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

By Aaron Hedlund

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.

Along the dimensions of fiscal and monetary policy, the United States government engaged in a series of unprecedented interventions during the Great Recession to reverse the deterioration in housing and macroeconomic conditions. However, despite repeatedly professing concern about the low level of inflation, the Federal Reserve studiously avoided signaling any openness to deviating from its 2 percent target. Such aversion to pursuing even temporarily higher inflation has not been without its critics, ranging from Paul Krugman to Robert Engle to Ken Rogoff. They and others point out that, by eroding the value of nominal mortgage debt, a policy of short-term higher inflation could boost home equity, push up house prices, and accelerate the recovery. Ken Rogoff has also emphasized the political-economy benefits of pursuing debt reduction through inflation instead of direct legislative intervention:

“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

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1From Ken Rogoff’s 2011 Financial Times piece, “The Bullets yet to be fired to stop the crisis.”
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 (2016a) 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, competitive lenders issue fixed-rate, nominal mortgages that price inflation expectations and individual default risk at origination. The long-term nature of mortgage contracts proves important quantitatively.

I restrict attention to three channels of inflation in this analysis. First, higher inflation erodes the real value of debt, which relaxes borrower budget constraints. However, the flip side of this debt erosion is a diminished value of repayments to lenders. This ex-post redistribution gives rise to the second channel of inflation whereby forward-looking lenders curtail the supply of credit ex-ante for new loans. Notably, in the case of either one-period debt or adjustable rate contracts, these two channels exactly offset each other, and inflation has no impact on real variables.

By contrast, the debt erosion and credit contraction channels of inflation do not cancel out with long-term fixed-rate mortgages (FRMs), which act as a significant nominal rigidity. For existing borrowers, temporary higher inflation delivers a boon by permanently reducing their outstanding debt. Furthermore, new borrowers also experience accelerated debt reduction in the early years of repayment because long-term rates do not adjust one-for-one to short-run nominal interest rate fluctuations.

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 stickiness, 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 stickiness. 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 sticky 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 percent but increases homeowner welfare by 1.43 percent—ranging from 0.19 percent for homeowners with minimal debt to 2.38 percent for highly leveraged owners. The aggregate welfare gain shrinks but remains positive with sticky nominal income and fixed-rate mortgages, but replacing fixed-rate mortgages with adjustable rate mortgages causes welfare to fall by approximately 1 percent 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 percent increase in welfare for renters who benefit from the spillover of higher aggregate consumption to income.

Implementation Issues. — Considering that inflation has remained stubbornly below the Federal Reserve’s current 2 percent target, questions over how to successfully implement an even higher inflation target bear examination. Although a full survey of the relevant literature is not feasible here, several papers provide some valuable insight. Krugman (1998), Eggertsson and Woodford (2003), and Benigno, Eggertsson and Romei (2014) point to the power of forward guidance—i.e. a credible commitment to keeping rates low even after the zero lower bound no longer binds—to generate inflation when a liquidity trap renders debt and
money perfect substitutes, especially in economies experiencing dynamic debt deleveraging. An alternative to inflation targeting in a world where governments cannot “credibly promise to be irresponsible,” the central bank can announce a target path for either the price-level or nominal GDP, as suggested by Eggertsson and Woodford (2003) and Sheedy (2014). Two alternative commitment devices include a currency depreciation followed by a peg at the lower rate or a reduction in the duration of government debt via quantitative easing—options put forward by Svensson (2003) and Bhattari, Eggertsson and Gafarov (2015), respectively. Lastly, monetary-fiscal coordination makes the implementation task even easier. 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 must generate inflation by acting as the equivalent of a helicopter money drop.

I. Related Literature

This paper bridges the literature on models of default with the literature on housing market search frictions, both of which Hedlund (2016a,b) describes in detail. In other related work, Dynan (2012) and Mian, Rao and Sufi (2013) establish the negative effect of debt overhang on consumption. Aladangady (2017) and Di Maggio et al. (2017) look at the transmission of monetary policy through changes to household balance sheets. Doepke and Schneider (2006), Meh, Ríos-Rull and Terajima (2010), Doepke, Schneider and Selezneva (2015), and Auerlert (2017) discuss the redistributive implications of inflation. Leeper and Zhou (2013) and Benigno, Eggertsson and Romei (2014) establish a positive 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, Reinhart and Sbrancia (2015) and Hilscher, Raviv and Reis (2017) 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 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 re-
duces 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.

II. 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) portfolio choice with savings in short-term bonds and borrowing in long-term, nominal mortgages, and iv) equilibrium default.

A. 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 $g_s(s'|s)$, and households receive their initial $s$ from the stationary distribution $G_s(s)$. 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 renters. Renters contract on a spot market each period to occupy apartment space $a \leq \overline{a}$ at unit cost $r_a$ that provides utility $c_h = a$. By contrast, homeowners occupy a durable house $h \in H = \{h_1, h_2, h_3\}$ that yields utility dividend $c_h = h$ each period. By assumption, homeowners cannot own multiple houses or rent their house to a tenant, and $\overline{a} < h$, i.e. houses are larger than apartments.\(^2\) Households discount the future at rate $\beta$.

\(^2\)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). Two distinct parameters, $\overline{a}$ and $h$, are needed because households prefer to make a discrete jump in housing services when switching from the flexible arrangement of renting to the consumption commitment of owning.
B. The Housing Market

APARTMENT SPACE. — Apartment space in the model is a nondurable flow of housing services produced from the numeraire good at rate $A$ using a reversible technology, which pins down $r_a = 1/A$. Thus, the cost of apartment space is pinned down technologically and is unresponsive to conditions in the owner-occupied housing market.

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 (2016a) by introducing passive real estate brokers as a modeling device to intermediate trades.

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 $\eta_j(\theta_{j,t}(x_j, h))$, and brokers find a household with probability $\alpha_j(\theta_{j,t}(x_j, h)) = \eta_j(\theta_{j,t}(x_j, h))$, where $\theta_{j,t}(x_j, h)$ is the ratio of brokers to households in submarket $(x_j, h)$ at period $t$. Each broker in submarket $(x_j, h)$ incurs an entry cost $\kappa_j h$, and all participants take $\theta_{j,t}(x_j, h)$ as given. Unsuccessful sellers incur a small utility cost $\xi$ and are free to adjust their list-price next period or take their house off the market. Sellers must repay their mortgage at the time of sale to avoid foreclosure.

A generalization would be to posit a reversible technology for durable apartments that landlords from outside the model trade at price $p_a = 1/A$ and rent out at $r_a$. Given depreciation $\delta_a$, prices $p_a$ and rents $r_a$ are related by $p_a = r_a + \frac{1-h_a}{1+r} p_a$, which implies $r_a = \frac{p_a + h_a}{1+r}$. This added complication changes little in an open economy because $r_a$ is still unresponsive to the owner-occupied market.

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. For the experiments in this paper, the unresponsiveness of rents could exaggerate swings in the homeownership rate.

The functions $\eta_j : \mathbb{R}_+ \to [0,1]$ are continuous and strictly increasing with $\eta_j(0) = 0$, while $\alpha_j$ 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.

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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, 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 prospective buyers. Analogous to an over-the-counter market, brokers trade the stock of temporarily acquired housing with each other at time-varying unit price \( p_t \) until it has all 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 ensures a deterministic total flow of housing to and from brokers.

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

\[
\begin{align*}
\kappa_b h & \geq \alpha_b(\theta_{b,t}(x_b, h)) \left( x_b - p_t h \right) \\
\kappa_s h & \geq \alpha_s(\theta_{s,t}(x_s, h)) \left( p_t h - x_s \right)
\end{align*}
\]

with strict equality in active submarkets. This \textit{block recursivity} greatly increases tractability by reducing the problem to finding \( p_t \) and substituting into (1) – (2).

C. Banking Sector

Competitive banks with access to external financing at time-varying rate real rate \( r_t \) offer one-period bonds at price \( q_{b,t} = \frac{1}{1+r_{t+1}} \) as a saving vehicle for all households. In addition, banks issue long-term, nominal, non-state-contingent mortgage contracts to homeowners that allow for default in equilibrium.

Mortgages. — A mortgage \( (\bar{R}_m, M_t) \) is characterized at each point in time by its nominal balance \( M_t \) and the borrower’s fixed nominal interest rate \( \bar{R}_m \) at which they can roll over outstanding balances each period, which I elaborate on momentarily.
Origination. — Owing to their nature as long term contracts, mortgages introduce both an extensive and intensive margin to home borrowing. When homeowners take out a new mortgage of nominal face value $M_{t+1}$, their default risk is assessed by the bank and incorporated into a borrower-specific mortgage price $q_{m,t}$ that depends on $(\bar{R}_m, M_{t+1})$ as well as the owner’s bond holdings $b_{t+1}$, house $h$, and current persistent income state $s_t$. The bank then delivers $q_{m,t}M_{t+1}$ in nominal resources to the borrower.

For fixed-rate mortgages, the borrower’s $\bar{R}_m$ is set equal to the prevailing rate $R_{m,t}$ at the time of origination $t$ and held constant until loan termination, which occurs either by repayment, refinancing, or default. When homeowners refinance—either to extract equity or because future market rates fall, i.e. $R_{m,\tau} < \bar{R}_m$ in some $\tau > t$—the old loan is paid in full and the origination process is begun anew. The presence of a proportional origination fee $\zeta$ impacts this extensive margin decision to refinance.

Later in the paper, I also consider the case of adjustable rate mortgages where $\bar{R}_m$ tracks $R_{m,t}$ each period. In steady state, no distinction exists between these two types of mortgage. Outside of steady state, a non-degenerate distribution of borrowers over $\bar{R}_m$ reflects heterogeneity over when they originated their mortgage.

Repayment Phase. — In a conventional 30-year fixed-rate mortgage, nominal payments are constant and the nominal balance follows a predefined amortization schedule. However, in practice, borrowers can always 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 the model while avoiding the curse of dimensionality, mortgages here do not have a set duration. Instead, borrowers make interest payments and choose how much principal to pay beyond that amount, and the remaining nominal balance is rolled over to the next period at the rate $\bar{R}_m$ set at origination. To be concrete, existing borrowers choose nominal payment $L_t \geq \frac{\bar{R}_m}{1+R_m}M_t$ and enter next period with nominal balance $M_{t+1} = (1 + \bar{R}_m)(M_t - L_t)$.

The nominal rate for new mortgages satisfies $R_{m,t} = \frac{(1 + \tau_{t+1})(1 + \phi)(1 + \pi_t) - 1}{1 + \pi_t}$, where $\pi_t$ is the inflation rate and $\phi$ is a per-period loan servicing cost that banks pass onto borrowers. Distinct from the origination fee, this cost creates an interest rate wedge between bonds and mortgages, which affects the intensive margin decision of how much to save in home equity (via paying down principal) versus in liquid assets.

Pricing. — For each $(\bar{R}_m, M_{t+1})$, competition produces borrower-specific equilibrium mortgage prices $q_{m,t}(\cdot)$ that deliver zero ex-ante profits loan-by-loan at origination. Given that mortgages are long-term contracts, $q_{m,t}$ is forward-looking:
it incorporates expectations over future default risk and deviations of $R_{m,\tau}$ from $\bar{R}_m \equiv R_{m,t}$ at any $\tau > t$, which can occur because of changes in the real risk free rate, inflation, or both. Thus, mortgage prices satisfy the following recursive relationship:

$$(1 + \zeta)q_{m,t}(\bar{R}_m, M_{t+1}, b_{t+1}, h, s_t)M_{t+1} = \frac{1}{1 + R_{m,t}}\mathbb{E} \left\{ \eta_s(\theta_{s,t+1}(x_{s,t+1}, h))M_{t+1} \right. \nu_{sell + repay} \left. \right\}$$

$$+ \left[ 1 - \eta_s(\theta_{s,t+1}(x_{s,t+1}, h)) \right] \left\{ d_{t+1} \min \left\{ P_{t+1}J_{REO,t+1}(h), M_{t+1} \right\} + (1 - d_{t+1}) \right\} \left\{ M_{t+1} \middle| \text{Refi}_{t+1} \right\}$$

$$+ 1_{\text{No Refi}_{t+1}} \left( \frac{L_{t+1}}{\text{nominal payment}} + \frac{(1 + \zeta)q_{m,t+1}(\bar{R}_m, M_{t+2}, b_{t+2}, h, s_{t+1})M_{t+2}}{\text{continuation with } M_{t+2} = (M_{t+1} - L_{t+1})(1 + \bar{R}_m)} \right) \right\}$$

where $P_{t+1}$ is the price level and $x_{s,t+1}$, $d_{t+1}$, $b_{t+2}$, and $L_{t+1}$ are the policy functions for list price, default ($\in \{0, 1\}$), bonds, and mortgage payment, respectively. In addition, $J_{REO,t+1}(h)$ is how much banks value repossessing a borrower’s foreclosed house $h$, as discussed next in section II.C. Search frictions reduce credit by increasing the probability of default, $(1 - \eta_s)d_{t+1}$, and reducing the value of collateral, $J_{REO,t+1}$.

Dividing through by $M_{t+1}$ and expressing quantities in real terms gives

$$(3) \quad (1 + \zeta)q_{m,t}(\bar{R}_m, m_{t+1}, b_{t+1}, h, s_t) = \frac{1}{1 + R_{m,t}}\mathbb{E} \left\{ \eta_s(\theta_{s,t+1}(x_{s,t+1}, h)) \right. \nu_{sell + repay} \left. \right\}$$

$$+ \left[ 1 - \eta_s(\theta_{s,t+1}(x_{s,t+1}, h)) \right] \left\{ d_{t+1} \min \left\{ \frac{J_{REO,t+1}(h)}{m_{t+1}/(1 + \pi_{t+1})}, 1 \right\} + (1 - d_{t+1}) \right\}$$

$$\times \left\{ 1_{\text{Refi}_{t+1}} + 1_{\text{No Refi}_{t+1}} \left( \frac{l_{t+1} + (1 + \zeta)q_{m,t+1}(\bar{R}_m, m_{t+2}, b_{t+2}, h, s_{t+1})m_{t+2}}{m_{t+1}/(1 + \pi_{t+1})} \right) \right\}$$

where $m_{t+1} \equiv M_{t+1}/P_t$ is real debt and $m_{t+2} = (1 + \bar{R}_m)(m_{t+1} - l_{t+1})/(1 + \pi_{t+1})$.

Abstracting from foreclosure, steady state $q_m = \frac{1}{(1 + \zeta)(1 + R_m)}$ with $1 + R_m = (1 + r)(1 + \phi)(1 + \pi)$, which shows clearly that mortgage prices are decreasing in the inflation rate $\pi$. Intuitively, for a given promised sequence of nominal repayments, banks reduce lending as expected inflation increases.$^7$

**Foreclosure Process.** — In the event of default, banks initiate foreclosure proceedings by repossessing the borrower’s house and erasing the outstanding

$^7$Section V.C provides a more in-depth discussion of the relationship between inflation and credit.
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 \( \lambda \in (0, 1) \). The house repossession and borrowing exclusion represent the only costs of foreclosure to borrowers.\(^8\)

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 \( \chi \) of the sales price and absorb all losses from foreclosure.\(^9\)

The value to a lender of repossessing a house \( h \) is

\[
J_{REO,t}(h) = R_{REO,t}(h) - \delta p_t h + \frac{1}{1 + r_{t+1}} J_{REO,t+1}(h)
\]

\[
R_{REO,t}(h) = \max \left\{ 0, \max_{x_s \geq 0} \eta_s \left( \theta_{s,t}(x_s, h) \right) \left[ (1 - \chi) x_s - \left( -\delta p_t h + \frac{1}{1 + r_{t+1}} J_{REO,t+1}(h) \right) \right] \right\}
\]

where \( \delta \) represents holding costs and \( R_{REO,t}(h) \) is the option value of selling.

D. Household Decisions

Each period contains three subperiods. In subperiod 1, households learn their endowment \((e_t, s_t)\) and credit score \( f_t \in \{0, 1\} \). 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 \( y_t \), mortgage rate and balance \((R_{m,t}, m_t)\), house \( h \), and persistent endowment \( s_t \). The individual state of a renter is simply \((y_t, s_t, f_t)\).

Transition Dynamics. — The quantitative experiments described more thoroughly in section V subject the steady state of the economy to a combination of unanticipated shocks that produce a perfect-foresight equilibrium transition path to a final steady state. The following prices experience changes during the transition: tightnesses \( \theta_{j,t} \) \((j = s, b)\) for every \((x_j, h)\), the house price index \( p_t \), mortgage prices \( q_{m,t} \), bond prices \( q_{b,t} = 1/r_{t+1} \), inflation \( \pi_t \), and the nominal mortgage rate \( R_{m,t} \) for new loans.

\(^8\)Without the exclusion penalty, borrowers would always immediately default whenever their house is worth less than their outstanding debt, which contradicts the data.

\(^9\)Pennington-Cross (2006) finds significant foreclosure costs in the data. In the model, \( \chi \) affects the loan recovery ratio \( J_{REO,t+1}(h)/m_{t+1} \) and, with it, the supply of mortgage credit. In the unlikely event of selling the house for more than the lien, banks must send profits to the foreclosed borrower.
Portfolio Choice. — End-of-period expenditures for non-refinancing owners consist of consumption, bond purchases, and a mortgage payment. In nominal terms,
\[ P_tC_t + P_t \delta Ph + P_t q_{b,t} b_{t+1} + L_t \leq P_t y_t \]
where \( L_t \equiv P_t l_t = M_t - \frac{M_{t+1}}{1+R_m} \) and \( L_t \geq \frac{R_m}{1+R_m} M_t \) so that \( M_{t+1} \leq M_t \). In real terms,
\[ c_t + \delta p_h + q_{b,t} b_{t+1} + \frac{m_t}{1+\pi_t} - \frac{m_{t+1}}{1+R_m} \leq y_t. \]

This constraint makes clear that higher inflation \( \pi_t \) reduces the value of outstanding debt. In steady state (to simplify notation), such owners have value function
\[
V_{\text{pay}}^{\text{pay}}(y, (R_m, m), h, s, f = 0) = \max_{b', c \geq 0, l \geq l_u} u(c, h) + \beta \mathbb{E} \left[(W_{\text{own}} + R_{\text{sell}})(y', (R_m, m'), h, s', f' = 0)\right]
\]
subject to
\[ c + \delta p_h + q_{b'} b' + l \leq y \]
\[ m' = \left( \frac{m}{1+\pi} - l \right) (1+R_m) \]
\[ y' = e's' + b' \]

For homeowners who refinance,
\[
V_{\text{refi}}(y, m, h, s, f = 0) = \max_{m', b', c \geq 0} u(c, h) + \beta \mathbb{E} \left[(W_{\text{own}} + R_{\text{sell}})(y', (R_m, m'), h, s', f' = 0)\right]
\]
subject to
\[ c + \delta p_h + q_{b'} b' + \frac{m}{1+\pi} \leq y + q_m((R_m, m'), b', h, s)m' \]
\[ q_m((R_m, m'), b', h, s)m' \leq \vartheta ph \]
\[ y' = e's' + b' \]

where \( 1 - \vartheta \) is the minimum down payment and \( R_m \) is the mortgage rate for new loans (recall that, outside of steady state, \( R_m \) is set to \( R_{m,t} \) for new borrowers in period \( t \) and held fixed for all \( \tau > t \) regardless of \( R_{m,\tau} \)). The continuation term \( W_{\text{own}} \) represents subperiod 1 homeowner utility, and \( R_{\text{sell}} \) is the option value of selling.
Homeowners with bad credit lack access to the mortgage market and have utility
\[ V_{\text{own}}(y, 0, h, s, f = 1) = \max_{y', c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (W_{\text{own}} + R_{\text{sell}})(y', 0, h, s', f') \right] \]
subject to
\[ c + \delta ph + q b' \leq y \]
\[ y' = c' s' + b' \]
where \( f' = 1 \) with probability \( \lambda \) and \( f' = 0 \) with probability \( 1 - \lambda \).

Lastly, regardless of credit status, renters choose apartment \( a \) and have utility
\[ V_{\text{rent}}(y, s, f) = \max_{b', c \geq 0, 0 \leq a \leq a_u(c, a)} u(c, a) + \beta \mathbb{E} \left[ (V_{\text{rent}} + R_{\text{buy}})(y', s', f') \right] \]
subject to
\[ c + r_a a + q b' \leq y \]
\[ y' = c' s' + b' \]
where \( R_{\text{buy}} \) 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 \( x_b \leq y - y(h, s) \), where \( y(h, s) < 0 \) captures the ability to take out a mortgage in subperiod 3. For buyers with bad credit, \( x_b \leq y \). The option value \( R_{\text{buy}} \) satisfies
\[ R_{\text{buy}}(y, s, 0) = \max\{0, \max_{h \in H, x_b \leq y} \eta_b(\theta_b(x_b, h)) [V_{\text{own}}(y - x_b, 0, h, s, 0) - V_{\text{rent}}(y, s, 0)]\} \]
\[ R_{\text{buy}}(y, s, 1) = \max\{0, \max_{h \in H, x_b \leq y} \eta_b(\theta_b(x_b, h)) [V_{\text{own}}(y - x_b, 0, h, s, 1) - V_{\text{rent}}(y, s, 1)]\} \]

**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
\[ W_{\text{own}}(y, (R_m, m), h, s, 0) = \max \left\{ V_{\text{pay}_\text{own}}(y, (R_m, m), h, s, 0), V_{\text{refi}_\text{own}}(y, m, h, s, 0), (V_{\text{rent}} + R_{\text{buy}}) \left( y + \max \left\{ 0, J_{\text{REO}}(h) - \frac{m}{1 + \pi} \right\}, s, 1 \right) \right\} \]

**Selling Houses.** — At the beginning of subperiod 1, owners who wish to sell choose a list price \( x_s \). The option value \( R_{\text{sell}} \) of selling for an owner with good
credit is
\begin{equation}
R_{sell}(y, (R_m, m), h, s, 0) = \max\{0, \max_{x_s} \eta_s(\theta_s(x_s, h)) \left( V_{rent} + R_{buy} \right) \left( y + x_s - \frac{m}{1 + \pi}, s, 0 \right) \}
\end{equation}

\begin{equation}
-W_{own}(y, (R_m, m), h, s, 0) + [1 - \eta_s(\theta_s(x_s, h))] (-\xi) \}
\end{equation}
subject to \( y + x_s \geq \frac{m}{1 + \pi} \)

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.

\section*{E. Equilibrium}

An equilibrium consists of value/policy functions for households and banks; market tightnesses \( \theta_{s,t} \) and \( \theta_{b,t} \); prices \( p_t \), \( r_a \), \( q_{b,t} \), and \( q_{m,t} \); distributions \( \Phi_{own,t} \) and \( \Phi_{rent,t} \); and REO housing stock \( \{ H_{REO,t}(h) \}_{h \in H} \) such that households optimize according to the above, market tightnesses satisfy (1) – (2), mortgage prices satisfy (3), the distributions evolve according to the proper laws of motion, and the housing market clears each period (successfully sold housing equals successfully purchased housing):
\begin{equation}
\int_{D_{h,t}(p_t)} h^*_t \eta_b(\theta_{b,t}(x^*_b, h^*_t; p_t)) d\Phi_{rent,t} = \underbrace{S_{REO,t}(p_t)}_{\text{REO sales}} + \underbrace{\int_{S_{h,t}(p_t)} h^*_s(\theta_{s,t}(x^*_s, h; p_t)) d\Phi_{own,t}}_{\text{sold by owner}}.
\end{equation}

where the asterisks indicate that the variable is a buyer/seller policy function.

\section*{III. 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.

\subsection*{A. External Parameters}

\textbf{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. In the spirit of Castañeda, Díaz-Giménez and Ríos-Rull (2003), I add a state for the top 1 percent (who bear most of the unanticipated bank losses.) The average quarterly endowment is normalized to 0.25. Households have CES utility

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

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 \( \omega \) and discount factor \( \beta \).

**Apartments and Houses.** — I set the apartment technology \( A \) to generate an annual rent-price ratio of 3.5 percent. Matching in the housing market is Cobb Douglas, i.e.

\[ \eta_s(\theta_s) = \min \{ \theta_s^{\gamma_s}, 1 \} \]

and

\[ \eta_b(\theta_b) = \min \{ \theta_b^{\gamma_b}, 1 \} \]

Using (1) and (2) gives

\[ \eta_s(\theta_s(x_s, h)) = \min \left\{ 1, \max \left\{ 0, \left( \frac{\phi - x_s}{\kappa_s h} \right)^{\frac{\gamma_s}{1 - \gamma_s}} \right\} \right\} \]

and

\[ \eta_b(\theta_b(x_b, h)) = \min \left\{ 1, \max \left\{ 0, \left( \frac{x_b - \phi h}{\kappa_b h} \right)^{\frac{\gamma_b}{1 - \gamma_b}} \right\} \right\} \].

The internal calibration determines \( \kappa_b, \kappa_s, \gamma_s, \gamma_b, \) and the disutility \( \xi \). I set quarterly holding costs (maintenance, property taxes, etc.) to \( \delta = 0.007 \).

**Banking Sector.** — To match the U.S. during 2003 – 2005, I set inflation to 1.9 percent, the nominal risk-free rate to 0.9 percent, the nominal mortgage rate to 6.0 percent via the loan servicing cost \( \phi \), and the origination cost to 0.4 percent. No down payment is required in the initial steady state. Lastly, I set the persistence of credit flags to \( \lambda = 0.95 \), and the internal calibration determines the REO discount \( \chi \).

**B. 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

---

10 The appendix explains the procedure that converts the continuous, annual process from Storesletten, Telmer and Yaron (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 percent. See Herkenhoff and Ohanian (2015).
Table 1—Model Calibration

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
<th>Model</th>
<th>Source/Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>( \rho )</td>
<td>0.952</td>
<td></td>
<td></td>
<td>Storesletten, Telmer and Yaron (2004)</td>
</tr>
<tr>
<td>SD of Persistent Shock</td>
<td>( \sigma_c )</td>
<td>0.17</td>
<td></td>
<td></td>
<td>Storesletten, Telmer and Yaron (2004)</td>
</tr>
<tr>
<td>SD of Transitory Shock</td>
<td>( \sigma_e )</td>
<td>0.49</td>
<td></td>
<td></td>
<td>Storesletten, Telmer and Yaron (2004)</td>
</tr>
<tr>
<td>Top Endowment Shock(^*)</td>
<td>( s_4/s_3 )</td>
<td>4</td>
<td></td>
<td></td>
<td>Kuhn and Ríos-Rull (2013)</td>
</tr>
<tr>
<td>Prob. of Top(^*)</td>
<td>( g_{3,4} )</td>
<td>0.0041</td>
<td></td>
<td></td>
<td>Kuhn and Ríos-Rull (2013)</td>
</tr>
<tr>
<td>Persistence of Top(^*)</td>
<td>( g_{4,i} )</td>
<td>0.9</td>
<td></td>
<td></td>
<td>Kuhn and Ríos-Rull (2013)</td>
</tr>
<tr>
<td>Intratemp. Elas. of Subst.</td>
<td>( \nu )</td>
<td>0.13</td>
<td></td>
<td></td>
<td>Flavin and Nakagawa (2008)</td>
</tr>
<tr>
<td>Risk Aversion</td>
<td>( \sigma )</td>
<td>2</td>
<td></td>
<td></td>
<td>Various</td>
</tr>
<tr>
<td>Holding Costs</td>
<td>( \delta )</td>
<td>0.007</td>
<td></td>
<td></td>
<td>Moody’s</td>
</tr>
<tr>
<td>Rent-Price Ratio (Annual)</td>
<td>( r_a )</td>
<td>0.035</td>
<td></td>
<td></td>
<td>Sommer, Sullivan and Verbrugge (2013)</td>
</tr>
<tr>
<td>Risk-Free Rate (Annual)</td>
<td>( r )</td>
<td>-0.01</td>
<td></td>
<td></td>
<td>Federal Reserve Board</td>
</tr>
<tr>
<td>Inflation (Annual)</td>
<td>( \pi )</td>
<td>0.019</td>
<td></td>
<td></td>
<td>PCE Index</td>
</tr>
<tr>
<td>Servicing Cost (Annual)</td>
<td>( \phi )</td>
<td>0.051</td>
<td></td>
<td></td>
<td>6 Percent Nominal Mortgage Rate</td>
</tr>
<tr>
<td>Mortgage Origination Cost</td>
<td>( \zeta )</td>
<td>0.004</td>
<td></td>
<td></td>
<td>FHFA</td>
</tr>
<tr>
<td>Minimum Downpayment</td>
<td>( 1 - \vartheta )</td>
<td>0</td>
<td></td>
<td></td>
<td>Fannie Mae</td>
</tr>
<tr>
<td>Credit Flag Persistence</td>
<td>( \lambda )</td>
<td>0.95</td>
<td></td>
<td></td>
<td>Fannie Mae</td>
</tr>
<tr>
<td><strong>Internal Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeownership Rate</td>
<td>( \pi )</td>
<td>2.3000</td>
<td>69.2</td>
<td>69.1</td>
<td>Census</td>
</tr>
<tr>
<td>Starter House Value</td>
<td>( h_1 )</td>
<td>2.7500</td>
<td>2.75</td>
<td>2.75</td>
<td>Corbae and Quintin (2015)</td>
</tr>
<tr>
<td>Housing Wealth (Owners)</td>
<td>( \omega )</td>
<td>0.8389</td>
<td>3.99</td>
<td>3.99</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Median Borrower LTV</td>
<td>( \beta )</td>
<td>0.9737</td>
<td>0.593</td>
<td>0.606</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Months of Supply(^**)</td>
<td>( \xi )</td>
<td>0.0014</td>
<td>4.90</td>
<td>4.86</td>
<td>Nat’l Assoc of Realtors</td>
</tr>
<tr>
<td>Buyer Search (Weeks)</td>
<td>( \gamma_b )</td>
<td>0.0940</td>
<td>10.00</td>
<td>9.82</td>
<td>Nat’l Assoc of Realtors</td>
</tr>
<tr>
<td>Maximum Bid Premium</td>
<td>( \kappa_b )</td>
<td>0.0250</td>
<td>0.025</td>
<td>0.025</td>
<td>Gruber and Martin (2003)</td>
</tr>
<tr>
<td>Maximum List Discount</td>
<td>( \kappa_s )</td>
<td>0.1500</td>
<td>0.15</td>
<td>0.15</td>
<td>RealtyTrac</td>
</tr>
<tr>
<td>Foreclosure Loss</td>
<td>( \chi )</td>
<td>0.0920</td>
<td>0.20</td>
<td>0.20</td>
<td>Pennington-Cross (2006)</td>
</tr>
<tr>
<td>Foreclosure Rate(^***) (Annual)</td>
<td>( \gamma_s )</td>
<td>0.6400</td>
<td>0.60</td>
<td>0.67</td>
<td>Nat’l Delinquency Survey</td>
</tr>
<tr>
<td><strong>Steady State Fit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borrower Share: ( LTV \geq 0.8 )</td>
<td></td>
<td>0.220</td>
<td>0.229</td>
<td>0.229</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Borrower Share: ( LTV \geq 0.9 )</td>
<td></td>
<td>0.105</td>
<td>0.106</td>
<td>0.106</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Borrower Share: ( LTV \geq 0.95 )</td>
<td></td>
<td>0.052</td>
<td>0.054</td>
<td>0.054</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Mean Net Worth</td>
<td></td>
<td>2.62</td>
<td>2.78</td>
<td>2.78</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Mean Liquid Assets</td>
<td></td>
<td>1.06</td>
<td>0.94</td>
<td>0.94</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Mean Owner Net Worth</td>
<td></td>
<td>3.13</td>
<td>3.19</td>
<td>3.19</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Mean Owner Liquid Assets</td>
<td></td>
<td>1.20</td>
<td>1.01</td>
<td>1.01</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Median Owner Liquid Assets</td>
<td></td>
<td>0.24</td>
<td>0.34</td>
<td>0.34</td>
<td>2004 SCF</td>
</tr>
</tbody>
</table>

\(^*\)The ratio \( s_4/s_3 = 4 \) corresponds to \( earn_{99-100}/earn_{95-99} \) in 2004 reported by Kuhn and Ríos-Rull (2013). The transitions resemble table 20 but have been adjusted to ensure that 1 percent of households have \( s = s_4 \). The transitions \( g_{4,i} = 0 \) and \( g_{4,i} = 0 \) for \( i = 1, 2 \).

\(^*\)Transitions resemble table 20 but have been adjusted to ensure that 1 percent of households have \( s = s_4 \). The transitions \( g_{4,i} = 0 \) and \( g_{4,i} = 0 \) for \( i = 1, 2 \).

\(^**\)Months of supply, which proxies for time on the market, equals ratios divided by the sales rate.

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

Note: See the online appendix for a more extensive summary of the role each parameter plays.
untargeted data moments. 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.

IV. Inflationary Policies in Normal Times

To summarize section II, 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 $q_m$. In other words, new borrowers receive fewer resources $q_m m'$ 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.

A. 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 $q_m = \frac{1}{1+r_m} = \frac{1}{(1+r_m)(1+\pi)}$. Thus, borrowers who choose mortgage $m'$ 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 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

\[^{12}\text{Figure B7 in the appendix provides additional information on the distributional fit of the model.}\]
Figure 1. (1) List price. (2) Difference in expected TOM (high inflation – baseline). (3) Distributions of expected TOM. (4) Monthly sales probabilities.
Table 2—Inflation in the Long Run

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Low Inflation (Baseline)</th>
<th>High Inflation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homeownership Rate (Percent)</td>
<td>69.1</td>
<td>69.0</td>
</tr>
<tr>
<td>Gross Housing Wealth</td>
<td>3.99</td>
<td>3.93</td>
</tr>
<tr>
<td>Percent of Borrowers with LTV ≥ 0.8</td>
<td>22.9</td>
<td>20.7</td>
</tr>
<tr>
<td>Percent of Borrowers with LTV ≥ 0.9</td>
<td>10.6</td>
<td>8.7</td>
</tr>
<tr>
<td>Percent of Borrowers with LTV ≥ 0.95</td>
<td>5.4</td>
<td>4.7</td>
</tr>
<tr>
<td>Foreclosure Rate (Percent)</td>
<td>0.67</td>
<td>0.56</td>
</tr>
</tbody>
</table>

*Inflation π = 0.079 (a 6 percentage point increase).

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.

B. 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 percent decrease in the aggregate endowment that lasts for three years. Absent any interventions, real house prices fall by 5 percent upon impact, consumption falls by 1.5 percent, and the foreclosure rate rises to 2.5 percent.

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 percent instead of 1.5 percent—before accelerating in its recovery. Overall, the temporary increase in the inflation target improves welfare by 0.5 percent, with renters (who, as potential future buyers, prefer lower house prices) losing 0.2 percent and owners gaining 0.8 percent in consumption-equivalent terms.

Nevertheless, this modest improvement depends on the nominal endowment immediately tracking with higher inflation. If nominal income is instead sticky,
higher inflation no longer mitigates the house price decline, and it causes a persistent deterioration in consumption.\footnote{This setup is isomorphic to a production economy without capital with sticky nominal wages. Section C.C1 provides more details on the implementation.} With sticky nominal income, there is actually a 0.3 percent welfare loss from the policy, with owners breaking even and renters experiencing a 1.1 percent 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.

V. 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 percent–6 percent 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 \textsuperscript{13} discusses implementation.
Table 3—The Housing Bust

<table>
<thead>
<tr>
<th></th>
<th>∆Prices (Percent)</th>
<th>∆Sales (Percent)</th>
<th>Peak Foreclosure Rate</th>
<th>Peak TOM</th>
<th>Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>-21.4</td>
<td>-42.2</td>
<td>4.9</td>
<td>43.5 weeks</td>
<td>69.1/64.5</td>
</tr>
<tr>
<td>Data</td>
<td>-25.2</td>
<td>-41.9</td>
<td>5.2</td>
<td>50.8 weeks</td>
<td>69.2/65.0</td>
</tr>
</tbody>
</table>

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.

A. 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 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 percent. Furthermore, the aggregate endowment declines by 5 percent for three years and the risk-free rate rises briefly for eight quarters before dropping back down. For simplicity, this paper abstracts from some of the other minor shocks and institutional details in Garriga and Hedlund (2017). 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 percent of households bear these losses in proportion to their bond holdings.

\[ \text{endowment transition matrix } g_s \text{ is replaced with } g_{recession}^s \text{ for three years. Specifically, } g_{recession}^s(s_2|s) = (1 - 0.028)g_s(s_2|s) \text{ for all } s, g_{recession}^s(s_j|s) = g_s(s_j|s) \text{ for all } s \text{ and } j = 2, 3, 4, \text{ and } g_{recession}^s(s_1|s) \text{ is increased until } \sum_{s'} g_{recession}^s(s'|s) = 1 \text{ for all } s. \]

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

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

\[ \text{Specifically, I assume that the government levies a flat tax on the liquid assets of the top 1 percent over the course of the transition path that it uses to finance a bailout of bank losses. Counterfactually assuming proportional bank ownership only modestly impacts the results, as shown in table A2.} \]
Figure 3. (All) 2007–2011 decline in detrended NIPA real nondurable consumption. (Disaggregated) 2007–2009 fall using PSID data and the sampling criteria of Arellano, Blundell and Bonhomme (2017). Low loan-to-value (LTV) is below 0.4, and high LTV is above 0.9.

Model Fit. — 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 percent, just shy of the 25 percent 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 percent to under 65 percent. Lastly, the model captures the drying up of housing liquidity with time on the market rising to almost a year.

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. In the aggregate, non-housing consumption drops by 10.2 percent in the model and 10.1 percent in the data, but these numbers mask substantial heterogeneity. While renter consumption in the model and data only falls by 4.3 percent and 3.5 percent, respectively, highly leveraged homeowners experience

18 Garriga and Hedlund (2017) provide an extensive discussion of the transmission mechanisms from household balance sheets to consumption during the Great Recession.
19 The aggregate number is the fall from 2007 to 2011, where the trend is fitted linearly from 1980 to 1998 (to omit the housing boom) and extrapolated. The PSID results shown in figure 3 are relative to a linear trend fitted over 1999–2007. Some papers report a more modest drop in consumption, partly because of different detrending, but also because I look at the entire 2007–2011 housing crash period and not just the 2007–2009 NBER recession dates. That said, other recent literature presents similar empirical results on aggregate consumption as this paper. For example, see Kaplan, Mitman and Violante (2017), Garriga, Manuelli and Peralta-Alva (2018), and table C.1 in Arellano, Blundell and Bonhomme (2017).
respective drops of 17.5 percent and 16 percent.

**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). Kaplan, Violante and Weidner (2014) and Baker (2018) find the same pattern for consumption and income shocks, which the model in this paper is able to reproduce, as shown by figure B9 of the appendix. 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, Rao and Sufi (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 percent fall in figure 3 is close to the 15 percent drop in Dynan (2012).

**B. 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.

**Inflation Targeting.** — I first consider moderately raising the inflation target by three percentage points (i.e. 4.9 percent instead of 1.9 percent) 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 percent 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 percent dampening of the crash. With high inflation, the magnitude is even larger at 2.9 and 3.3 percentage points for the two respective
Figure 4. The effects of inflation targeting.
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 percent, the foreclosure rate stops its ascent at less than 2 percent. 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

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20Because extending the implementation of high inflation to four years provides little added benefit
Table 4—Debt Erosion and the Amplifying Effects of Leverage

<table>
<thead>
<tr>
<th>Policy</th>
<th>$\Delta t=0$</th>
<th>$\Delta t=2$</th>
<th>$\Delta t=0$</th>
<th>$\Delta t=2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real House Prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation: Benchmark</td>
<td>2.4</td>
<td>2.5</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Moderate Inflation: High LTV</td>
<td>3.1</td>
<td>3.5</td>
<td>0.6</td>
<td>1.5</td>
</tr>
<tr>
<td>High Inflation: Benchmark</td>
<td>2.9</td>
<td>3.1</td>
<td>0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>High Inflation: High LTV</td>
<td>3.5</td>
<td>3.9</td>
<td>1.8</td>
<td>3.3</td>
</tr>
</tbody>
</table>

All numbers are percentage point (pp) changes. Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. $\Delta t$ is the difference from baseline at time $t$.

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 percent 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.

C. 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.

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 relative to the ten quarter implementation, from now on I only consider the shorter duration version.
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 percent to 40 percent larger in the heavily-indebted economy. For consumption, the amplification is even larger at 50 percent after two years of either policy.

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 superneu-trality argument of section IV.A applies and the dynamics of the crisis are nearly unaffected by inflation.

21 This economy features a median borrower LTV of 85 percent compared to 60 percent in the benchmark.
22 Figure B1 in the appendix shows this “mortgage tilt” for thirty-year fixed-rate mortgages.
Table 6—Liquidity and the Consumption Boost from Inflation

<table>
<thead>
<tr>
<th>Policy</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>0.6pp</td>
<td>1.0pp</td>
<td>0.8pp</td>
<td>2.2pp</td>
</tr>
<tr>
<td>No Liquidity Response</td>
<td>0.4pp</td>
<td>0.6pp</td>
<td>0.6pp</td>
<td>1.8pp</td>
</tr>
</tbody>
</table>

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

Foreclosures, Credit, and Consumption. — Notably, by reducing default premia, the steep drop in foreclosures bolsters consumption by mitigating the contraction in credit that otherwise occurs due to higher inflation—a channel that is distinct from any posited direct impact of foreclosure alleviation on consumption. In fact, quite to the contrary, Garriga and Hedlund (2017) demonstrate that the actual act of going into foreclosure is an insurance mechanism that allows financially distressed borrowers to avoid an even steeper consumption decline. Thus, the causal link between fewer foreclosures and higher consumption is through the supply of credit. Otherwise, any further correlation simply corresponds to the fact that homeowners who find a way to avoid foreclosure probably do so because something loosened their budget constraints.

The Role of Liquidity. — As inflation erodes real mortgage balances, prospective sellers are less debt-constrained when setting their list price to attract buyers. For highly-leveraged sellers, this newfound flexibility leads to quicker sales, thereby allowing them to avoid the prospect of either severe cuts to consumption or foreclosure. Quantitatively, higher inflation mitigates the deterioration in average time on the market by almost two months during the crisis while also

Figure 6. The impact of inflation on debt overhang and selling delays.
Table 7—The Cross-Sectional Impact of Liquidity

<table>
<thead>
<tr>
<th></th>
<th>Low LTV</th>
<th>Medium LTV</th>
<th>High LTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Liquidity Boost</td>
<td>0.0pp</td>
<td>0.2pp</td>
<td>0.9pp</td>
</tr>
</tbody>
</table>

The liquidity boost is the \( \text{additional} \) increase in consumption from moderate inflation with the liquidity channel, i.e. \( \Delta C_{\text{benchmark}} - \Delta C_{\text{noliq}} \). Low LTV < 0.4; high LTV > 0.8.

reducing 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 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 percent and 25 percent in the moderate and high inflation cases, respectively. In the cross section, by alleviating debt overhang in the selling process, the liquidity boost to consumption from higher inflation is concentrated especially among homeowners with the most leverage. As shown in table 7, the liquidity channel adds 0.2 percentage points to consumption for moderately leveraged homeowners and an even more sizable 0.9 percentage points to consumption for highly leveraged homeowners.

D. Further Discussion

This section describes two extensions and a comparison to direct debt relief.

Interest Rate Duration and Demand Externalities. — The picture emerging thus far is one in which the impact of temporary inflation on the economy depends significantly on whether homeowners borrow using fixed-rate mortgages or adjustable-rate mortgages. In the case of fixed-rate mortgages, higher inflation boosts consumption and house prices while reducing foreclosures. However, as V.C already explained, inflation has no net impact in an economy with only adjustable-rate mortgages. Thus, the duration of interest rates (i.e. mortgage maturity) plays an important role in determining the impact of inflation, which is consistent with the emphasis in Auclert (2017) on unhedged interest rate exposures. Even so, in no scenario thus far has inflation been harmful during a crisis episode, in part because I have assumed that the nominal endowment responds instantly to inflation. The first extension in section C re-introduces the nominal
income stickiness from section IV.B and shows that inflation is still stimulative with fixed-rate mortgages but actually worsens the crisis when adjustable-rate mortgages are dominant.\footnote{Adjustable-rate mortgages peaked at 42 percent of new originations in 2005, but what matters for the effect of inflationary policies is their share of the outstanding stock of mortgage debt. Figure D3 shows that this share peaked at 25 percent and has since fallen precipitously.} The second extension introduces a demand externality that magnifies the effects of inflation by allowing it to indirectly affect aggregate income through a consumption spillover, akin to the “aggregate demand” mechanism present in New Keynesian models.

\textbf{Indirect Relief Through Inflation versus Direct Targeted Transfers.} — The consumption benefits from higher inflation implemented during a crisis are felt more acutely by households with the most nominal debt, but inflation is still a blunt instrument. \textit{Every} homeowner with a mortgage experiences debt erosion, not just those financially distressed borrowers near the margin of foreclosure. By contrast, in 2009 the U.S. government implemented the Home Mortgage Modification Program (HAMP) and the Home Affordable Refinance Program (HARP) as an attempt to deliver targeted debt relief to distressed homeowners. Furthermore, the California Housing Finance Agency administered several “Keep Your Home California” initiatives, including a principal reduction program. Section C.C3 compares the inflationary policies studied thus far to direct debt relief. Compared to indirect debt relief from inflation, an unanticipated one-time forgiveness of mortgage debt above 95 percent leverage after the onset of the crisis significantly reduces foreclosures but has a much smaller effect on house prices and consumption. Making the policy more aggressive to forgive debt above 80 percent leverage delivers a boost to house prices and consumption similar to that of temporarily higher inflation, but several mitigating factors that are likely to exist in practice (e.g. labor supply distortions from the higher taxes needed to reimburse the banks for taking a haircut, moral hazard for borrowers near the leverage threshold, administrative costs, etc.) make the policy potentially less appealing.

\textit{E. 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.

Absent any interventions, the welfare cost of the Great Recession is 3.6 percent in the aggregate but varies from a 2.4 percent gain for renters to a 6.3
percent 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 percent welfare loss, and highly-leveraged borrowers experience a 8.6 percent welfare decline.

Figure 7 shows how inflation targeting alters the cost of the Great Recession, and table 8 demonstrates how different assumptions about the nature of mortgage contracts, nominal income stickiness, 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 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, sticky nominal income reduces 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 B5 illustrates. Just as leverage
### Table 8—Inflationary Policies and the Welfare Cost of the Great Recession

<table>
<thead>
<tr>
<th>Policy</th>
<th>All</th>
<th>Renters</th>
<th>Owners</th>
<th>Low LTV</th>
<th>Medium LTV</th>
<th>High LTV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benchmark (Inflation Targeting)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation</td>
<td>0.96</td>
<td>−0.12</td>
<td>1.43</td>
<td>0.19</td>
<td>1.82</td>
<td>2.38</td>
</tr>
<tr>
<td>High Inflation</td>
<td>1.35</td>
<td>−0.15</td>
<td>2.02</td>
<td>0.43</td>
<td>2.35</td>
<td>4.37</td>
</tr>
<tr>
<td><strong>Sticky Nominal Income with Fixed-Rate Mortgages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation</td>
<td>0.02</td>
<td>−1.10</td>
<td>0.52</td>
<td>−0.43</td>
<td>0.78</td>
<td>1.15</td>
</tr>
<tr>
<td>High Inflation</td>
<td>0.11</td>
<td>−1.48</td>
<td>0.82</td>
<td>−0.38</td>
<td>1.01</td>
<td>2.67</td>
</tr>
<tr>
<td><strong>Sticky Nominal Income with Adjustable-Rate Mortgages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation</td>
<td>−0.91</td>
<td>−1.02</td>
<td>−0.86</td>
<td>−0.61</td>
<td>−0.83</td>
<td>−1.86</td>
</tr>
<tr>
<td>High Inflation</td>
<td>−1.24</td>
<td>−1.39</td>
<td>−1.18</td>
<td>−0.75</td>
<td>−1.18</td>
<td>−2.27</td>
</tr>
<tr>
<td><strong>Demand Externality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation</td>
<td>1.23</td>
<td>0.12</td>
<td>1.72</td>
<td>0.38</td>
<td>2.14</td>
<td>2.78</td>
</tr>
<tr>
<td>High Inflation</td>
<td>1.73</td>
<td>0.21</td>
<td>2.40</td>
<td>0.68</td>
<td>2.78</td>
<td>4.87</td>
</tr>
</tbody>
</table>

**Notes:** Each number is the percentage point (pp) change in consumption-equivalent welfare. 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.

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.

**VI. 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.
REFERENCES


**Supplementary Tables**

**Table A1—Inflation Targeting with Sticky Nominal Income**

<table>
<thead>
<tr>
<th>Policy</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Real House Prices</td>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate Inflation: Sticky FRM</td>
<td>0.8</td>
<td>0.2</td>
<td>-0.3</td>
<td>-0.3</td>
</tr>
<tr>
<td>Moderate Inflation: Sticky ARM</td>
<td>-0.9</td>
<td>-1.3</td>
<td>-1.4</td>
<td>-1.1</td>
</tr>
<tr>
<td>High Inflation: Sticky FRM</td>
<td>0.7</td>
<td>0.3</td>
<td>-0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>High Inflation: Sticky ARM</td>
<td>-1.7</td>
<td>-1.4</td>
<td>-2.2</td>
<td>-1.5</td>
</tr>
<tr>
<td>Moderate Inflation: Sticky FRM</td>
<td>-2.4</td>
<td>-0.4</td>
<td>0.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Moderate Inflation: Sticky ARM</td>
<td>3.1</td>
<td>-0.1</td>
<td>-2.2</td>
<td>-1.7</td>
</tr>
<tr>
<td>High Inflation: Sticky FRM</td>
<td>-2.7</td>
<td>-0.2</td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td>High Inflation: Sticky ARM</td>
<td>6.0</td>
<td>-0.2</td>
<td>-3.5</td>
<td>-3.2</td>
</tr>
</tbody>
</table>

Each number is the impact of inflation in percentage point (pp) terms. Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. $\Delta_t$ is the difference from baseline at time $t$. 
Table A2—Inflation and the Incidence of Ex-Post Creditor Losses

<table>
<thead>
<tr>
<th>Policy</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Real House Prices</td>
<td></td>
<td></td>
<td>Consumption</td>
</tr>
<tr>
<td>Moderate Inflation: Benchmark (Only Rich)</td>
<td>2.4</td>
<td>2.5</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Moderate Inflation: Proportional</td>
<td>1.6</td>
<td>1.6</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>High Inflation: Benchmark (Only Rich)</td>
<td>2.9</td>
<td>3.1</td>
<td>0.8</td>
<td>2.2</td>
</tr>
<tr>
<td>High Inflation: Proportional</td>
<td>2.0</td>
<td>2.0</td>
<td>0.5</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Foreclosures</td>
<td></td>
<td></td>
<td>Homeownership</td>
</tr>
<tr>
<td>Moderate Inflation: Benchmark (Only Rich)</td>
<td>−3.0</td>
<td>−0.6</td>
<td>1.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Moderate Inflation: Proportional</td>
<td>−3.0</td>
<td>−0.6</td>
<td>1.2</td>
<td>2.2</td>
</tr>
<tr>
<td>High Inflation: Benchmark (Only Rich)</td>
<td>−3.5</td>
<td>−0.5</td>
<td>1.4</td>
<td>2.3</td>
</tr>
<tr>
<td>High Inflation: Proportional</td>
<td>−3.5</td>
<td>−0.5</td>
<td>1.4</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Each number is the impact of inflation in percentage point (pp) terms. Moderate inflation is a 3pp increase for 4 years. High inflation is a 6pp increase for 10 quarters. $\Delta_t$ is the difference from baseline at time $t$. In the benchmark model, only the rich bear direct mortgage losses from unanticipated inflation. The alternative shown is a version where losses are borne by all households in proportion to liquid assets.
Figure B1. 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 B2. The ineffectiveness of inflation targeting with adjustable rate mortgages.

Figure B3. The paths of the nominal and real aggregate endowment.
Figure B4. The aggregate endowment with and without the demand externality.
Figure B5. Consumption and welfare in the Great Recession with inflation targeting. (Top) The model with nominal income stickiness 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 B6. (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 B7. (Left) The model exhibits substantial inequality, though less than in the data. (Right) The housing wealth share is consistently high but eventually declines.

Figure B8. Detrended (log) real nondurable consumption from NIPA.
Figure B9. The marginal propensity to consume for renters and owners with varying degrees of leverage in the model. Low LTV is below 0.4 and high LTV is above 0.9.
Extensions

This section pursues two significant extensions that explore how nominal income stickiness and demand spillovers affect the case for inflationary policies, and it also compares inflation to direct debt relief via targeted fiscal transfers.

C1. Sticky Nominal Income

First, I return to the stickiness issue of section IV.B. Sticky 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 $W_t = (1 - \psi)(1 + \pi_{\text{steady}})W_{t-1} + \psi W_t^*$, where $W_t^*$ is the flexible path and $\psi = 0.16$. This low quarterly value of $\psi$ is approximately equivalent to 50 percent 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 C1 shows the dynamics of the economy with inflation and sticky nominal income. 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 homeownership is still bolstered. By contrast, inflation is quite counterproductive in the adjustable rate economy. Recall that without stickiness, inflation is essentially irrelevant with adjustable rate mortgages. However, with the endowment stickiness, 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.

C2. 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 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, \( C^\omega \), to the real aggregate endowment with \( \omega = 0.367 \). Introducing this externality allows me to shut down the exogenous 5 percent negative endowment shock and still generate the same decline in house prices during the crash.

Figure B4 in the appendix plots the path of the aggregate endowment in this economy, and table C1 shows the impact of temporarily increasing the inflation target. On impact, the boost to house prices and consumption is 38 percent and 67 percent higher with the demand externality under the moderate inflation target, respectively, and the corresponding values under the high inflation target are 51 percent and 75 percent. 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.
C3. A Comparison to Targeted Fiscal Transfers

In this section, I compare the effects of inflationary policies to that of a direct debt relief program implemented via targeted fiscal transfers. Much in the same vein as Kaplan, Mitman and Violante (2017), I consider a one-time policy intervention that forgives all mortgage debt above some leverage threshold after the onset of the crisis. More realistically, I first consider debt forgiveness above 95 percent loan-to-value at the time of the crisis, but I subsequently analyze a more aggressive 80 percent policy.

Figure C2 shows that the 95 percent implementation is equally as potent as high inflation at reducing foreclosures and limiting the exodus from homeownership.

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24 Rognlie, Shleifer and Simsek (2018) and Berger, Turner and Zwick (2018) also investigate the effectiveness of policies targeted at constrained agents during times of crisis.

25 As with the inflationary policies, I assume that the ex-post losses to banks are borne by the top 1 percent of households in proportion to their bond holdings. In practice, because such a policy would involve direct government outlays to reimburse banks, the cost would be more likely to be distributed across households in proportion to their tax burden. As a result, and especially without endogenous labor supply, the implementation here likely gives an overly optimistic scenario for direct debt relief.
Table C2—Decomposing the Consumption Gains Across Policies

<table>
<thead>
<tr>
<th>Homeowner Share</th>
<th>Pre-Crisis Low LTV</th>
<th>Pre-Crisis Medium LTV</th>
<th>Pre-Crisis High LTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to $\Delta C_{t=0}$</td>
<td>0.324</td>
<td>0.472</td>
<td>0.204</td>
</tr>
<tr>
<td>Contribution to $\Delta C_{t=1}$</td>
<td>-0.170</td>
<td>0.208</td>
<td>0.962</td>
</tr>
<tr>
<td>Contribution to $\Delta C_{t=2}$</td>
<td>0.075</td>
<td>0.475</td>
<td>0.450</td>
</tr>
</tbody>
</table>

**High Inflation**

| Contribution to $\Delta C_{t=0}$ | 0.013 | 0.172 | 0.815 |
| Contribution to $\Delta C_{t=1}$ | 0.005 | 0.161 | 0.834 |
| Contribution to $\Delta C_{t=2}$ | 0.034 | 0.161 | 0.805 |

**Direct Debt Relief Above 95 Percent LTV**

| Contribution to $\Delta C_{t=0}$ | 0.006 | 0.310 | 0.684 |
| Contribution to $\Delta C_{t=1}$ | 0.001 | 0.290 | 0.709 |
| Contribution to $\Delta C_{t=2}$ | 0.010 | 0.274 | 0.716 |

**Direct Debt Relief Above 80 Percent LTV**

$\Delta C_t = C_{policy,t} - C_{baseline,t}$ is the policy impact on consumption after year $t$. Contributions sum to 1. High inflation is a 6pp increase for 10 quarters. Direct debt relief refers to targeted transfers that wipe out all mortgage debt above an LTV threshold in the first period of the transition. The absolute impacts on aggregate consumption are shown in figure C2.

but its impact on house prices and consumption is more modest. Expanding the program to relieve all debt above 80 percent leverage at the trough of the crash boosts house prices almost identically to the policy of temporary high inflation. In the short run, such aggressive direct debt relief is even more effective at boosting consumption than inflation, though after two years their trajectories reunite. Keep in mind, though, that a practical implementation of this direct debt relief policy would likely create labor market distortions from higher taxes, moral hazard from borrowers near the leverage threshold, and administrative costs from modifying mortgage contracts—all of which I ignore in the model simulation.

Table C2 quantifies the contribution of different homeowners to the aggregate consumption response to the policies under consideration. With temporary inflation, homeowners entering the crisis with high loan-to-value mortgages account for the lion share—over 96 percent—of the immediate increase in consumption. However, moderately leveraged homeowners contribute nearly 21 percent to the consumption boost. Seeing as these two numbers sum up to over 100 percent, it must be the case that low-LTV homeowners deliver a negative contribution, which is confirmed in the table as well as figure 7. Such homeowners suffer from the contraction in credit and the cost of bearing the bank’s ex-post losses, all with relatively little nominal debt to be eroded. Nevertheless, their absolute consumption decline is quite modest. Notably, table C2 shows that low-LTV homeowners

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26Calculating the decomposition using pre-crisis leverage allows me to follow the same set of homeowners over time and across policies. Using post-crisis leverage runs into the problem that each policy induces a different equilibrium path of house prices and, therefore, individual leverage.
Table D1—Benchmark vs. Cobb-Douglas Specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Benchmark</th>
<th>Cobb-Douglas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-Calibrated Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largest Apartment $\pi$</td>
<td>2.300</td>
<td>1.650</td>
</tr>
<tr>
<td>Search Cost $\xi$</td>
<td>0.0014</td>
<td>0.0135</td>
</tr>
<tr>
<td>Discount Factor $\beta$</td>
<td>0.9737</td>
<td>0.9767</td>
</tr>
<tr>
<td>Utility Parameter $\omega$</td>
<td>0.8389</td>
<td>0.6809</td>
</tr>
<tr>
<td>Foreclosure Loss $\chi$</td>
<td>0.092</td>
<td>0.047</td>
</tr>
<tr>
<td>Select Model Moments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeownership Rate</td>
<td>69.1</td>
<td>68.1</td>
</tr>
<tr>
<td>Owner Housing Wealth</td>
<td>3.99</td>
<td>3.95</td>
</tr>
<tr>
<td>Owner Median Liq Assets</td>
<td>0.34</td>
<td>0.33</td>
</tr>
<tr>
<td>Median LTV</td>
<td>0.564</td>
<td>0.603</td>
</tr>
<tr>
<td>Owner Share: $LTV \geq 0.8$</td>
<td>0.204</td>
<td>0.268</td>
</tr>
<tr>
<td>Owner Share: $LTV \geq 0.9$</td>
<td>0.095</td>
<td>0.099</td>
</tr>
<tr>
<td>Owner Share: $LTV \geq 0.95$</td>
<td>0.048</td>
<td>0.048</td>
</tr>
<tr>
<td>Months of Supply</td>
<td>4.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Foreclosure Rate</td>
<td>0.67</td>
<td>0.68</td>
</tr>
</tbody>
</table>

gradually experience small gains from inflation, while the bulk of the gains become more evenly distributed between medium-LTV and high-LTV homeowners. By comparison, targeted fiscal transfers are more directed at homeowners with the most debt. At every time horizon, over 80 percent of the consumption gain from the more modest debt relief policy comes from homeowners with high initial leverage. The remainder comes from homeowners just under that threshold who end up qualifying after the decline in house prices boosts their leverage above the cut-off point. Under the same logic, the more aggressive policy that forgives debt above 80 percent loan-to-value encapsulates more homeowners who have moderate pre-crisis leverage.

**Robustness**

This section investigates how the effectiveness of inflation is affected by the degree of substitutability between housing and consumption and the shocks driving the crash.

**D1. Substitutability Between Housing and Consumption**

In light of the ongoing debate over the elasticity of substitution between housing and consumption, this section recalibrates the model under the assumption of Cobb-Douglas preferences and re-simulates the main experiments.\textsuperscript{27}

\textsuperscript{27}For example, Davis and Heathcote (2005) point out that Cobb-Douglas preferences are consistent with the relatively constant share of household income spent on shelter between 1984 and 2001 reported
Figure D1. (Top Row) Benchmark with housing and consumption as complements. (Bottom Row) A re-calibrated Cobb-Douglas version of the model.

Table D1 reports that the benchmark and Cobb-Douglas calibrations mirror each other quite closely in terms of model fit. However, notable differences appear between how the two economies respond to the set of shocks from Garriga and Hedlund (2017) that generate the crisis. In particular, the deterioration in house prices, homeownership, and foreclosures is smaller under the Cobb-Douglas economy, although the drop in consumption is larger. While in principle the shocks could be magnified to reverse engineer the same drop in house prices, the result would be an even more exaggerated fall in consumption. Nevertheless, conditional on the same shocks, figure D1 shows that the two economies behave similarly with regard to the impact of inflationary policies. In both cases, inflation boosts house prices, homeownership, and consumption while significantly reducing foreclosure activity. Thus, the effectiveness of inflation is robust to the degree of substitutability between housing and consumption.

D2. Alternative Shock Scenarios

Figure D2 shows two alternative scenarios for shocks that generate a similar decline in consumption while also matching other features of the data at least qualitatively.28 Alternate 1 is a “credit tightening only” scenario that omits the

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28Only the benchmark economy quantitatively reproduces the peak-to-trough movement of house prices, foreclosures, homeownership, and consumption from the data.
Figure D2. (Top) Benchmark. (Middle) Alternate 1 replaces the increase in downside income risk and the temporary rise in the risk-free rate with an extreme tightening of down payment constraints. (Bottom) Alternate 2 replaces all credit shocks with an exaggerated shock to downside income risk. All plots feature fixed-rate mortgages.
increase in downside income risk and the short-lived positive shock to the risk-free rate. In their place, the maximum loan-to-value at origination is reduced temporarily to a severe 40 percent (i.e. a 60 percent minimum down payment). For reference, the credit tightening in the benchmark specification entails a 90 percent maximum loan-to-value ratio during the crisis. Alternate 2 is an “income uncertainty only” scenario that imposes no tightening in down payments at all during the crisis, leaves the risk-free rate unchanged, and puts in their place a larger, protracted increase in downside income risk.\footnote{Another possible alternative would be to introduce a negative preference shock for housing, but Kaplan, Mitman and Violante (2017) point out that such a shock generates a counterfactual rise in consumption during the bust. Kaplan, Mitman and Violante (2017) instead consider a news shock regarding future preferences for housing, but a model with aggregate shocks is needed to analyze that scenario.}

Both alternative shock scenarios generate a much larger foreclosure spike than either the benchmark or the data as well as an exaggerated decline in homeownership. In both cases, homeownership falls below 60 percent and foreclosures hit peaks above 10 percent. Even so, neither alternate creates a larger drop in house prices than the benchmark, and in the case of alternate 1, house prices fall by considerably less. Thus, neither set of alternative shocks does as well as the benchmark at reproducing the movements in the data. However, even putting this issue aside, it is clear from each of the panels that inflation has the same stimulative effects: house prices, homeownership, and consumption are boosted while foreclosures are attenuated. Therefore, on the central matter of how inflation affects recessionary dynamics, neither alternative specification changes the main conclusion that temporary inflation can mitigate severe crisis episodes resembling that of the U.S. Great Recession.

\textit{D3. A Hybrid Model with FRMs and ARMs}

Section V.D highlighted the importance of interest rate duration for the efficacy of inflation as a policy intervention during crisis episodes. With fixed-rate mortgages, inflation significantly reduces foreclosures and boosts house prices and consumption, whereas adjustable-rate mortgages render such a policy ineffective, albeit harmless as long as nominal income does not exhibit stickiness. In the data, adjustable-rate mortgages peaked at 42 percent of new originations in 2005, though they only reached 25 percent of the outstanding stock of mortgage debt, as shown in the left panel of figure D3.

The other two panels show the impact of temporarily higher inflation when the model features a 75/25 split between fixed-rate and adjustable-rate mortgages. Homeowners are randomly allocated to each mortgage type, because the absence of aggregate shocks renders the portfolio choice problem between contracts indeterminate. Given this particular split, inflation maintains most, though not all, of its potency.
CALIBRATING THE INDIVIDUAL ENDOWMENT PROCESS

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, Telmer and Yaron (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, Telmer and Yaron (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, Telmer and Yaron (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:

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

As a result, the transition matrix prior to adding the fourth state corresponding
transitory shock is

\[ g_s(\cdot, \cdot) = 0.75I_3 + 0.25\tilde{g}_s(\cdot, \cdot) = \begin{pmatrix} 0.9881 & 0.0059 & 0.0001 \\ 0.0171 & 0.9883 & 0.0171 \\ 0.0001 & 0.0059 & 0.9881 \end{pmatrix} \]

Transitory Shocks. — Storesletten, Telmer and Yaron (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, Telmer and Yaron (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.

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, \( \{p_t\}_{t=1}^T \). The algorithm then does backward induction on the recursive mortgage 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.