bigger punch in this scenario by partially reversing the deleterious spike in leverage.

To check the robustness of inflation as a crisis-fighting tool, I reintroduce nominal income sluggishness. Even in this scenario, higher inflation provides a modest boost to real house prices and consumption while significantly reducing foreclosure activity and the decline in homeownership—as long as mortgages are fixed rate contracts. With adjustable rate mortgages, however, the mortgage supply response cancels out debt erosion and what remains is the reduction in purchasing power from inflation. Therefore, with adjustable rate mortgages and sluggish nominal income, implementing a higher inflation target actually *deepens* the crisis. Lastly, returning to the case of flexible nominal income, I show that adding an externality that makes income partly demand-determined enhances the benefits of higher inflation during a crisis.

Behind these aggregate results is a rich heterogeneous response of households to higher inflation. Absent intervention, homeowners suffer larger drops in consumption than renters during the Great Recession, and in terms of lifetime welfare, renters actually come out *ahead* because of the increased affordability of housing. Conditional on homeownership, the consumption and welfare drops caused by the Great Recession both increase with leverage. If policymakers implement a higher inflation target to combat the crisis, these highly leveraged homeowners also become the biggest winners while renters are modestly hurt. Quantitatively, a moderately higher inflation target reduces renter welfare by 0.12% but increases homeowner welfare by 1.43%—ranging from 0.19% for homeowners with minimal debt to 2.38% for highly leveraged owners. The aggregate welfare gain shrinks but remains positive with sluggish nominal income and fixed rate mortgages, but replacing fixed rate mortgages with adjustable rate mortgages causes welfare to fall by approximately 1% both for renters and owners.

In fact, leverage amplifies the consumption and welfare losses from inflation in this scenario just as it amplifies the benefits in the benchmark with flexible nominal income and fixed rate mortgages. Lastly, the demand externality magnifies the homeowner welfare gains from inflation and even gives rise to a 0.12% increase in welfare for renters who benefit from the spillover of higher aggregate consumption to income.

1.1 Implementation Issues

Thus far, I have set aside concerns about how to generate higher inflation. Normally, this issue is not controversial. However, when the economy is in a liquidity trap at the zero lower bound, concerns about the government's ability to generate inflation achieve greater salience. Thankfully, a growing body of literature sheds light on which tools the government has at its disposal after the usual ammunition runs dry.

At the zero lower bound, conventional open market operations no longer generate inflation because government debt and money become perfect substitutes. However, Krugman (1998) and Eggertsson and Woodford (2003) point out that a credible commitment to pursue higher future inflation, i.e. forward guidance, puts upward pressure on the *current* price level. For example, monetary authorities can commit to keeping the policy rate low even *after* the zero lower bound no longer binds. Eggertsson and Giannoni (2013) explain that, during a liquidity trap, the more anticipated is inflation, the greater stimulative impact it has.

Historically, central banks have expressed reluctance to undertake such an endeavor, fearing that public skepticism about the central bank's ability to attain the higher target would undermine credibility. Bernanke (2000) addresses these concerns by pointing out that central banks have more tools at their disposal than they would like to admit and by stressing the importance of transparent communication. Woodford (2012) reiterates and expands upon both of these points. In recent work, Benigno, Eggertsson and Romei (2014) shows that future inflation commitments have considerably larger effects on current inflation in economies experiencing dynamic

debt deleveraging at the zero lower bound. However, what if the government cannot "credibly promise to be irresponsible"? As one way to demonstrate commitment, the central bank can announce a target path for the *price-level*, rather than inflation. Eggertsson and Woodford (2003) suggest this course of action, and Sheedy (2014) goes a step further by advocating nominal GDP targeting. Meanwhile, Svensson (2003) explains that a currency depreciation followed by a peg at the lower rate serves as a "conspicuous commitment to a higher price level in the future." Bhattari, Eggertsson and Gafarov (2015) also make the point that, by lowering the duration of government debt, quantitative easing creates the future incentive to pursue higher inflation.

Additional policy avenues open up when one allows for coordination between fiscal and monetary authorities. For example, Eggertsson (2006), Bernanke (2000), and Galí (2014) all make the point that a sufficiently large money-financed tax cut at the zero lower bound acts as the equivalent of helicopter drops and must generate inflation. As Ben Bernanke himself has said, "sufficient injections of money will ultimately always reverse a deflation. Under a fiat money system, a government should always be able to generate increased nominal spending and inflation, even when the short-term nominal interest rate is at zero."

1.2 Related Literature

This paper bridges the literature on models of default with the literature on housing market search frictions, both of which Hedlund (2016) and Hedlund (2015) describe in detail. In other related work, Mian, Rao and Sufi (2013) and Dynan (2012) establish the negative effect of debt overhang on consumption. Di Maggio, Kermani, Keys, Piskorski, Ramcharan, Seru and Yao (2017) and Aladangady (2017) look at the transmission of monetary policy through changes to household balance sheets. Doepke, Schneider and Selezneva (2015), Doepke and Schneider (2006), Meh, Ríos-Rull and Terajima (2010), and Auclert (2017) discuss the redistributive implications of inflation. Benigno et al. (2014) and Leeper and Zhou (2013) establish a posi-

tive role for inflation during times of high debt. Sheedy (2014) makes the case for nominal GDP targeting to improve risk-sharing from the presence of noncontingent nominal debt. Lessard and Modigliani (1975), Kearl (1979), and Piazzesi and Schneider (2012) study the real effects of high 1970s inflation. In the recent sovereign debt literature, Hilscher, Raviv and Reis (2017) and Reinhart and Sbrancia (2015) study the effectiveness of inflation at reducing public debt. Galí (2014) studies the effects of an increase in government purchases financed through seignorage and finds that it compares favorably to more conventional debt financing under certain conditions.

In a related paper, Garriga, Kydland and Sustek (2015) study the transmission of monetary policy under adjustable rate and fixed rate mortgages. As in this paper, they take into account how inflation simultaneously erodes the the value of existing debt and increases the cost of new credit. However, they employ a representative agent model with fully amortizing mortgages, whereas I study an economy with the option to refinance and an endogenous distribution of assets, debt, and housing. Furthermore, search frictions make housing illiquid in this paper. These added features allow me to study the effect of inflation on household portfolios, housing liquidity, foreclosures, and credit pricing during the Great Recession.

Chatterjee and Eyigungor (2015) also briefly evaluate the effect of inflation on housing and foreclosures during the Great Recession. They find that inflation reduces foreclosures but has no impact on real house prices. However, debt overhang is effectively nonexistent in their setup because they model frictionless housing markets and forbid refinancing. The interaction of endogenous credit constraints and housing illiquidity in this paper proves crucial to the efficacy of inflationary policies.

Midrigan and Philippon (2016) and Garriga and Hedlund (2017) study the role of house prices and deleveraging during the Great Recession, while Gorea and Midrigan (2017) also analyze the importance of housing illiquidity. However, to the best of my understanding, no other paper has examined the potential of inflation to combat economic crises characterized by a deep housing slump and foreclosure crisis.

2 The Model

The model is an infinite horizon, open endowment economy populated by a continuum of ex-ante identical households, a housing sector, and a banking sector. The following ingredients feature prominently: i) uninsurable, idiosyncratic household income risk, ii) housing market search frictions, iii) nominal mortgages, and iv) mortgage default.

2.1 Households

Endowments Households receive a stochastic endowment $e \cdot s$ that consists of persistent and transitory components. The persistent component $s \in S$ follows a finite-state Markov chain with transitions $\pi_s(s'|s)$, and households receive their initial s from the stationary distribution $\Pi_s(s)$. Households draw the transitory component $e \in E \subset \mathbb{R}_+$ each period from the cumulative distribution function $F(e)$.

Preferences Households enjoy utility from consumption c and housing services c_h, either as homeowners or apartment-dwellers. Apartment-dwellers, or "renters," purchase apartment space $a \leq \overline{a}$ each period at unit cost p_a and receive $c_h = a$. Homeowners with house $h \in H = \{\underline{h}, h_2, h_3\}$ receive utility $c_h = h$. By assumption, homeowners cannot own multiple houses or rent their house to a tenant, and $\overline{a} \leq \underline{h}$, i.e. houses are larger than apartments.[2] Households discount the future at rate β.

2.2 The Housing Market

Apartments The numeraire consumption good can be converted back and forth into apartment space at the rate A, which pins down its price at $p_a = 1/A$.[3]

[2] The prohibition on owning multiple houses improves tractability. Own-to-own transitions occur in the model when homeowners sell their current house and buy a new house within the same period. The segmentation of housing and apartments is consistent with empirical evidence from Halket, Nesheim and Oswald (2017).

[3] Empirically, Sommer, Sullivan and Verbrugge (2013) and Davis, Lehnert and Martin (2008) report that real rents have remained essentially unchanged over the past 30 years, even while house prices have experienced large swings.

Houses There is a fixed stock of durable houses that are traded in a decentralized market subject to search frictions. Specifically, buyers and sellers direct their search by house size and price. Homeowners who post high list prices take more time to sell in expectation, whereas buyers who are willing to pay a higher price expect to more quickly find a seller. In general, the presence of rich heterogeneity among buyer and seller types by income, assets, and debt would give rise to an intractable dynamic sorting problem. To circumvent this issue, I follow Hedlund (2016) by introducing passive real estate brokers as a modeling device to intermediate trades.

2.2.1 Decentralized Trade in the Housing Market

Households ($j = s$ for sellers, $j = b$ for buyers) direct their search to submarket $(x_j, h) \in \mathbb{R}_+ \times H$ by choosing a price x_j at which to transact house $h \in H$ with a broker. Homeowners match with brokers to sell their current house, and buyers match with brokers to purchase a house of their choosing. Households find a broker with probability $p_j(\theta_j(x_j, h))$, and brokers find a household with probability $\alpha_j(\theta_j(x_j, h)) = \frac{p_j(\theta_j(x_j,h))}{\theta_j(x_j,h)}$. Each broker in submarket (x_j, h) incurs an entry cost $\kappa_j h$, and all participants take $\theta_j(x_j, h)$ as given.[4] Unsuccessful sellers incur a small utility cost ξ and are free to adjust their list-price next period or take their house off the market.[5] Sellers must pay off their mortgage at the time of sale to avoid foreclosure.

2.2.2 Dynamic Sorting and Two-Sided Heterogeneity

Real-estate brokers resolve what would otherwise be an intractable dynamic sorting problem by breaking up a one-stage matching problem with two-sided heterogeneity into a two-stage problem with one-sided heterogeneity plus free entry. Without the brokers, every submarket tightness would depend on the distribution of seller income,

[4]The functions $p_j : \mathbb{R}_+ \to [0, 1]$ are continuous and strictly increasing with $p_j(0) = 0$, while α_j are strictly decreasing. Removing the dependence of the entry cost on h would create large, systematic differences in the magnitude of search frictions across submarkets for different house sizes.

[5]The utility cost prevents homeowners nearly indifferent about selling from fishing for buyers by posting unreasonably high prices that lead to inordinate time on the market.

assets, and mortgage debt as well as the distribution of buyer income and assets. Furthermore, sellers and buyers would both need to forecast the evolution of these distributions to understand the dynamics of the housing market.

By contrast, in this setup, one group of brokers *temporarily* obtains houses from successful sellers, and another group of brokers matches with buyers looking to purchase. Analogous to an over-the-counter market, brokers trade the stock of temporarily acquired houses with each other at unit price p_h until the entire stock has changed hands from sellers to buyers. Reflecting their status as passive market-makers, brokers are not permitted to carry houses from one period to the next, and the law of large numbers implies that total housing flows to and from brokers are deterministic.

Brokers enter submarket (x_s, h) until the entry cost $\kappa_s h$ exceeds the expected revenue, which is given by $p_h h - x_s$. An analogous process occurs for brokers matching with buyers. Thus, the menu of market tightnesses only depends on p_h and not directly on the household distributions:

$$\kappa_b h \geq \overbrace{\alpha_b(\theta_b(x_b, h))}^{\text{prob of match}} \overbrace{(x_b - p_h h)}^{\text{broker revenue}} \tag{1}$$

$$\kappa_s h \geq \underbrace{\alpha_s(\theta_s(x_s, h))}_{\text{prob of match}} \underbrace{(p_h h - x_s)}_{\text{broker revenue}} \tag{2}$$

with strict equality in active submarkets. This *block recursivity* greatly increases tractability by reducing the problem to finding p_h and substituting into (1) – (2).

2.3 Banking Sector

Competitive banks issue mortgages to homeowners and offer one-period real bonds as a saving vehicle to all households. Banks have access to external funding at rate r, which pins down the price of bonds at $q_b = \frac{1}{1+r}$. Mortgages in the model are long-term, nominal, non-state-contingent contracts that allow for default in equilibrium. Furthermore, because the likelihood of default depends on borrower characteristics

such as income and savings, mortgages are individually risk-priced at origination.

In a conventional 30-year fixed rate mortgage, nominal payments are constant and the outstanding nominal balance follows a predetermined amortization schedule. In reality, however, homeowners can adjust their *cumulative* leverage by taking out multiple liens (e.g. second mortgages, home equity lines of credit, etc.). To capture this leverage flexibility in a way that avoids the curse of dimensionality, mortgages in the model feature no predetermined duration. Instead, borrowers choose how much principal to pay down each period, and any outstanding nominal balance is rolled over at the interest rate set at origination (i.e. the bank faces one-sided commitment).

Mathematically, when a borrower with savings b', house h, and income state s takes out a new mortgage with nominal face value M' and rate $\overline{R}_m$, the bank transfers $q_m^0((\overline{R}_m, M'), b', h, s)M'$ in nominal units to the borrower. In subsequent periods, non-defaulting borrowers with outstanding debt M choose how much of their balance, $M' \leq M$, to roll over at the rate $\overline{R}_m$, which requires a nominal payment L satisfying $M' = (M - L)(1 + \overline{R}_m)$. The only way for borrowers to *increase* their debt or reset the rate is to refinance into a new loan. However, reclassification risk and the presence of an origination cost ζ prevent most borrowers from refinancing in any given period.[6]

For each contract $(\overline{R}_m, M')$, perfect competition produces borrower-specific equilibrium mortgage prices $q_m^0(\cdot)$ that deliver zero ex-ante profits loan-by-loan. In addition to default risk, mortgage prices incorporate inflation risk, interest rate risk, and a wedge ϕ from per-period servicing costs. Banks discount future cash flows at the rate $1 + R_m = (1 + \phi)(1 + r)(1 + \pi) \equiv (1 + r_m)(1 + \pi)$, where π is the inflation rate. For tractability, I restrict the set of contracts $(\overline{R}_m, \cdot)$ to those where all default risk is priced into q_m^0, which implies that $\overline{R}_m = R_m$ at origination.[7] Outside of steady state, q_m^0 incorporates the risk that R_m deviates from $\overline{R}_m$ over time.

[6]Despite the lack of explicit mortgage duration, most borrowers pay down their debt over time and only occasionally refinance, as in figure 14 from the appendix.

[7]This assumption is tantamount to requiring risky borrowers to pay their default premium upfront through points instead of over time through higher interest payments.

Mortgage prices for contract $(\overline{R}_m, M')$ satisfy the following recursive relationship:

$$(1+\zeta)q_m^0((\overline{R}_m, M'), b', h, s)M' = \frac{1}{1+R_m}\mathbb{E}\left\{\overbrace{p_s(\theta_s(x_s', h))M'}^{\text{sell + repay}} + \overbrace{[1-p_s(\theta_s(x_s', h))]}^{\text{no sale (do not try/fail)}}\left[\overbrace{d'\min\{P' J_{REO}(h), M'\}}^{\text{default}}\right.\right.$$
$$\left.\left.+(1-d')\left\{M'\mathbf{1}_{[\text{Refi}]} + \mathbf{1}_{[\text{No Refi}]}\left(\underbrace{L'}_{\text{nominal payment}} + \underbrace{(1+\zeta)q_m^0((\overline{R}_m, M''), b'', h, s')M''}_{\text{continuation with } M''=(M'-L')(1+\overline{R}_m)}\right)\right\}\right]\right\}$$

where P' is the price level and x_s', d', b'', and M'' are the policy functions for list price, default ($\in \{0,1\}$), bonds, and next period's mortgage balance, respectively. In addition, $J_{REO}(h)$ is how much the bank values repossessing the borrower's foreclosed house, as discussed in section 2.3.1. Search frictions reduce credit by increasing the probability of default, $(1-p_s)d'$, and reducing the value of housing collateral, J_{REO}.

Dividing through by M' and expressing quantities in real terms gives

$$(1+\zeta)q_m^0((\overline{R}_m, m'), b', h, s) = \frac{1}{1+R_m}\mathbb{E}\left\{p_s(\theta_s(x_s', h)) + [1-p_s(\theta_s(x_s', h))]\left[d'\min\left\{\frac{J_{REO}(h)}{m'/(1+\pi)}, 1\right\}\right.\right.$$
$$\left.\left.+(1-d')\left\{\mathbf{1}_{[\text{Refi}]} + \mathbf{1}_{[\text{No Refi}]}\left(\frac{l' + (1+\zeta)q_m^0((\overline{R}_m, m''), b'', h, s')m''}{m'/(1+\pi)}\right)\right\}\right]\right\} \tag{3}$$

Absent default, steady state $q_m^0((R_m, m'), b', h, s) = \frac{1}{(1+\zeta)(1+R_m)} = \frac{1}{(1+\zeta)(1+r_m)(1+\pi)}$, which is clearly a decreasing function of inflation π. Intuitively, for a given promised sequence of nominal repayments, banks reduce lending as expected inflation increases.[8]

2.3.1 Foreclosure Process

In the event of default, banks initiate foreclosure proceedings by repossessing the borrower's house and erasing the outstanding debt balance. In addition to the consequence of losing their house, foreclosed borrowers receive a flag $f = 1$ on their credit record that prevents them from accessing the mortgage market. These flags persist to the following period with probability $\gamma_f \in (0,1)$. The house repossession and borrowing exclusion represent the only costs of foreclosure to borrowers.

[8] Section 5.3.2 provides a more in-depth discussion of the relationship between inflation and credit.

Banks sell repossessed houses (REO properties) in the decentralized housing market, just as anybody else. However, reflecting the pecuniary costs of foreclosure, banks lose a proportion χ of the sales price and absorb all losses from foreclosure.[9]

The value to a lender of repossessing a house h is

$$J_{REO}(h) = R_{REO}(h) - \gamma p_h h + \frac{1}{1+r} J_{REO}(h)$$
$$R_{REO}(h) = \max\left\{0, \max_{x_s \geq 0} p_s(\theta_s(x_s, h)) \left[(1-\chi)x_s - \left(-\gamma p_h h + \frac{1}{1+r} J_{REO}(h)\right)\right]\right\} \tag{4}$$

where γ represents holding costs and $R_{REO}(h)$ is the option value of selling.

2.4 Household Decisions

Each period contains three subperiods. In subperiod 1, households learn their endowment (e, s) and credit score $f \in \{0, 1\}$. Homeowners decide whether to try to sell, and non-selling borrowers decide whether to default, make a payment, or refinance. In subperiod 2, renters decide whether to try to purchase a house. Lastly, in subperiod 3, all households make consumption and portfolio choice decisions. The individual state of a homeowner is cash at hand y, mortgage rate and balance $(\overline{R}_m, m)$, house h, and persistent endowment s. The individual state of a renter is simply (y, s, f).

Portfolio Choice End-of-period expenditures for non-refinancing owners consist of consumption, bond purchases, and a mortgage payment. In nominal terms,

$$Pc + P\gamma p_h h + P q_b b' + L \leq Py$$

where $L \equiv Pl = M - \frac{M'}{1+\overline{R}_m}$ and $L \geq \underline{L} \equiv \frac{\overline{R}_m}{1+\overline{R}_m} M$ to ensure $M' \leq M$. In real terms,

$$c + \gamma p_h h + q_b b' + \underbrace{\frac{m}{1+\pi} - \frac{m'}{1+\overline{R}_m}}_{l} \leq y.$$

[9]The bank must send any potential profits back to the borrower.

This constraint makes clear that higher inflation π reduces the value of outstanding debt. In the stationary environment, such owners have value function

$$V_{own}^{pay}(y,(\overline{R}_m,m),h,s,f=0)=\max_{b',c\geq 0,l\geq \underline{l}} u(c,h)+\beta\mathbb{E}\left[(W_{own}+R_{sell})(y',(\overline{R}_m,m'),h,s',f'=0)\right]$$
$$\text{subject to}$$
$$c+\gamma p(h)+q_b b'+l\leq y$$
$$m'=\left(\frac{m}{1+\pi}-l\right)(1+\overline{R}_m)$$
$$y'=e's'+b' \tag{5}$$

For homeowners who refinance,

$$V_{own}^{refi}(y,m,h,s,f=0)=\max_{m',b',c\geq 0} u(c,h)+\beta\mathbb{E}\left[(W_{own}+R_{sell})(y',(R_m,m'),h,s',f'=0)\right]$$
$$\text{subject to}$$
$$c+\gamma p(h)+q_b b'+\frac{m}{1+\pi}\leq y+q_m^0((R_m,m'),b',h,s)m'$$
$$q_m^0((R_m,m'),b',h,s)m'\leq \vartheta p_h h$$
$$y'=e's'+b' \tag{6}$$

where $1-\vartheta$ is the minimum down payment ratio. The continuation term W_{own} is homeowner subperiod 1 utility, and R_{sell} is the option value of selling.

Homeowners with bad credit lack access to the mortgage market and have utility

$$V_{own}(y,0,h,s,f=1)=\max_{m',b',c\geq 0} u(c,h)+\beta\mathbb{E}\left[(W_{own}+R_{sell})(y',0,h,s',f')\right]$$
$$\text{subject to}$$
$$c+\gamma p(h)+q_b b'\leq y$$
$$y'=e's'+b' \tag{7}$$

where $f'=1$ with probability γ_f and $f'=0$ with probability $1-\gamma_f$.

Lastly, regardless of credit status, renters choose apartment a and have utility

$$
\begin{aligned}
V_{rent}(y,s,f) = \max_{b',c\geq 0, 0\leq a\leq \overline{a}} u(c,a) + \beta\mathbb{E}\left[(V_{rent}+R_{buy})(y',s',f')\right] \\
\text{subject to} \\
c + p_a a + q_b b' \leq y \\
y' = e's' + b'
\end{aligned} \tag{8}
$$

where R_{buy} is the option value of buying a house.

Buying Houses In subperiod 2, prospective buyers choose their desired house size h and price x_b. Buyers with good credit are bound by the constraint $x_b \leq y - \underline{y}(h,s)$, where $\underline{y}(h,s) < 0$ captures the ability to take out a mortgage in subperiod 3. For buyers with bad credit, $x_b \leq y$. The option value R_{buy} satisfies

$$
R_{buy}(y,s,0) = \max\{0, \max_{h\in H, x_b\leq y-\underline{y}} p_b(\theta_b(x_b,h))[V_{own}(y-x_b,0,h,s,0) - V_{rent}(y,s,0)]\} \tag{9}
$$

$$
R_{buy}(y,s,1) = \max\{0, \max_{h\in H, x_b\leq y} p_b(\theta_b(x_b,h))[V_{own}(y-x_b,0,h,s,1) - V_{rent}(y,s,1)]\} \tag{10}
$$

Mortgage Default, Refinancing, and Repayment At the end of subperiod 1, any borrowers who did not sell their house at the beginning of the period choose whether to default, refinance, or make a payment. The value function is

$$
\begin{aligned}
W_{own}(y,(\overline{R}_m,m),h,s,0) = \max\Big\{V_{own}^{pay}(y,(\overline{R}_m,m),h,s,0), V_{own}^{refi}(y,m,h,s,0), \\
(V_{rent}+R_{buy})\left(y + \max\left\{0, J_{REO}(h) - \frac{m}{1+\pi}\right\}, s, 1\right)\Big\}
\end{aligned} \tag{11}
$$

Selling Houses At the beginning of subperiod 1, owners who wish to sell choose a list price x_s. The option value R_{sell} of selling for an owner with good credit is

$$R_{sell}(y, (\overline{R}_m, m), h, s, 0) = \max\{0, \max_{x_s} p_s(\theta_s(x_s, h)) \Big[(V_{rent} + R_{buy}) \left(y + x_s - \frac{m}{1+\pi}, s, 0\right) - W_{own}(y, (\overline{R}_m, m), h, s, 0)\Big] + [1 - p_s(\theta_s(x_s, h))](-\xi)\} \text{ subject to } y + x_s \geq \frac{m}{1+\pi} \tag{12}$$

where homeowners are constrained when setting their list price to be able to pay off their debt upon selling. By reducing the real value of outstanding debt, inflation relaxes this constraint. Homeowners with bad credit face an analogous problem but do not have any outstanding mortgage debt to restrict their choice of list price.

2.5 Equilibrium

A stationary equilibrium consists of value/policy functions for households and banks; market tightnesses θ_s and θ_b; prices p_h, p_a, q_b, and q_m^0; distributions Φ_{own} and Φ_{rent}; and REO housing stock $\{H_{REO}(h)\}_{h \in H}$ such that households optimize according to above, market tightnesses satisfy (1) – (2), mortgage prices satisfy (3), and the housing market clears (successfully sold housing equals successfully purchased housing):

$$\underbrace{\int h^* p_b(\theta_b(x_b^*, h^*; p_h)) d\Phi_{rent}}_{D_h(p_h)} = \underbrace{\overbrace{S_{REO}(p_h)}^{\text{REO sales}} + \overbrace{\int h p_s(\theta_s(x_s^*, h; p_h)) d\Phi_{own}}^{\text{sold by owner}}}_{S_h(p_h)}. \tag{13}$$

3 Bringing the Model to the Data

I calibrate the model to match features of the U.S. economy during 2003 – 2005, prior to the 2005 – 2007 monetary policy tightening and subsequent Great Recession. Some model parameters are taken directly from the data or from the literature, while the remaining parameters are calibrated jointly to match key housing moments and important dimensions of the household portfolio distribution.

3.1 External Parameters

Endowments and Preferences The endowment $e \cdot s$ is adapted from Storesletten, Telmer and Yaron (2004), where $\ln(s)$ follows an AR(1) process and e is log-normal.[10] In the spirit of Castañeda, Díaz-Giménez and Ríos-Rull (2003), I add a state for the top 1% (who bear most of the unanticipated bank losses.) The average quarterly endowment is normalized to 0.25. Households have CES utility

$$u(c, c_h) = \frac{([\omega c^{\frac{\nu-1}{\nu}} + (1-\omega)c_h^{\frac{\nu-1}{\nu}}]^{\frac{\nu}{\nu-1}})^{1-\sigma}}{1-\sigma}$$

with an intratemporal elasticity of substitution of $\nu = 0.13$, consistent with evidence in Flavin and Nakagawa (2008) and Kahn (2009). I set risk aversion to $\sigma = 2$, and the joint calibration determines the consumption share ω and discount factor β.

Apartments and Houses I set the apartment technology A to generate an annual rent-price ratio of 3.5%. Matching in the decentralized housing market is Cobb Douglas, i.e. $p_s(\theta_s) = \min\{\theta^{\gamma_s}, 1\}$ and $p_b(\theta_b) = \min\{\theta^{\gamma_b}, 1\}$. Using (1) and (2) gives

$$p_s(\theta_s) = \begin{cases} 0 & \text{if } x_s > p_h h \\ \left(\frac{p_h h - x_s}{\kappa_s h}\right)^{\frac{\gamma_s}{1-\gamma_s}} & \text{if } (p_h - \kappa_s)h \leq x_s \leq p_h h \end{cases} \qquad p_b(\theta_b) = \begin{cases} \left(\frac{x_b - p_h h}{\kappa_b h}\right)^{\frac{\gamma_b}{1-\gamma_b}} & \text{if } p_h h \leq x_b \leq (p_h + \kappa_b)h \\ 0 & \text{if } x_b < p_h h \end{cases}$$

The internal calibration determines κ_b, κ_s, γ_s, γ_b, and the disutility ξ. I set holding costs (maintenance, property taxes, etc.) to $\gamma = 0.007$.

Banking Sector To match the U.S. during 2003 – 2005, I set inflation to 1.9%, the nominal risk-free rate to 0.9%, the nominal mortgage rate to 6.0% via the servicing cost ϕ, and the origination cost to 0.4%. No down payment is required in the initial steady state.[11] Lastly, I set the persistence of credit flags to $\gamma_f = 0.95$, and the internal calibration determines the REO discount χ.

[10] The appendix explains the procedure that converts the continuous, annual process from Storesletten et al. (2004) into a discrete, quarterly process.

[11] In fact, the popularity of cash-out refinancing during the mid-2000s resulted in many new mortgages with cumulative loan-to-value ratios exceeding 100%. See Herkenhoff and Ohanian (2015).

Table 1: Model Calibration

Description	Parameter	Value	Target	Model	Source/Reason
		External Parameters			
Autocorrelation	ρ	0.952			Storesletten et al. (2004)
SD of Persistent Shock	σ_ϵ	0.17			Storesletten et al. (2004)
SD of Transitory Shock	σ_e	0.49			Storesletten et al. (2004)
Top 1% Labor Efficiency*	s_4/s_3	4			Kuhn and Ríos-Rull (2013)
Prob. of Top 1%*	$\pi_{3,4}$	0.0041			Kuhn and Ríos-Rull (2013)
Persistence of Top 1%*	$\pi_{4,4}$	0.9			Kuhn and Ríos-Rull (2013)
Intratemp. Elas. of Subst.	ν	0.13			Flavin and Nakagawa (2008)
Risk Aversion	σ	2			Various
Holding Costs	γ	0.7%			Moody's
Rent-Price Ratio (Annual)	p_a	3.5%			Sommer et al. (2013)
Risk-Free Rate (Annual)	r	−1.0%			Federal Reserve Board
Inflation (Annual)	π	1.9%			PCE Index
Servicing Cost (Annual)	ϕ	0.051			6.0% Nominal Mortgage Rate
Mortgage Origination Cost	ζ	0.4%			FHFA
Minimum Downpayment	$1-\vartheta$	0%			Fannie Mae
Credit Flag Persistence	λ_f	0.95			Fannie Mae
		Internal Parameters			
Homeownership Rate	$\overline{a}$	2.3000	69.2%	69.1%	Census
Starter House Value	h_1	2.7500	2.75	2.75	Corbae and Quintin (2015)
Housing Wealth (Owners)	ω	0.8389	3.99	3.99	2004 SCF
Median Borrower *LTV*	β	0.9737	59.30%	60.63%	2004 SCF
Months of Supply**	ξ	0.0014	4.90	4.86	Nat'l Assoc of Realtors
Buyer Search (Weeks)	γ_b	0.0940	10.00	9.82	Nat'l Assoc of Realtors
Maximum Bid Premium	κ_b	0.0250	2.5%	2.5%	Gruber and Martin (2003)
Maximum List Discount	κ_s	0.1500	15%	15%	RealtyTrac
Foreclosure Discount	χ	0.0920	20%	20%	Pennington-Cross (2006)
Foreclosures*** (Annual)	γ_s	0.6400	0.60%	0.67%	Nat'l Delinquency Survey
		Steady State Fit			
Borrowers with $LTV \geq 80\%$			22.00%	22.91%	2004 SCF
Borrowers with $LTV \geq 90\%$			10.50%	10.61%	2004 SCF
Borrowers with $LTV \geq 95\%$			5.20%	5.41%	2004 SCF
Mean Net Worth			2.62	2.78	2004 SCF
Mean Liquid Assets			1.06	0.94	2004 SCF
Mean Owner Net Worth			3.13	3.19	2004 SCF
Mean Owner Liquid Assets			1.20	1.01	2004 SCF
Median Owner Liquid Assets			0.24	0.34	2004 SCF

*The ratio $s_4/s_3 = 4$ corresponds roughly to the earnings ratio $\text{earn}_{99-100}/\text{earn}_{95-99}$ in 2004 reported by Kuhn and Ríos-Rull (2013). The transition probabilities resemble the values in table 20 but have been adjusted to ensure that exactly 1% of households at any point in time have $s = s_4$. The transition probabilities $\pi_{i,4} = 0$ and $\pi_{4,i} = 0$ for $i = 1, 2$.

**Months of supply, which proxies for time on the market, equals inventories divided by the sales rate.

***Foreclosure starts are 1.2% but Herkenhoff and Ohanian (2015) report that nearly half self-cure.

3.2 Internal Calibration

I determine the remaining parameters to ensure that the model replicates many features of the U.S. economy during the pre-bust 2003–2005 period. Included in the list of targets are select household portfolio moments from the 2004 Survey of Consumer Finances (SCF), which is important for properly quantifying the heterogeneous impact of inflationary policies. In addition, to correctly capture the behavior of housing and mortgage markets, certain key moments related to sales volume, average search duration, price spreads, and foreclosures are included. Table 1 shows that the parametrized model successfully replicates these and other untargeted data moments.[12] Notably, the model generates an appropriate quantity of liquid assets and an empirically accurate distribution of mortgage leverage, which ends up playing an important role for the behavior of consumption in and out of steady state.

4 Inflationary Policies in Normal Times

To summarize section 2, inflation operates through three channels in the model. First, inflation erodes the value of outstanding mortgage debt in the household budget constraint. Second, the supply of mortgage credit contracts via a reduction in mortgage prices q_m^0. In other words, new borrowers receive fewer resources $q_m^0 m'$ for any given choice of m'. Lastly, housing liquidity is enhanced by the relaxation of the list price constraint $x_s \geq \frac{m}{1+\pi} - y$ for sellers. This section discusses the overall economic impact of inflation in the long run and during "typical" recessions.

4.1 Inflation and Housing in the Long Run

With one-period contracts and no option to default, the debt erosion and credit supply channels of inflation exactly offset each other. In this simplified environment, mortgage prices are $q_m^0 = \frac{1}{(1+r_m)(1+\pi)}$. Thus, borrowers who choose mortgage m'

[12] Figure 15 in the appendix provides additional information on the distributional fit of the model.

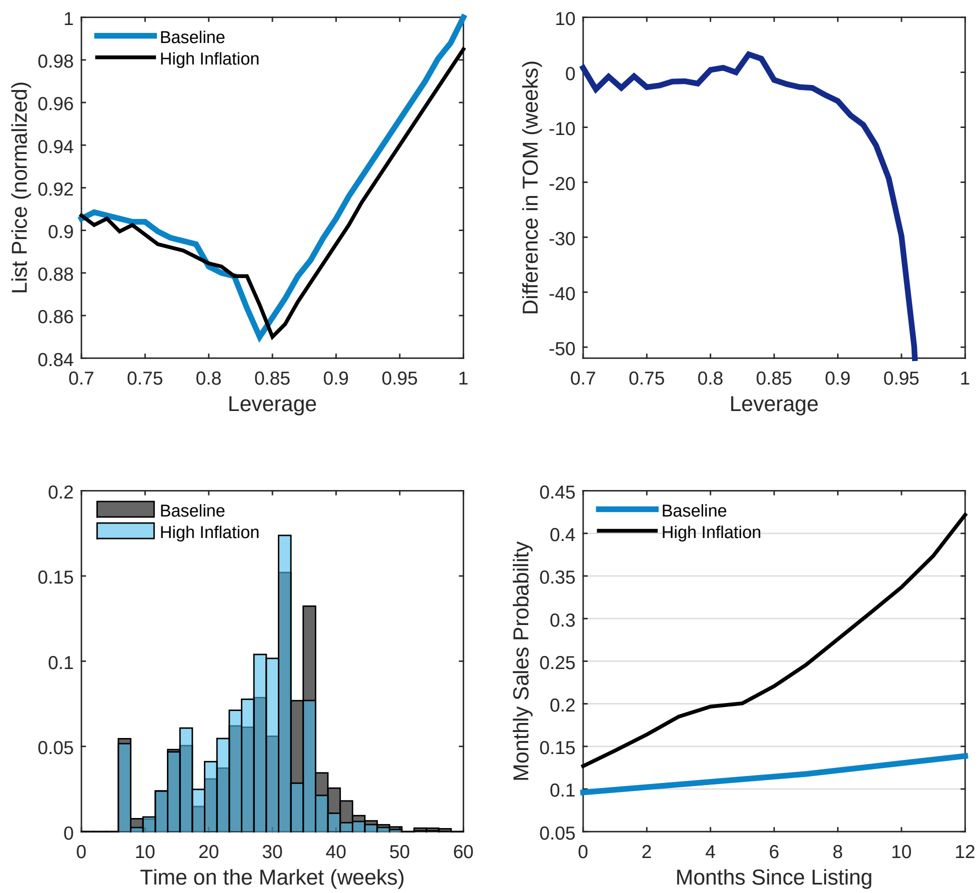

Figure 1: (1) List price. (2) Difference in expected TOM (high inflation − baseline). (3) Distributions of expected TOM. (4) Monthly sales probabilities.

receive real resources $\frac{1}{(1+r_m)(1+\pi)}m'$ this period and owe real resources $\frac{m'}{1+\pi}$ next period from the erosion of nominal debt. Dividing the real payment next period by the real resources received this period gives the gross real mortgage interest rate, $1 + r_m$. Unsurprisingly, this rate is independent of the inflation rate. Intuitively, in an environment with high inflation, borrowers receive fewer resources for any given choice of m' but also make a smaller payment in the future. Therefore, borrowers just scale up their choice of m' and end up unaffected by the inflation rate.

Adding long-term mortgages, default, and illiquid housing has the potential to break this superneutrality. First, with the option to default, mortgage prices incorporate a foreclosure premium that is set *at origination*. Importantly, borrowers do not

Table 2: Inflation in the Long Run

Statistic	Low Inflation (Baseline)	High Inflation*
Homeownership Rate	69.1%	69.0%
Gross Housing Wealth	3.99	3.93
Borrowers with LTV $\geq$ 80%	22.9%	20.7%
Borrowers with LTV $\geq$ 90%	10.6%	8.7%
Borrowers with LTV $\geq$ 95%	5.4%	4.7%
Foreclosure Rate	0.67%	0.56%

*Inflation $\pi = 7.9\%$ (a 6pp increase).

face any roll-over risk as long as they continue paying down their mortgage. However, higher inflation automatically accelerates the repayment of principal. Borrowers who wish to counteract this amortization (such as to avoid tying up too much of their net worth in illiquid housing) must repeatedly extract equity through refinancing, which exposes them to roll-over risk and the origination cost.

Secondly, the liquidity of the housing market is affected by debt-constrained sellers whose houses sit on the market for an extended period of time because they are unable to lower their list price. As shown in the top panels of figure 1, higher inflation erodes mortgage debt and gives highly leveraged sellers greater list price flexibility, resulting in quicker sales. Furthermore, as seen in the bottom right panel, the housing liquidity benefits of inflation grow with time as debt continues to erode at an accelerated pace. In the steady state, although average time on the market does not vary markedly with the inflation rate, higher inflation compresses the right tail of the distribution by reducing the prevalence of extremely long selling delays (bottom left panel).

Even with these added features, however, table 2 shows that the model barely deviates quantitatively from strict superneutrality. A fairly substantial six percentage point permanent increase in inflation has almost no impact on the homeownership rate, housing wealth, the distribution of mortgage debt, and the foreclosure rate. Moreover, real house prices are essentially unaffected.

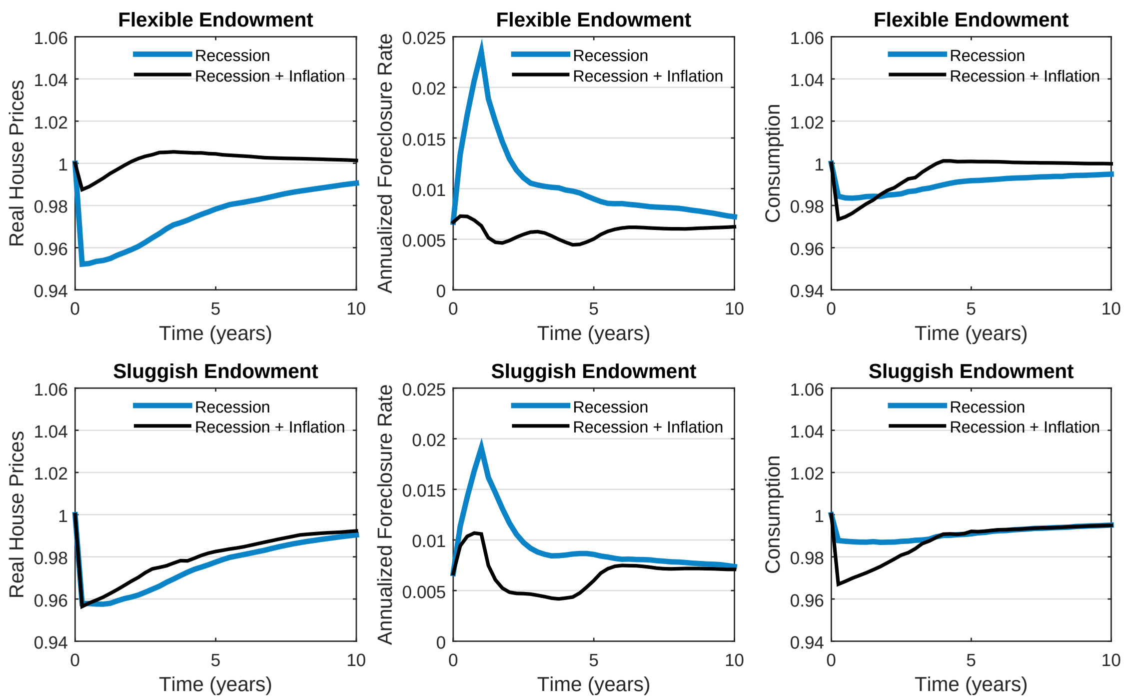

Figure 2: A "typical" recession with flexible vs. sluggish nominal endowments.

4.2 Using Inflation to Fight "Typical" Recessions

In reality, economies are never at a standstill, and experts have been calling with increasing frequency to add inflation to the recession-fighting toolkit. The top row of figure 2 shows an unanticipated recession driven by a 5% decrease in the aggregate endowment that lasts for three years. Absent any interventions, real house prices fall by 5% upon impact, consumption falls by 1.5%, and the foreclosure rate rises to 2.5%.

Impressively, a moderate inflation increase of three percentage points synchronized with the income decline almost completely arrests the fall in house prices and stops the foreclosure spike from materializing. The impact on consumption depends on the time horizon, however. Initially, consumption falls *further* with higher inflation—by 2.6% instead of 1.5%—before accelerating in its recovery. Overall, the temporary increase in the inflation target improves welfare by 0.5%, with renters (who, as potential future buyers, prefer lower house prices) losing 0.2% and owners gaining 0.8% in consumption-equivalent terms.

Nevertheless, this modest improvement depends on the nominal endowment immediately tracking with higher inflation. If the nominal endowment is instead sluggish, higher inflation no longer mitigates the house price decline, and it causes a persistent deterioration in consumption.[13] With sluggish endowments, there is actually a 0.3% welfare *loss* from the policy, with owners breaking even and renters experiencing a 1.1% drop in welfare. Taken together, and also in light of any inflation-fighting reputational concerns by the Federal Reserve, these scenarios suggest that inflation is not a particularly effective way to mitigate "typical" recessions and may even be harmful.

5 Inflation, Housing, and the Great Recession

While inflation may not be the appropriate remedy for typical recessions, perhaps a "once-in-75-year crisis calls for outside-the-box measures," as Ken Rogoff has advocated. Specifically, Rogoff (accompanied by the supporting voices of Robert Engle, Paul Krugman, and others) suggested several years of 4%–6% inflation to combat debt overhang and accelerate the recovery from the crisis. This section assesses the potential of temporary inflation to mitigate the severity of and accelerate the recovery from episodes like the Great Recession. Here, I take as given that the government can achieve the desired higher inflation, but section 1.1 discusses implementation.

5.1 The Baseline Great Recession

To simulate the U.S. Great Recession in the model, I largely follow the approach of Garriga and Hedlund (2017), who highlight two important factors behind the crash: elevated downside labor market risk and a tightening of downpayment constraints. These shocks, in addition to a productivity-driven decline in income and brief increase in interest rates during the monetary policy tightening of 2005–2007, propagate to the

[13] This setup is isomorphic to a production economy without capital with sticky nominal wages. Section 5.4.1 provides more details on the implementation.

Table 3: The Housing Bust

	ΔHouse Prices	ΔSales Rate	Peak Foreclosures	Peak TOM	Ownership Rate
Model	−21.4%	−42.2%	4.9%	43.5 weeks	69.1%/64.5%
Data	−25.2%	−41.9%	5.2%	50.8 weeks	69.2%/65.0%

Sources: (House Prices) FHFA house price index deflated by the core PCE. (Sales) National Association of Realtors existing sales. (Foreclosures) Mortgage Bankers Association. (Time On Market) National Association of Realtors. (Ownership) US Census.

economy through household balance sheets and the endogenous response of liquidity in the housing and credit markets. I defer to Garriga and Hedlund (2017) for a deeper discussion of the role of each of these shocks and the transmission channels.

Instead, the purpose here is to use the simulated Great Recession as a laboratory through which to evaluate inflationary interventions. To make matters concrete, the steady state of the model is subjected to a temporary, unexpected increase in downside income risk via changes to the individual endowment process and a tightening of the downpayment constraint to 10%.[14] Furthermore, the aggregate endowment declines by 5% for three years and the risk-free rate rises briefly for eight quarters before dropping back down.[15] For simplicity, this paper abstracts from some of the other minor shocks and institutional details in Garriga and Hedlund (2017).[16] Because these shocks occur completely by surprise, the resulting housing crash and recession produce unanticipated mortgage losses from foreclosure. Given the highly skewed ownership of financial institution equity in the data, I assume that the top 1% of households by income bear these losses.[17]

[14]The endowment transition matrix π_s is replaced with $\widetilde{\pi}_s^{recession}(s'|s)$ for three years. Specifically, $\widetilde{\pi}_s^{recession}(s_2|s) = (1 - 0.028)\pi_s(s_2|s)$ for all s, $\widetilde{\pi}_s^{recession}(s_j|s) = \pi_s(s_j|s)$ for all s and $j = 2, 3, 4$, and $\widetilde{\pi}_s^{recession}(s_1|s)$ is increased until $\sum_{s'} \widetilde{\pi}_s^{recession}(s'|s) = 1$ for all s.

[15]See Fernald (2014) for evidence on productivity during the Great Recession. The risk-free rate remained elevated throughout 2006 and 2007 until the aggressive rate cutting of 2008. However, in the model as in the data, long-term mortgage rates barely respond to this short-lived increase.

[16]For example, mortgage origination costs increased, and long foreclosure delays allowed delinquent borrowers to live "rent-free" in their houses for extended periods of time before being evicted.

[17]Specifically, I assume that the government levies a flat tax on the liquid assets of the top 1% over the course of the transition path that it uses to finance a bailout of bank losses. Counterfactually assuming proportional bank ownership only modestly impacts the results, as shown in table 10.

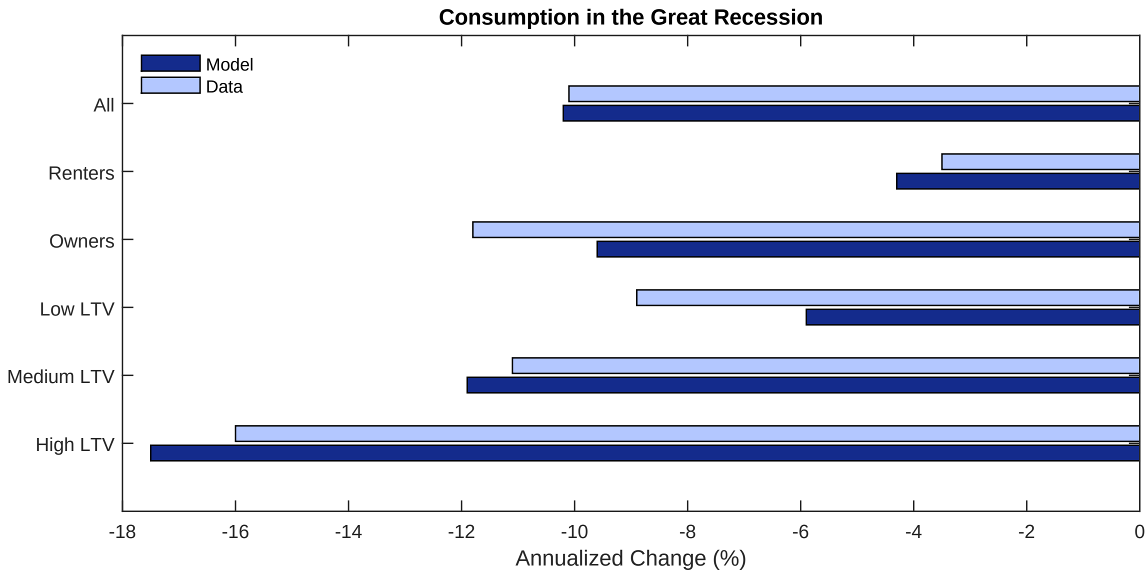

Figure 3: (All) Detrended non-housing consumption data from NIPA. (Disaggregated) PSID data following the sample selection criteria of Arellano et al. (2017). Low loan-to-value (LTV) is below 40%, and high LTV is above 90%.

5.1.1 Model Fit

Housing Table 3 shows that the model-generated crisis replicates the severity of the housing crash in the data. Real house prices fall by 21.4%, just shy of the 25% decline in the inflation-adjusted FHFA house price index. Furthermore, the model matches the drop in sales, the spike in foreclosures, and the erosion in homeownership from over 69% to under 65%. Lastly, the model captures the drying up of housing liquidity with time on the market rising to almost a year.

Consumption The model also resembles the cross-sectional behavior of consumption during the Great Recession. Figure 3 shows that the model is consistent with the empirical relationship between mortgage leverage and the decline in non-housing consumption.[18] In the aggregate, non-housing consumption drops by 10.2% in the model and 10.1% in the data, but these numbers mask substantial heterogeneity.[19] While

[18]Garriga and Hedlund (2017) provide an extensive discussion of the transmission mechanisms from household balance sheets to consumption during the Great Recession.

[19]Kaplan, Mitman and Violante (2017) find a similar aggregate consumption drop.

renter consumption in the model and data only falls by 4.3% and 3.5%, respectively, highly leveraged homeowners experience respective drops of 17.5% and 16%.

Additional Micro Evidence These cross-sectional findings are in line with other recent research on the relationship between mortgage debt and consumption. Using geographically-linked household data, Aladangady (2017) finds a marginal propensity to consume out of housing wealth that rises with leverage—consistent with Berger, Guerrieri and Lorenzoni (2018)—just as Kaplan, Violante and Weidner (2014) and Baker (2018) find for consumption and income shocks. In addition, Bhutta and Keys (2016) show that younger homeowners—who tend to be more highly leveraged—and those likely to be more credit-constrained exhibit a stronger consumption response to house price growth. Di Maggio et al. (2017) demonstrate that the spending response of highly leveraged homeowners to a decrease in mortgage rates is more than twice as large as that of homeowners with little mortgage debt.

Pertaining specifically to the Great Recession, Meyer and Sullivan (2013) find that homeowners reduced consumption more than renters, and Mian et al. (2013) reveal that zip codes with more highly leveraged households experienced larger consumption declines. Lastly, Dynan (2012) shows that non-housing consumption of the median highly leveraged homeowner fell twice as much as the median for other households. The corresponding 17.5% fall in figure 3 is close to the 15% drop in Dynan (2012).

5.2 Inflationary Interventions

The close alignment of the model with the data makes it a suitable environment for evaluating the impact of inflationary policies aimed at combating the crisis. This section first considers a set of temporary inflation targeting policies that result in a permanent increase in the nominal price level. Afterwards, I assess price-level targeting policies that create higher inflation initially followed by a period of disinflation.

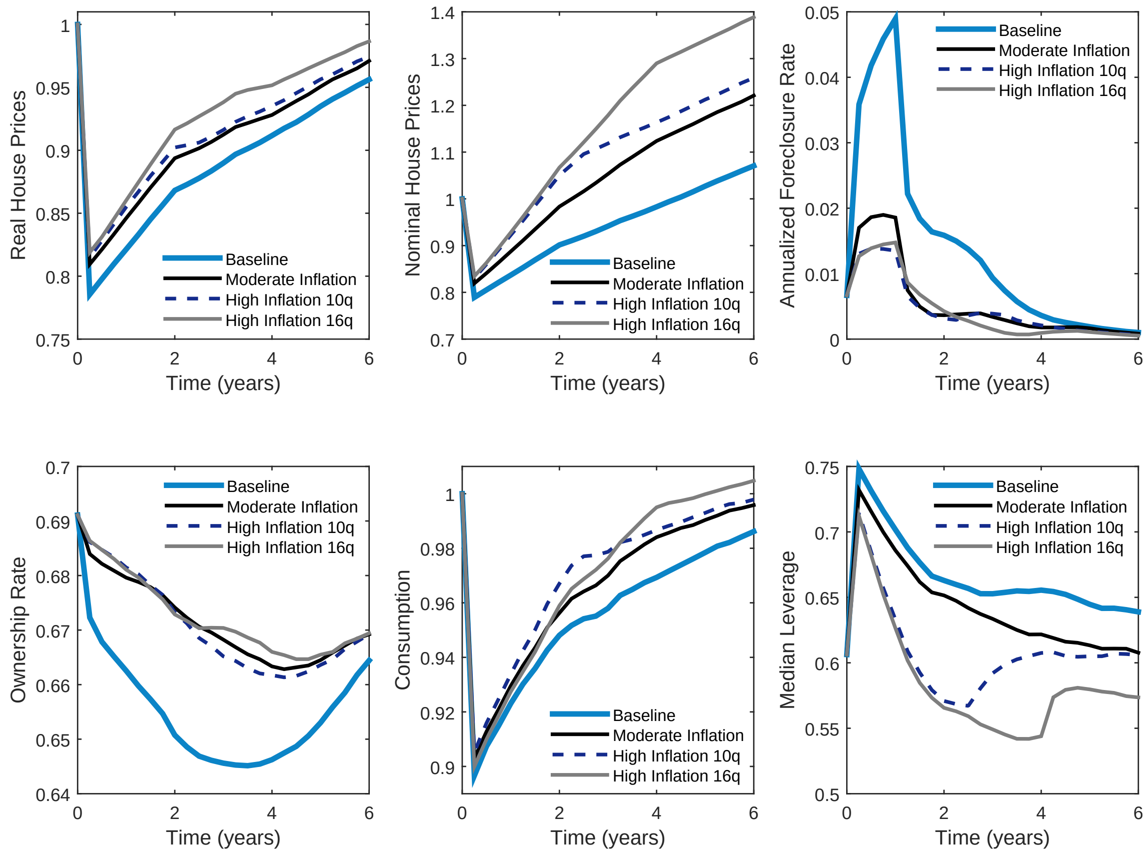

Figure 4: The effects of inflation targeting.

5.2.1 Inflation Targeting

I first consider moderately raising the inflation target by three percentage points (i.e. 4.9% instead of 1.9%) for four years. Next, I analyze an even more ambitious high inflation policy that raises the target by six percentage points, but only for ten quarters so as to create the same total inflation. Lastly, I also implement high inflation for the full four years. As with the surprise foreclosure losses in the crisis, the top 1% bears any direct credit losses from the unanticipated higher inflation.

All of the inflation targeting policies ameliorate the crisis and accelerate the recovery. Moderate inflation initially boosts house prices by 2.4 percentage points, which represents an 11% dampening of the crash. With high inflation, the magnitude is even larger at 2.9 and 3.3 percentage points for the two respective implementations.

As debt continues to erode, the positive effects of higher inflation compound to create an even larger rise in house prices, which can be seen in figure 4. Similarly, elevated inflation causes consumption to outpace its baseline trajectory. By year two, moderate inflation strengthens consumption by 1 percentage point relative to baseline, and high inflation adds 2.2 percentage points (which, for perspective, represents almost one half of the consumption gap at that stage in the recovery).

Inflation has even more dramatic implications for foreclosures and homeownership. Instead of peaking at 4.9%, the foreclosure rate stops its ascent at less than 2%. Furthermore, with inflation, foreclosures return to their pre-crisis level almost three years earlier than in the baseline. In addition, inflation almost completely arrests the initial ownership decline and restores two percentage points to the trough.[20]

5.2.2 Price-Level Targeting

Invariably, each of the inflation targeting policies *permanently* raise the price level, thereby forever reducing the value of outstanding debt to creditors. As an alternative, I consider price-level targeting policies that create short-term higher inflation before shifting to a period of disinflation that restores nominal prices to their original trajectory. Figure 5 compares inflation targeting and price-level targeting.

In all cases, inflation boosts house prices above the baseline, but inflation targeting is more potent. Every policy also dramatically reduces the foreclosure rate relative to its baseline 4.9% peak, with inflation targeting again having a modestly larger impact. However, for consumption, the magnitude of the short-term inflation rate during the crisis matters more than what happens to the long run price level. In essence, the difference between both sets of policies comes down to whether or not borrowers receive a long-term reduction in their obligations. Consistent with Ganong and Noel (2017), this long-run reduction plays a smaller role in governing consumption dynamics than does the short-term debt relief from inflation during the crisis.

[20]Because extending the implementation of high inflation to four years provides little added benefit relative to the ten quarter implementation, from now on I only consider the shorter duration version.

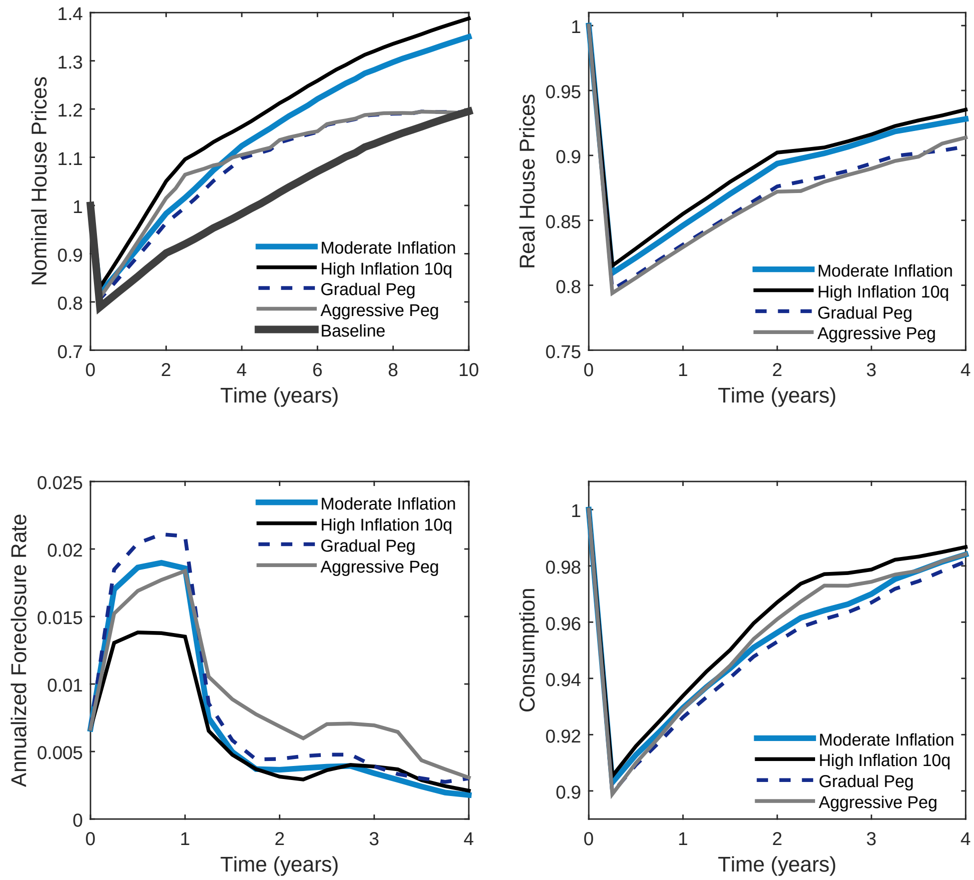

Figure 5: Inflation vs. price-level targeting (higher inflation followed by 0% until the price level reverts to baseline trend). Gradual is +3pp for 4 years; aggressive is +6pp for 10 quarters. Panel 1 shows the reversion of nominal prices to trend under the peg.

Table 4: Debt Erosion and the Amplifying Effects of Leverage

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=0}$	$\Delta_{t=2}$
	Real House Prices		*Consumption*	
Moderate Inflation: Benchmark	2.4pp	2.5pp	0.6pp	1.0pp
Moderate Inflation: High LTV	3.1pp	3.5pp	0.6pp	1.5pp
High Inflation: Benchmark	2.9pp	3.1pp	0.8pp	2.2pp
High Inflation: High LTV	3.5pp	3.9pp	1.8pp	3.3pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Δ_t is the difference from baseline at time t.

5.3 Understanding the Channels

These results demonstrate that, unlike in the long run, an injection of inflation during a housing crisis deviates substantially from superneutrality by stimulating higher prices, consumption, and homeownership while reducing foreclosures. This section assesses the contribution of each of the inflation channels present in the model—namely, debt erosion, the response of mortgage supply, and the role of liquidity.

5.3.1 Debt Erosion

The most salient way that inflation impacts households in the model is by eroding the real value of existing borrowers' nominal mortgage debt. This automatic injection of equity relaxes household budget constraints, which reduces the incidence of mortgage default, boosts consumption, and causes fewer desperate homeowners to list their house on the market. It is reasonable to expect, therefore, that the aggregate economic impact of inflation should rise with the amount of mortgage debt in the economy. Table 4 confirms this intuition by comparing the benchmark model with and without inflation targeting to a comparison economy initialized with more highly-leveraged homeowners.[21] Depending on the policy and time horizon, the response of house prices to inflation is anywhere from 20% to 40% larger in the heavily-indebted economy. For consumption, the amplification is even larger at 50% after two years of either policy.

[21] This economy features a median borrower LTV of 85% compared to 60% in the benchmark.

5.3.2 The Mortgage Supply Response

For existing borrowers with locked-in interest rates, higher inflation is a boon that temporarily lowers the effective real rate at which they roll over their mortgage balances and *permanently* reduces the real value of their future mortgage payments. While new borrowers also receive the direct benefits of debt erosion, their access to credit changes as banks adjust the supply of mortgages in anticipation of eroding future payments. With long-term, fixed-rate mortgages, banks spread out the impact of temporary inflation over time, resulting in higher initial payments that fall rapidly as inflation takes hold.[22]

To quantify this credit response, I consider a counterfactual where banks do not price the temporary inflation into new mortgages (whether out of inattention or some other friction). In this scenario, moderate inflation provides an *additional* boost of nearly six percentage points to house prices and three percentage points to consumption, and the foreclosure spike disappears. Therefore, the response of mortgage supply substantially counteracts the benefits of debt erosion, although not completely.

However, the overall non-neutrality of inflation depends on the dominance of fixed rate mortgages in the economy, which act as a form of nominal rigidity. By contrast, with adjustable rate mortgages—which resemble one-period debt except for their insurance of roll-over risk—the superneutrality argument of section 4.1 applies and the dynamics of the crisis are nearly unaffected by inflation.

[22] Figure 9 in the appendix shows this "mortgage tilt" for thirty-year fixed-rate mortgages.

Table 5: Shutting Down the Mortgage Supply Response

Policy	$t = 0$	$t = 2$	$t = 0$	$t = 2$	$t = 0$	$t = 2$
	*Real House Prices**		*Consumption**		*Foreclosures*	
Moderate Inflation	−19.0%	−10.2%	−9.7%	−3.8%	1.9%	0.3%
No Credit Response	−13.1%	−8.0%	−6.9%	−2.1%	1.1%	0.1%
Difference	−5.9pp	−2.2pp	−2.8pp	−1.7pp	0.8pp	0.2pp

*Reported values are the % deviation from steady state.

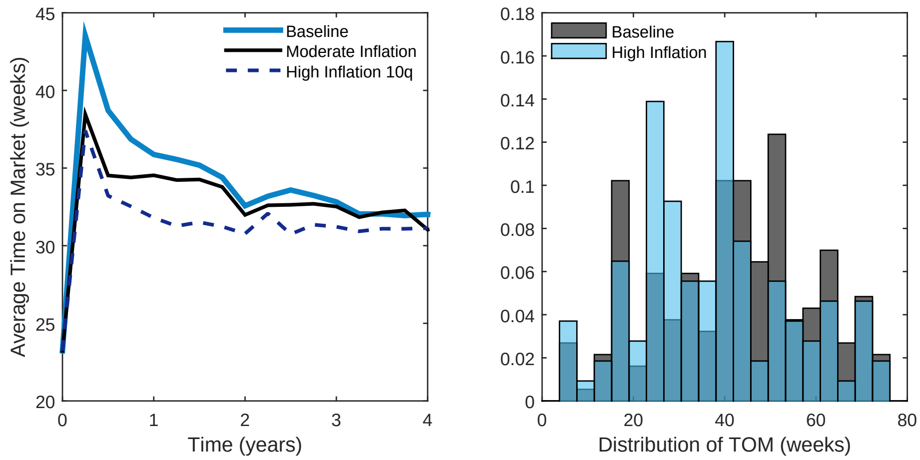

Figure 6: The impact of inflation on debt overhang and selling delays.

5.3.3 The Role of Liquidity

As inflation erodes the value of debt, homeowners looking to sell are less constrained when setting their list price to attract buyers. For highly-leveraged sellers, this new-found flexibility means the ability to sell more quickly and avoid the prospect of either severe cuts to consumption or foreclosure. Auspiciously, higher inflation mitigates the deterioration in housing liquidity during the crisis by curtailing time on the market by almost two months on average and reducing the incidence of extreme selling delays, as shown in figure 6.

By partially restoring liquidity in the housing market, higher inflation thus allows financially-distressed sellers to unload their houses more rapidly without engaging in a fire sale or default. To determine the quantitative significance of this channel, I

Table 6: Liquidity and the Consumption Boost from Inflation

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=0}$	$\Delta_{t=2}$
	Moderate Inflation		*High Inflation*	
Benchmark	0.6pp	1.0pp	0.8pp	2.2pp
No Liquidity Response	0.4pp	0.6pp	0.6pp	1.8pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Δ_t is the difference from baseline at time t.

consider a mirror Walrasian economy without search frictions that features the same initial portfolio distribution and follows the same path of house prices during the crisis as the benchmark economy. The principal difference is that housing illiquidity in the Walrasian model only arises from a fixed, policy-invariant transaction cost. Table 6 shows that the absence of the endogenous liquidity response to inflation noticeably attenuates the consumption boost. Specifically, the initial consumption jump is reduced by 33% and 25% in the moderate and high inflation cases, respectively.

5.4 Extensions

While it is impossible to incorporate every channel of inflation, this section pursues two significant extensions to assess the robustness of the case for higher inflation.

5.4.1 Sluggish Endowments

First, I return to the issue of sluggish endowments from section 4.2. Sluggish nominal endowments introduce the risk that higher inflation may substantially erode not just debt but also purchasing power. To be concrete, I suppose that the aggregate component of the nominal endowment during the crisis follows $W_t = (1-\lambda)(1+\pi_{\text{steady}})W_{t-1} + \lambda W_t^*$, where W_t^* is the flexible path and $\lambda = 0.16$. This low quarterly value of λ is approximately equivalent to 50% in annual terms and creates complete downward nominal rigidity in the aggregate endowment during the crisis. However, it is actually *upward* rigidity that potentially undermines the case for inflation.

Figure 7 shows the dynamics of the economy with inflation and sluggish endowments.[23] In the top row, mortgages are fixed-rate contracts, which is the scenario that breaks superneutrality and has thus far produced gains from higher inflation during the crisis. With the extreme upward rigidity of nominal endowments, the erosion of purchasing power cancels out much but not all of the positive impact of inflation on house prices and consumption. However, foreclosures still fall dramatically and

[23] Once again, this setup mirrors a production economy without capital with sticky nominal wages.

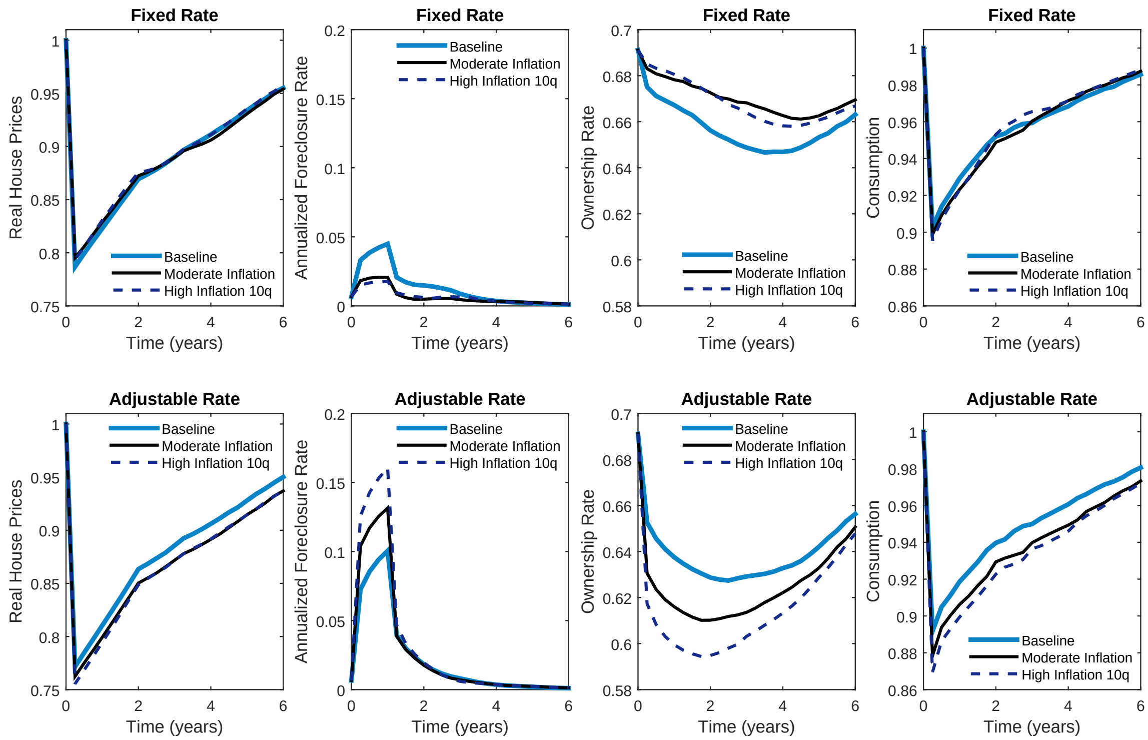

Figure 7: Inflation targeting with sluggish endowments under FRMs and ARMs.

homeownership is still bolstered. By contrast, inflation is quite counterproductive in the adjustable rate economy. Recall that without sluggishness, inflation is essentially irrelevant with adjustable rate mortgages. However, with the endowment sluggishness, higher inflation worsens the drop in house prices and consumption, produces substantially more foreclosure activity, and harms homeownership. Considering the significant cross-country variation in mortgage contracts and institutions, this insight is important for governments considering such inflationary interventions.

5.4.2 Demand Externalities

I now move in the opposite direction and introduce a demand externality that allows inflation to indirectly impact aggregate income through the response of household consumption. Such an externality mimics the aggregate demand channel in the New Keynesian literature and also shares the flavor of mechanisms explored recently by

Table 7: Inflation Targeting with the Demand Externality

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=0}$	$\Delta_{t=2}$
	Real House Prices		*Consumption*	
Moderate Inflation: Benchmark	2.4pp	2.5pp	0.6pp	1.0pp
Moderate Inflation: Demand Externality	3.3pp	3.6pp	1.0pp	1.2pp
High Inflation: Benchmark	2.9pp	3.1pp	0.8pp	2.2pp
High Inflation: Demand Externality	4.4pp	4.6pp	1.4pp	2.5pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Δ_t is the difference from baseline at time t.

Bai, Ríos-Rull and Storesletten (2012), Huo and Ríos-Rull (2013), and Kaplan and Menzio (2016). Concretely, I follow Krueger and Mitman (2016) and introduce a multiplicative consumption spillover, C^{ω}, to the real aggregate endowment with $\omega = 0.367$. Introducing this externality allows me to shut down the exogenous 5% negative endowment shock and still generate the same decline in house prices during the crash.

Figure 12 in the appendix plots the path of the aggregate endowment in this economy, and table 7 shows the impact of temporarily increasing the inflation target. On impact, the boost to house prices and consumption is 38% and 67% higher with the demand externality under the moderate inflation target, respectively, and the corresponding values under the high inflation target are 51% and 75%. Furthermore, this added kick is persistent. As inflation increases consumption, the demand externality causes income to rise, which fuels even higher consumption and house prices.

5.5 Distributional Consequences and Welfare

The main lesson that emerges up to this point is that inflation can effectively mitigate housing-induced crises like the Great Recession as long as most homeowners have fixed rate mortgages and nominal income is not excessively upwardly rigid. However, the ultimate barometer for these policies is their impact on welfare, both in the aggregate and cross section. To assess the distributional consequences of higher inflation, I compute consumption-equivalent welfare for different types of households.

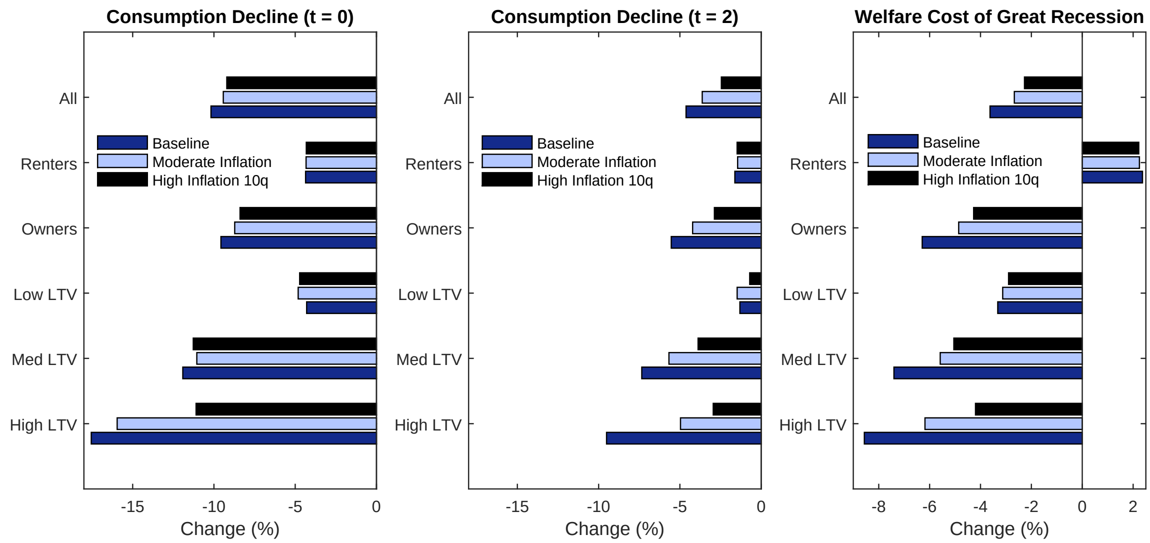

Figure 8: The cross-sectional impact of inflation in the benchmark model.

Absent any interventions, the welfare cost of the Great Recession is 3.6% in the aggregate but varies from a 2.4% *gain* for renters to a 6.3% loss for owners. Intuitively, although renters suffer from the direct effect of higher downside income risk and tighter credit, they benefit from the opportunity to purchase cheaper houses that are expected to appreciate during the recovery. By contrast, homeowners are slammed with the exogenous shocks plus the endogenous decline in wealth and liquidity. Across the leverage distribution, borrowers with low loan-to-value (LTV) suffer a 3.3% welfare loss, and highly-leveraged borrowers experience a 8.6% welfare decline.

Figure 8 shows how inflation targeting alters the cost of the Great Recession, and table 8 demonstrates how different assumptions about the nature of mortgage contracts, endowment sluggishness, and the demand externality affect these values. In the first panel, the elevated inflation target has no impact on the consumption of renters—as one would expect—while reducing the drop in consumption for homeowners. However, this mitigated consumption drop is initially concentrated almost entirely among highly leveraged owners. Two years later, nearly all homeowners benefit substantially from inflation, which manifests in the welfare results as well. Welfare for homeowners increases by 1.43 and 2.02 percentage points under moderate and

Table 8: Inflationary Policies and the Welfare Cost of the Great Recession

Policy	All	Renters	Owners	Low LTV	Medium LTV	High LTV
			Benchmark (Inflation Targeting)			
Moderate Inflation	0.96pp	−0.12pp	1.43pp	0.19pp	1.82pp	2.38pp
High Inflation	1.35pp	−0.15pp	2.02pp	0.43pp	2.35pp	4.37pp
			Sluggish Endowments with Fixed Rate Mortgages			
Moderate Inflation	0.02pp	−1.10pp	0.52pp	−0.43pp	0.78pp	1.15pp
High Inflation	0.11pp	−1.48pp	0.82pp	−0.38pp	1.01pp	2.67pp
			Sluggish Endowments with Adjustable Rate Mortgages			
Moderate Inflation	−0.91pp	−1.02pp	−0.86pp	−0.61pp	−0.85pp	−1.86pp
High Inflation	−1.24pp	−1.39pp	−1.18pp	−0.75pp	−1.18pp	−2.27pp
			Demand Externality			
Moderate Inflation	1.23pp	0.12pp	1.72pp	0.38pp	2.14pp	2.78pp
High Inflation	1.73pp	0.21pp	2.40pp	0.68pp	2.78pp	4.87pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Each number is the change in the welfare cost of the Great Recession relative to baseline.

high inflation, respectively, with the corresponding values for highly leveraged owners coming in at an even stronger 2.38 and 4.37 percentage points. Only renters (very modestly) dislike the higher inflation because of how it pushes up house prices.

Unsurprisingly, sluggish endowments reduce the positive effects of inflation, but aggregate welfare still improves as long as mortgages are fixed rate contracts. With adjustable rate contracts, though, not only is there an aggregate welfare *decline* of around 1 percentage point, but highly leveraged owners go from the biggest winners to the biggest losers, as figure 13 illustrates. Just as leverage magnifies the benefits of rising prices on consumption in the benchmark economy, it also amplifies the negative response of house prices to inflation in this case. Lastly, the demand externality enhances the consumption and welfare response to higher inflation. Qualitatively, the main difference in the externality model is that inflation also improves renter welfare because of the feedback from aggregate consumption to aggregate income.

6 Conclusions

Debt, deleveraging, and default remain issues of interest as the economy moves beyond the Great Recession. This paper sheds light on the role inflation can play in mitigating some of the deleterious effects of mortgage debt overhang. In particular, temporarily raising the inflation target reduces the magnitude of the recession and speeds up the recovery. By eroding the real value of debt, inflation relaxes budget constraints and creates home equity that increases housing liquidity, reduces foreclosures, and fuels an increase in real house prices, wealth, and consumption.

The results of this work suggest future avenues for research in and beyond the realm of housing. For example, to what extent can inflation alleviate overhang of other types of debt, such as sovereign debt? In the context of housing, this paper opens the door to further research on how housing markets affect the transmission of monetary and fiscal policy to the macroeconomy both in normal times and crises.

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A Supplementary Tables

Table 9: Inflation Targeting with Sluggish Endowments

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=0}$	$\Delta_{t=2}$
	Real House Prices		*Consumption*	
Moderate Inflation: Sluggish FRM	0.8pp	0.2pp	−0.3pp	−0.3pp
Moderate Inflation: Sluggish ARM	−0.9pp	−1.3pp	−1.4pp	−1.1pp
High Inflation: Sluggish FRM	0.7pp	0.3pp	−0.7pp	0.4pp
High Inflation: Sluggish ARM	−1.7pp	−1.4pp	−2.2pp	−1.5pp
	Foreclosures		*Homeownership*	
Moderate Inflation: Sluggish FRM	−2.4pp	−0.4pp	0.8pp	1.7pp
Moderate Inflation: Sluggish ARM	3.1pp	−0.1pp	−2.2pp	−1.7pp
High Inflation: Sluggish FRM	−2.7pp	−0.2pp	1.0pp	1.6pp
High Inflation: Sluggish ARM	6.0pp	−0.2pp	−3.5pp	−3.2pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Δ_t is the difference from baseline at time t.

Table 10: Inflation and the Incidence of Ex-Post Creditor Losses

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=0}$	$\Delta_{t=2}$
	Real House Prices		*Consumption*	
Moderate Inflation: Benchmark (Top 1%)	2.4pp	2.5pp	0.6pp	1.0pp
Moderate Inflation: Proportional	1.6pp	1.6pp	0.4pp	0.8pp
High Inflation: Benchmark (Top 1%)	2.9pp	3.1pp	0.8pp	2.2pp
High Inflation: Proportional	2.0pp	2.0pp	0.5pp	1.8pp
	Foreclosures		*Homeownership*	
Moderate Inflation: Benchmark (Top 1%)	−3.0pp	−0.6pp	1.2pp	2.4pp
Moderate Inflation: Proportional	−3.0pp	−0.6pp	1.2pp	2.2pp
High Inflation: Benchmark (Top 1%)	−3.5pp	−0.5pp	1.4pp	2.3pp
High Inflation: Proportional	−3.5pp	−0.5pp	1.4pp	2.2pp

Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. Δ_t is the difference from baseline at time t. In the benchmark model, only the top 1% bears the direct mortgage losses from unanticipated inflation. The alternative shown is a version where losses are borne by *all households* in proportion to earnings.

B Supplementary Figures

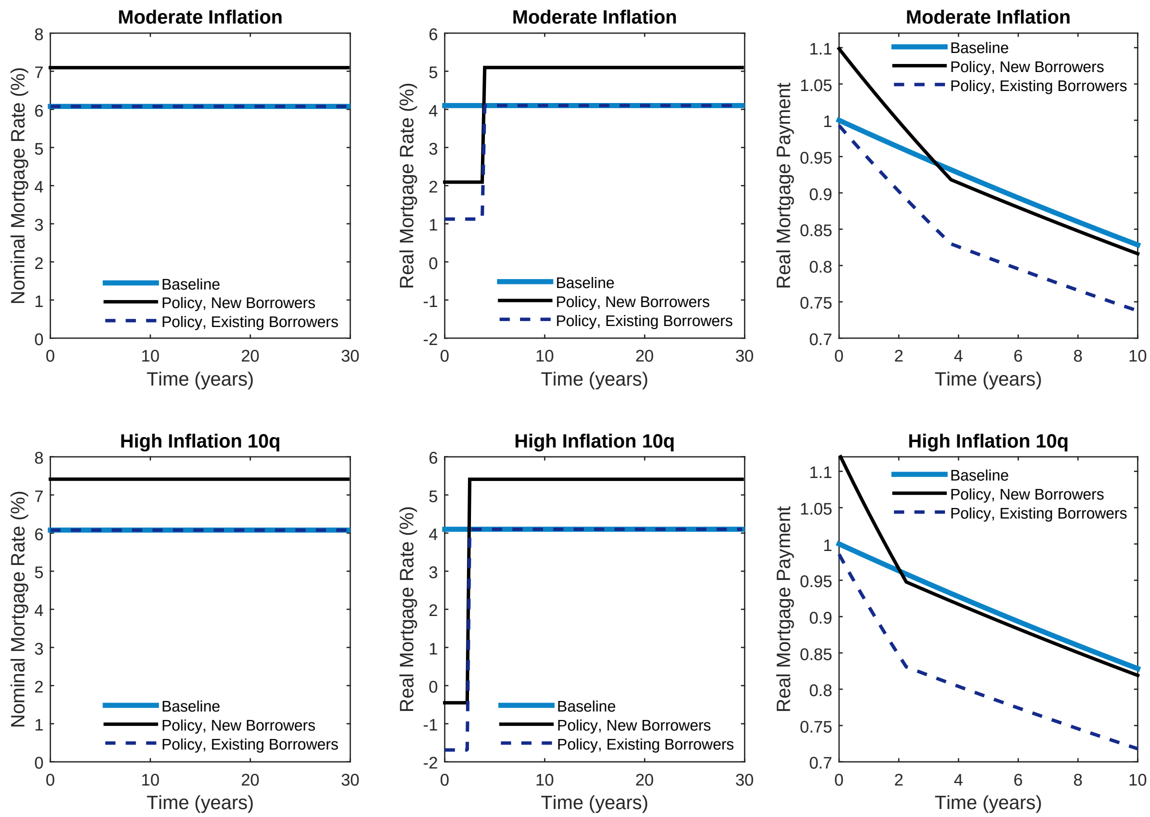

Figure 9: An illustration of how mortgage rates and *real* payments for fixed rate mortgages respond to a temporary increase in inflation. Existing borrowers experience a boon, while new borrowers face higher rates and a twisting of real payments.

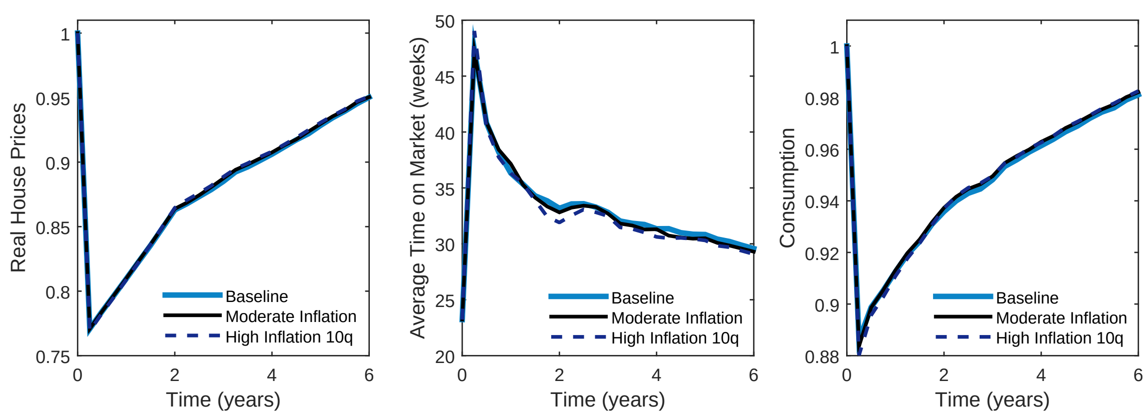

Figure 10: The ineffectiveness of inflation targeting with adjustable rate mortgages.

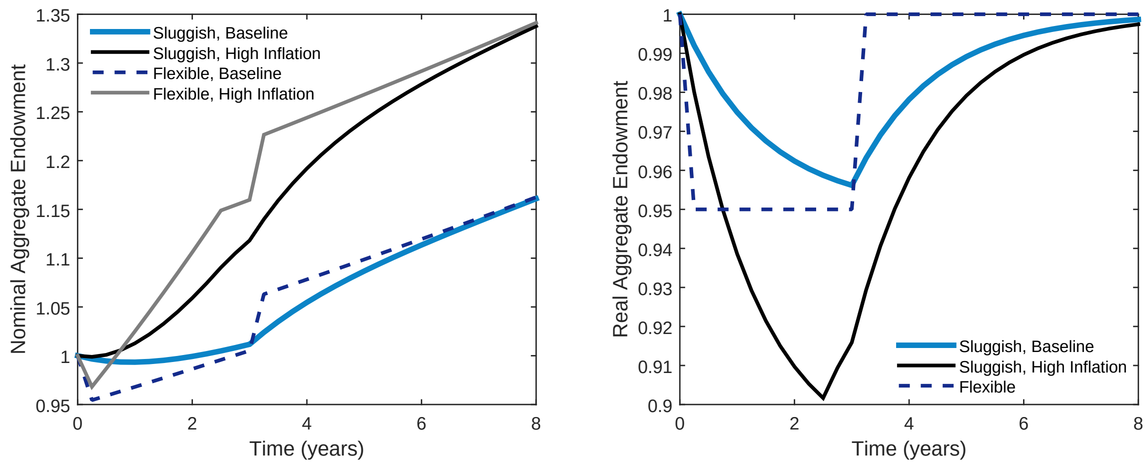

Figure 11: The paths of the nominal and real aggregate endowment.

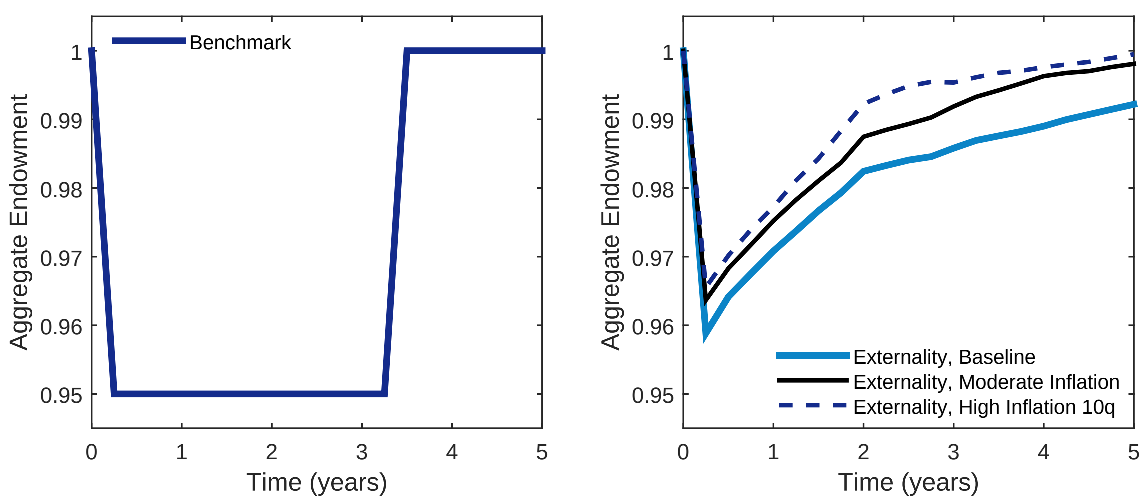

Figure 12: The aggregate endowment with and without the demand externality.

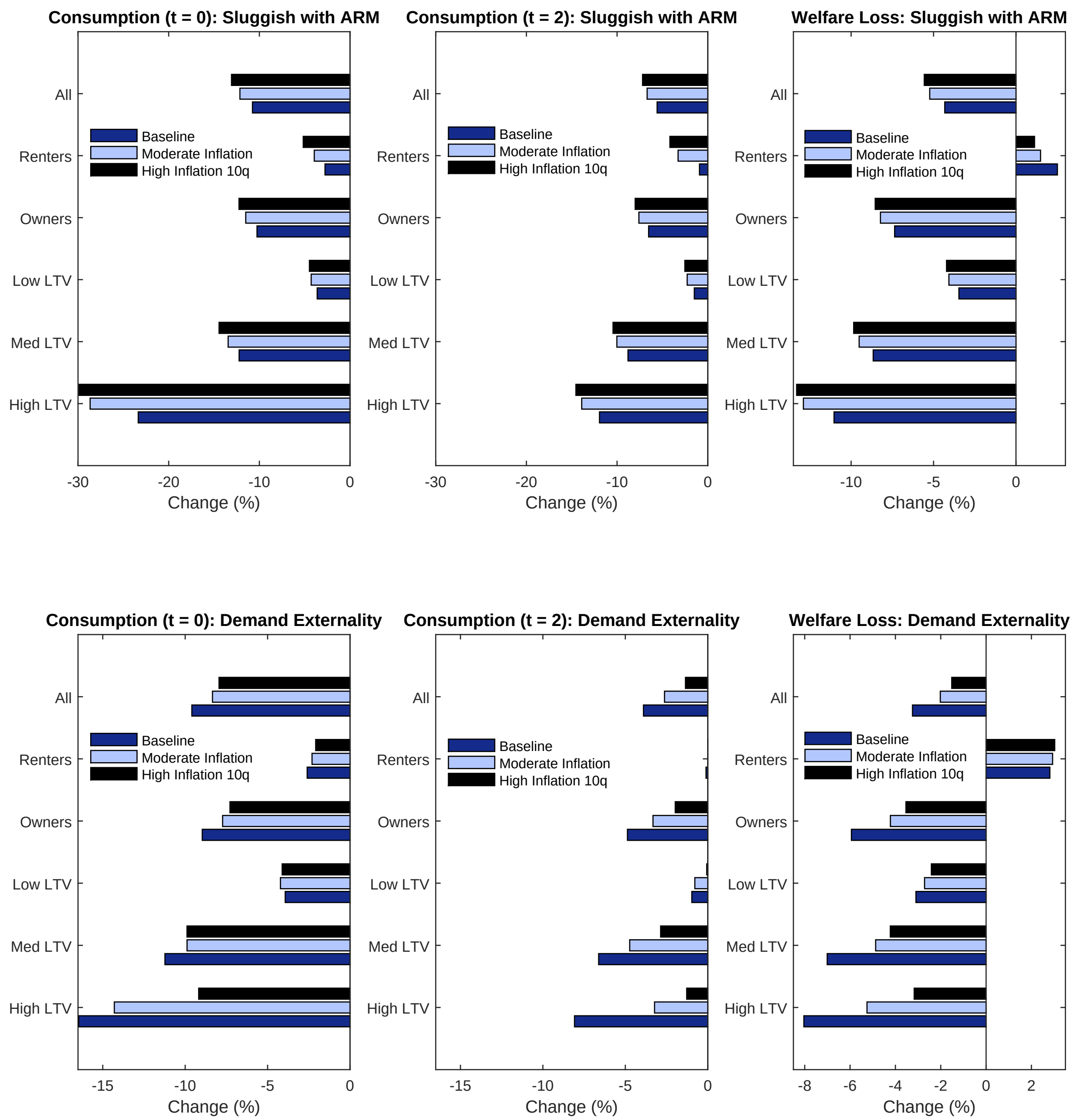

Figure 13: Consumption and welfare in the Great Recession with inflation targeting. (Top) The model with sluggish endowments and ARMs. Inflation harms consumption for all households, and welfare is reduced. (Bottom) The model with the demand externality. Inflation increases consumption and welfare, even for renters.

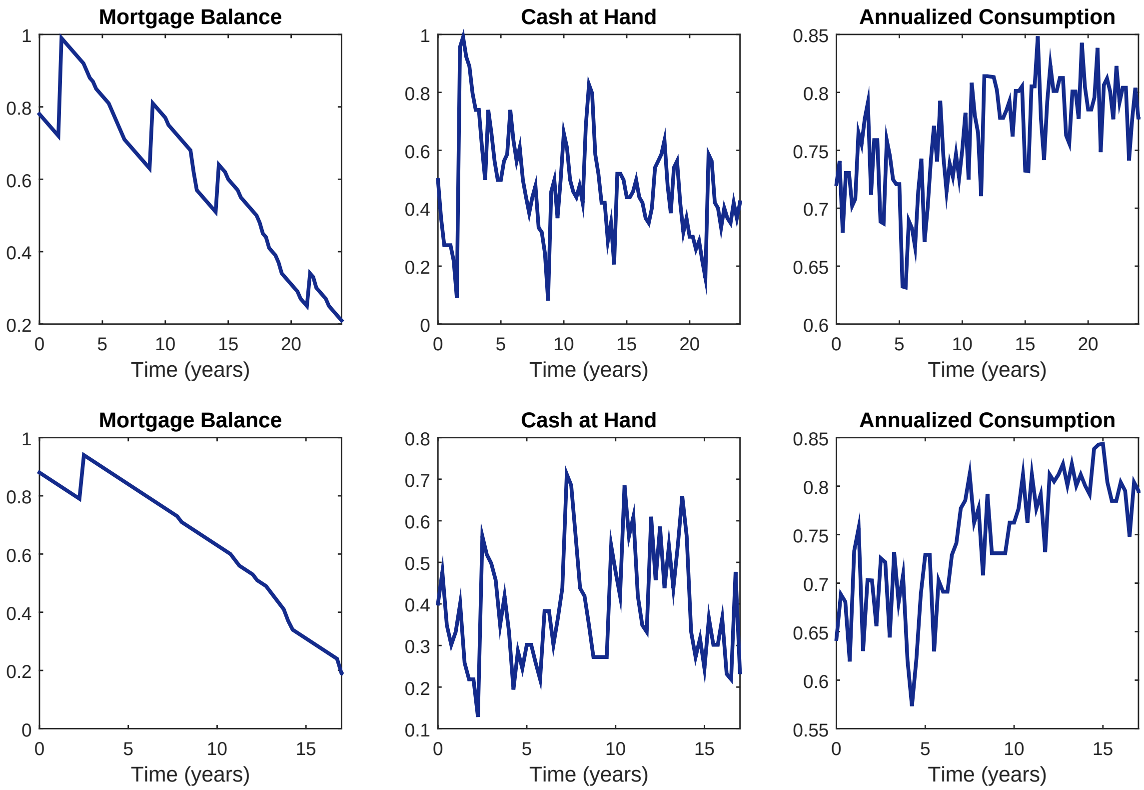

Figure 14: (Top) A sample homeowner gradually pays down mortgage debt but sporadically extracts equity to help smooth consumption. (Bottom) A sample homeowner gradually pays down debt and smooths consumption mostly with liquid assets.

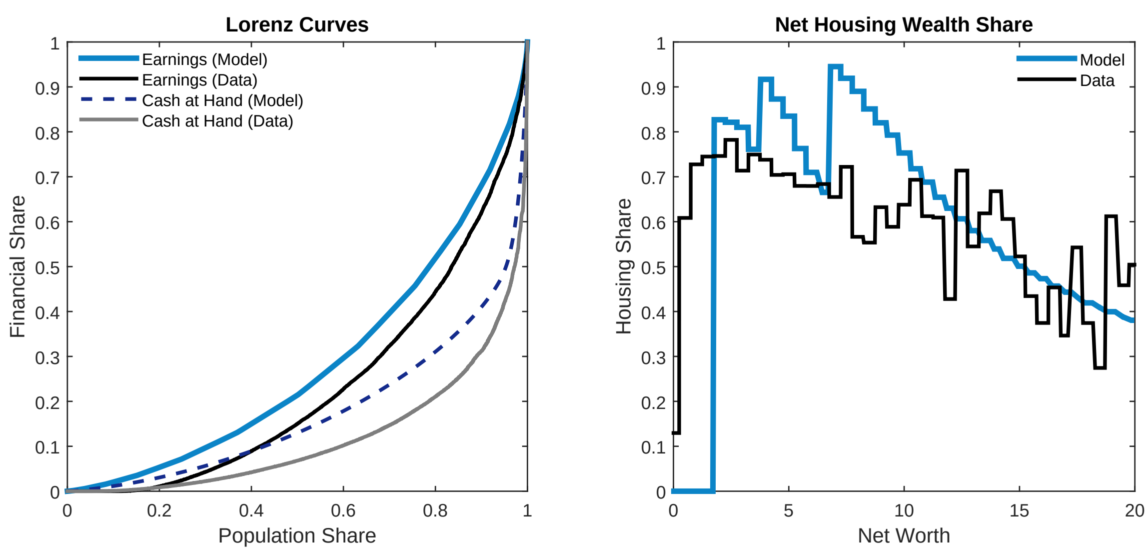

Figure 15: (Left) The model exhibits substantial inequality, though less than in the data. (Right) The housing wealth share is consistently high but eventually declines.

C Calibrating Labor Efficiency

As explained in the calibration section, it is not possible to estimate quarterly income processes from PSID data because the PSID is only conducted annually. Instead, I start by specifying a labor process like that in Storesletten et al. (2004), except without life cycle effects or a permanent shock at birth. I adopt their values for the annual autocorrelation of the persistent shock and for the variances of the persistent and transitory shocks, and I transform them to quarterly values.

Persistent Shocks I assume that in each period households play a lottery in which, with probability 3/4, they receive the same persistent shock as they did in the previous period, and with probability 1/4, they draw a new shock from a transition matrix calibrated to the persistent process in Storesletten et al. (2004) (in which case they still might receive the same persistent labor shock). This is equivalent to choosing transition probabilities that match the expected amount of time that households expect to keep their current shock. Storesletten et al. (2004) report an annual autocorrelation coefficient of 0.952 and a frequency-weighted average standard deviation over expansions and recessions of 0.17. I use the Rouwenhorst method to calibrate this process, which gives the following transition matrix:

$$\tilde{\pi}_s(\cdot,\cdot) = \begin{pmatrix} 0.9526 & 0.0234 & 0.0006 \\ 0.0469 & 0.9532 & 0.0469 \\ 0.0006 & 0.0234 & 0.9526 \end{pmatrix}$$

As a result, the transition matrix *prior to adding the fourth state corresponding to the top 1%* is

$$\pi_s(\cdot,\cdot) = 0.75 I_3 + 0.25\tilde{\pi}_s(\cdot,\cdot) = \begin{pmatrix} 0.9881 & 0.0059 & 0.0001 \\ 0.0171 & 0.9883 & 0.0171 \\ 0.0001 & 0.0059 & 0.9881 \end{pmatrix}$$

Transitory Shocks Storesletten et al. (2004) report a standard deviation of the transitory shock of 0.255. To replicate this, I assume that the annual transitory shock is actually the sum of four, independent quarterly transitory shocks. I make use of the same identifying assumption that Storesletten et al. (2004) use, namely, that all households receive the same initial persistent shock. Any variance in initial labor income is then due to different draws of the transitory shock. Recall that the labor productivity process is given by

$$\ln(e \cdot s) = \ln(s) + \ln(e)$$

Therefore, total labor productivity (which, when multiplied by the wage w, is total wage income) over a year in which s stays constant is

$$(e \cdot s)_{\text{year 1}} = \exp(s_0)[\exp(e_1) + \exp(e_2) + \exp(e_3) + \exp(e_4)]$$

For different variances of the transitory shock, I simulate total annual labor productivity for many individuals, take logs, and compute the variance of the annual transitory shock. It turns out that quarterly transitory shocks with a standard deviation of 0.49 give the desired standard deviation of annual transitory shocks of 0.255.

D Computation

The household problem is solved using value function iteration. The state space (y, m, h, s) for homeowners with good credit standing is discretized using 275 values for y, 131 values for m, 3 values for h, and 4 values for s (the calibration of labor efficiency is described in the previous section). Homeowners with bad credit standing $(f = 1)$ have state (y, h, s), and renters have state (y, s). To compute the equilibrium transition path, the algorithm starts with an initial guess for the path of shadow house prices, $\{p_{h,t}\}_{t=1}^{T}$. The algorithm then does backward induction on the recursive mort-

gage price equation and the household Bellman equations before forward iterating on the distribution of households and REO properties. Equilibrium house prices (which depend on the current guess for the house price trajectory) are calculated period by period during the forward iteration. The initial guess is then compared with these equilibrium prices, and a convex combination of these two sequences is used for the next guess. This process continues until convergence.