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

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October 16, 2015

Abstract

Can inflating away nominal mortgage liabilities cure debt overhang and combat a severe housing bust? With a focus on the Great Recession, I address this question using a structural macroeconomic model of illiquid housing, endogenous credit supply, and equilibrium default. First, I show that the model successfully replicates and provides insight into the dynamics of the U.S. economy since 2006. Second, I show that temporarily raising the inflation target would have cut foreclosures by over 60% and led to a more robust recovery in real economic variables. Price-level targeting that promises to offset this temporary inflation with future disinflation has more modest positive effects. In short, forward guidance matters. Higher inflation loses its potency in the counterfactual where all homeowners have adjustable rate mortgages, which highlights the importance of nominal rigidities for the effectiveness of these policies. Lastly, inflation proves effective even if wages exhibit substantial nominal stickiness.

Keywords: Housing; Liquidity; Mortgage Debt; Foreclosure; Inflation

JEL Classification Numbers: D31, D83, E21, E22, G11, G12, G21, R21, R31

*Comments are welcome at hedlunda@missouri.edu. I thank Grey Gordon, Carlos Garriga, Joe Haslag, Chris Otrok, Todd Walker, Juan Carlos Hatchondo, Kurt Mitman, Fatih Karahan, Serdar Ozkan, Allen Head, Victor Rios-Rull, Gianluca Violante, and participants at the spring 2015 Midwest Macroeconomic Conference, the 2015 NBER Summer Institute, and the 2015 World Society of the Econometric Society for their useful comments. Any errors are my own.
1 Introduction

In response to the Great Recession and the unprecedented collapse in the housing mar-
ket, the U.S. government undertook dramatic interventions to stimulate the economy out of its slump. However, the Federal Reserve diligently avoided any attempt to push inflation above its usual two percent target.\textsuperscript{1} Even when signaling its discontent with the low level of inflation and its willingness to take additional action, the Fed continually re-invoked its long-run target, as it did in September 2010:

\begin{quote}
"Measures of underlying inflation are currently at levels somewhat below those the Committee judges most consistent, over the longer run, with its mandate to promote maximum employment and price stability."
\end{quote}

On the one hand, these actions demonstrate an understandable reluctance by the Fed to put at risk its hard-won inflation fighting credibility. On the other hand, household debt has throttled the economy for several years, with economic growth only recently demonstrating signs of durable strength. Even though foreclosures have subsided, real house prices and existing house sales remain considerably below their peaks. Figure 1 plots the federal funds and inflation rates, real house prices, existing sales and average time on the market from 2004 – 2014.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Fed funds rate and inflation rate; real house prices; existing sales and time on the market}
\end{figure}

\textsuperscript{1}See \url{http://www.federalreserve.gov/faqs/economy_14400.htm}. 
The protracted recession and sluggish recovery have led to calls at various points for a temporary regime of higher inflation to battle debt’s long shadow. Robert Engle and Paul Krugman have emerged as vocal supporters of this view, and Ken Rogoff has lent his voice in agreement:

“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. Any inflation above 2 percent may seem anathema to those who still remember the anti-inflation wars of the 1970s and 1980s, but a once-in-75-year crisis calls for outside-the-box measures.”

In this paper, I address whether such an outside-the-box measure of explicitly inflating away mortgage debt can effectively improve economic performance during and after a deep recession. To do so, I construct a macroeconomic model along the lines of Hedlund (2015a) and Hedlund (2015b) that features illiquid housing, endogenous mortgage pricing, 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 earnings risk and can accumulate buffer savings. Illiquidity arises in the housing market because of matching frictions à la directed search. Lastly, lenders in the mortgage market issue long-term, fixed rate, nominal mortgages that price inflation expectations and individual default risk at origination.

To motivate the analysis, I focus on three channels of inflation. First, inflation erodes the real value of debt and relaxes household budget constraints. However, just as inflation erodes the burden of debt to borrowers, it also reduces the value of nominal repayments to banks. This dimension of inflation acts as a redistribution between borrower and lender ex-post but impacts lending behavior ex-ante. Specifically, the second channel of higher inflation leads to reduced equilibrium mortgage prices, which means that banks transfer fewer resources to households in exchange for a given
promise of future nominal payments by the household. In the case of either one-period or adjustable rate contracts, the response of mortgage prices completely nullifies the positive effect of inflation on the household budget constraint, and only the real interest rate matters for determining the cost and burden of debt.

By contrast, long-term fixed rate mortgages (FRMs) introduce an important nominal rigidity. First, because long-term fixed rates do not respond one-for-one to short-run nominal interest rate fluctuations, short-lived higher inflation, even when fully anticipated, can temporarily lower real rates (at the expense of a modestly higher real rate once inflation subsides). More importantly, an unexpected bout of inflation erodes the debt of current borrowers, and FRMs shield such borrowers from any offsetting rate increase. As a result, unanticipated inflation substantially lowers the real rate at which existing borrowers in FRMs roll over their debt.

Illiquidity in housing markets 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. Highly indebted homeowners find themselves unable to price their houses competitively, which leads to longer selling delays and a greater risk of foreclosure. Inflation provides additional pricing flexibility to these sellers by eroding their debt and creating equity. The resulting reduced time on the market proves especially key for distressed homeowners, as it gives them an escape from burdensome debt besides default.

In this paper, I quantitatively evaluate these channels to answer whether, on balance, temporary inflation mitigates a deep housing bust or whether it causes further damage to the economy. To do so, I first show that the model successfully replicates the dynamics of the U.S. economy during and after the Great Recession and, therefore, represents a good laboratory for the ensuing counterfactual experiments. In particular, the model generates a 25% drop in real house prices, a 50% drop in sales, a more than doubling of average time on the market from 22 weeks to 52 weeks, and a spike in the foreclosure rate to almost 6%—all consistent with the data.
Next, I evaluate the steady state effects of long-run inflation, and I show that the economy exhibits approximate supernutrality. In particular, real house prices, the homeownership rate, housing wealth, and other aggregates do not respond to changes in the long-run inflation rate. Thus, the debt erosion and credit contraction effects of inflation (from lower mortgage prices) exactly offset, and only a substantially diminished liquidity effect remains.

Next, I progress to the first main policy experiment, which assesses the impact of temporarily raising the inflation target at the beginning of the Great Recession. In the first variant of this policy, I consider a 3pp increase in the inflation target from 1.9% to 4.9% that lasts for four years. For comparison, I also look at a 6pp increase in the target to 7.9% for either two and a half years or four years (the two and a half year duration of 7.9% inflation generates the same price level increase as the 3pp increase for four years). In all three cases, the higher inflation target dramatically reduces foreclosures, improves housing liquidity by reducing average time on the market, and generates a faster recovery in real house prices, net worth, and consumption. Quantitatively, the foreclosure rate hits a peak of 2.3% instead of 5.7%, the spike in time on the market shrinks by 9 weeks, and two years into the recovery, real house prices, net worth, and consumption sit up to 6.2%, 3.6%, and 13.6% higher than they would absent the intervention. Impressively when compared to the data, the economy and housing market achieve almost a full recovery after only four years.

To assess the power of the debt erosion and liquidity channels of inflation, I proceed to simulate the dynamics of the economy under higher inflation when banks naively neglect to re-price mortgage debt. In this counterfactual, the 6pp increase of inflation for four years transforms the Great Recession into a shallow and short-lived blip. Specifically, real house prices fall by only 5% instead of 25%, the foreclosure rate never exceeds 1%, and the economy achieves full recovery after two years.

Comparison of the initial and naive policy experiments shows that the response of mortgage prices significantly attenuates the benefits of higher inflation. In response,
I analyze an alternative price level targeting policy that avoids a long run devaluation in repayments. Such a policy generates higher inflation initially but later creates a disinflation that returns the price level to its original trajectory. I show that this policy substantially reduces foreclosures but has more modest positive effects on real house prices, net worth, and consumption. I view this outcome as confirmation of the important role of forward guidance in monetary interventions.

Lastly, I return to the initial higher inflation target policies, and I show how the response of the economy changes when households have adjustable rate instead of fixed rate mortgages or if wages exhibit nominal stickiness. As expected, removing the nominal rigidity of fixed rate mortgages causes the credit contraction effect of inflation to completely undo the benefits of debt erosion, and higher inflation proves utterly incapable of combating the Great Recession. When I reinstate the assumption of fixed rate mortgages but impose substantial nominal wage stickiness in a way designed to most harm the case for higher inflation, the original higher inflation target policies once again demonstrate remarkable, though diminished, effectiveness at combating the Great Recession. Only when I combine adjustable rate mortgages with nominal wage stickiness does temporary higher inflation hurt short-run economic performance.

1.1 Related Literature

This paper bridges the literature on models of default with the literature on housing market search frictions, both of which Hedlund (2015a) and Hedlund (2015b) describe in detail. In other related work, Mian, Rao and Sufi (2013) and Dynan (2012) establish the negative effect of debt overhang on consumption. DiMaggio, Kermani and Ramcharan (2015) and Aladangady (2014) look at the transmission of monetary policy through changes to household balance sheets. Doepke, Schneider and Selezneva (2015), Doepke and Schneider (2006), Meh, Ríos-Rull and Terajima (2010), and Auclert (2015) discuss the redistributive implications of inflation and the Fisher channel. Benigno, Eggertsson and Romei (2014) and Leeper and Zhou (2013) establish a pos-
itive role for inflation during times of high debt. Sheedy (2014) makes the case for nominal GDP targeting to improve risk-sharing from the presence of noncontingent nominal debt. Lessard and Modigliani (1975), Kearl (1979), and Piazzesi and Schneider (2012) study the real effects of high 1970s inflation. In the recent sovereign debt literature, Hilscher, Raviv and Reis (2014) and Reinhart and Sbrancia (2015) study the effectiveness of inflation at reducing public debt. Galí (2014) studies the effects of an increase in government purchases financed through seignorage and finds that it compares favorably to more conventional debt financing under certain conditions.

In a related paper, Garriga, Kydland and Sustek (2015) study the transmission of monetary policy under adjustable rate and fixed rate mortgages. As in this paper, they take into account how inflation simultaneously erodes the the value of existing debt and increases the cost of new credit. However, whereas their model environment has two representative agents (homeowners and capital owners), I study an economy with imperfect risk-sharing 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 conduct a brief exercise that studies the effect of one possible inflationary policy on housing and foreclosures during the Great Recession. They find a sizeable reduction in foreclosures with no change in real house prices. However, debt overhang is effectively nonexistent in their setup because they model frictionless housing markets and forbid refinancing.

Lastly, Arslan, Guler and Taskin (2015) study housing and foreclosures during the Great Recession along with the impact of a policy intervention that restricts the loan-to-value of new mortgages. 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, debt overhang, and a slow recovery.
2 The Model

In this section, I construct a discrete time, infinite horizon open economy with production sectors for the numeraire good for housing construction. The model also contains the following ingredients: i) uninsurable, idiosyncratic household earnings risk, ii) search frictions in the housing market, iii) nominal mortgage contracts, and iv) equilibrium mortgage default.

2.1 Households

2.1.1 Endowments

Households are infinitely lived and inelastically supply a stochastic labor endowment $e \cdot s$ to the labor market. The persistent component $s \in S$ follows a finite state Markov chain with transitions $\pi_s(s'|s)$, and households draw the transitory component $e \in E \subset \mathbb{R}_+$ from the cumulative distribution function $F(e)$. Households receive their initial $s$ from the invariant distribution $\Pi_s(s)$.

2.1.2 Preferences

Households discount the future at the rate $\beta$ and have preferences over consumption $c$ and housing services $c_h$. Households obtain housing services either by owning and occupying a house or by residing in an apartment. Apartment-dwellers, or “renters,” purchase apartment space $a \leq \bar{a}$ each period at a cost of $r_h$ per unit. Each unit of apartment space generates one unit of housing services. Agents become homeowners by purchasing a house $h \in H = \{h_1, h_2, h_3\}$ in the decentralized housing market. House $h$ generates $c_h = h$ units of housing services each period. I do not allow homeowners to own multiple houses or to rent out their house to a tenant.\(^2\) Furthermore, I assume $\bar{a} \leq h$, which implies that all owners choose to occupy their house.

\(^2\)As I discuss later, owner-to-owner transitions occur when homeowners sell their current house at the beginning of the period and then immediately purchase a different house.
2.2 Technology

2.2.1 Consumption Good Sector

A representative firm produces the composite good using labor $N_c$ as the sole input,

$$Y_c = A_c N_c.$$ 

Total factor productivity $A_c$ is constant in the steady state but varies during the Great Recession. The cost of labor is $w$ per unit of labor efficiency.

The profit maximization condition of the composite good firm is

$$w = A_c. \quad (1)$$

2.2.2 Apartments

Landlords operate a linear, reversible technology that converts one unit of the consumption good into $A_h$ units of apartment space.$^3$ Landlords sell apartment space at price $r_h$.

The profit maximization condition of landlords is

$$r_h = \frac{1}{A_h}. \quad (2)$$

$^3$This construction technology resembles the one in Jeske, Krueger and Mitman (2013), except here it refers to the production of apartment space, not houses. The model’s stark divide between the housing and apartment markets implies that rents $r_h$ depend only on the technology for producing apartments and not at all on house prices. 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.


2.2.3 Housing Construction Sector

Home builders construct new houses using a constant returns to scale production function with land $L$, structures $S_h$, and labor $N_h$,

$$Y_h = F_h(L, S_h, N_h).$$

Builders purchase new land permits from the government at price $p_l$, pay wage $w$, and purchase structures $S_h$ from the consumption good sector. As in Favilukis, Ludvigson and Van Nieuwerburgh (2015), the government supplies a fixed amount $L > 0$ of new permits each period, and all revenues go to government consumption. Home builders do not experience construction lags and sell directly to real estate brokers at price $p_h$ per unit of housing. Individual houses depreciate stochastically with probability $\delta_h$.\(^4\)

In the aggregate, the housing stock evolves according to

$$H' = (1 - \delta_h)H + Y'_h$$

The relevant profit maximization conditions of home builders are

$$1 = p_h \frac{\partial F_h(L, S_h, N_h)}{\partial S_h}$$

$$w = p_h \frac{\partial F_h(L, S_h, N_h)}{\partial N_h}.$$ (4)

2.3 Housing Market

As in Hedlund (2015a) and Hedlund (2015b), real estate brokers intermediate all trades in the decentralized housing market. First, owners (owner-occupiers or banks in possession of foreclosed properties) choose a list price $x_s$ for their property to

\(^4\)Complete depreciation averts the need to deal with situations where mortgaged homeowners suddenly find themselves underwater because a portion of their house depreciates. As I discuss in section 2.4.1, I assume complete mortgage forgiveness in the low probability event that a house depreciates.
attract seller-brokers willing to pay $x_s$ to buy their house. Meanwhile, buyers choose a desired house type $h \in H$ and purchase price $x_b$ and direct their search for a buyer-broker willing to sell said house at said price. The market “clears” as seller-brokers, buyer-brokers, and home builders trade housing frictionlessly with each other at the shadow housing price $p_h$. Brokers are not permitted to carry housing inventories into future periods, but inventories do arise in equilibrium from the portion of the housing stock that owners put on the market but fail to sell.

2.3.1 Directed Search in the Housing Market

Buyers  Prospective buyers direct their search for houses by choosing a desired price $x_b \geq 0$ and a house size $h \in H$. Formally, buyers enter submarket $(x_b, h) \in \mathbb{R}_+ \times H$. With probability $p_b(\theta_b(x_b, h))$, a buyer matches with and purchases a house from a buyer-broker, where $\theta_b(x_b, h)$ is the ratio of brokers to buyers, i.e. the market tightness of submarket $(x_b, h)$. The probability that a broker finds a buyer is $\alpha_b(\theta_b(x_b, h)) = \frac{p_b(\theta_b(x_b, h))}{\theta_b(x_b, h)}$. The function $p_b : \mathbb{R}_+ \to [0, 1]$ is continuous and strictly increasing with $p_b(0) = 0$; $\alpha_b$ is strictly decreasing. It is possible that $\alpha_b > 1$, in which case the same broker finds multiple buyers, to which the broker sells one house each.

Successful buyers immediately move into their house and switch from apartment-dweller (“renter”) status to homeowner status. Unsuccessful buyers remain as renters until the next period. Each broker in submarket $(x_b, h)$ incurs an entry cost $\kappa_b h$, and both sides of the market take $\theta_b(x_b, h)$ parametrically.

Sellers  Sellers of existing houses, which includes homeowners and lenders selling foreclosed properties, simply choose a list price $x_s \geq 0$ each period that they commit to honoring if they match with a seller-broker. In the parlance of directed search, sellers enter submarket $(x_s, h)$, where $h$ is the size of house they are selling. With probability $p_s(\theta_s(x_s, h))$, a seller successfully matches and sells the house, provided

\footnote{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.}
that they have the ability to pay off any outstanding mortgage debt.\footnote{Short sales create the potential for moral hazard, which I abstract from here.} Brokers find sellers with probability $\alpha_s$, where $p_s$ and $\alpha_s$ are analogous to $p_b$ and $\alpha_b$, respectively. Each broker incurs an entry cost $\kappa_s h$, and owners that try and fail to sell pay a small utility cost $\xi$.\footnote{The utility cost prevents homeowners nearly indifferent about selling from fishing for buyers by posting unreasonably high prices that lead to inordinate time on the market.} Both sides of the market take $\theta_s(x_s, h)$ parametrically.

The profit maximization conditions of the real estate brokers are

$$
\kappa_b h \geq \alpha_b(\theta_b(x_b, h)) \left( x_b - p_b h \right) 
$$

(5)

$$
\kappa_s h \geq \alpha_s(\theta_s(x_s, h)) \left( p_b h - x_s \right)
$$

(6)

with $\theta_b(x_b, h) \geq 0$, $\theta_s(x_s, h) \geq 0$, and complementary slackness holding.

The revenue to a seller-broker that purchases a house from a seller is $p_b h - x_s$. Therefore, brokers continue to enter submarket $(x_s, h)$ until the cost $\kappa_s h$ exceeds the expected revenue. An analogous process occurs for buyer-brokers.

### 2.3.2 Block Recursivity

As the above analysis shows, the menu of market tightnesses does not depend directly on the distribution of household characteristics (particularly income, assets, and debt). Instead, $\theta_s(x_s, h)$ and $\theta_b(x_b, h)$ depend only on $p_b$, as in\footnote{Hedlund (2015a) and Hedlund (2015b):}

\[
\theta_b(x_b, h) = \alpha^{-1}_b \left( \frac{\kappa_b h}{x_b - p_b h} \right) 
\]

(7)

\[
\theta_s(x_s, h) = \alpha^{-1}_s \left( \frac{\kappa_s h}{p_b h - x_s} \right)
\]

(8)

This block recursivity result greatly increases computational tractability without altering the substance of the frictional buying and selling problems of the households.
In particular, solving for the dynamics of the market tightnesses reduces to finding the equilibrium path of \( p_h \) and then substituting into (7) – (8).

2.4 Financial Markets

Households save through the use of one period real bonds that trade at price \( q_b = \frac{1}{1+r} \), where \( r \) is the (exogenous) risk-free rate. In addition, homeowners can borrow in the form of long term, fixed rate nominal mortgage contracts.

2.4.1 Mortgages

Banks price aggregate and individual borrower risk into new mortgage contracts. Specifically, when a borrower with bonds \( b' \), house \( h \), and persistent labor efficiency \( s \) takes out a mortgage of nominal size \( M' \) at rate \( r_m \), the bank delivers \( q^0_m((q_m, M'), b', h, s)M' \) in nominal units to the borrower at origination, where \( q_m \equiv \frac{1}{1+r_m} \) remains fixed for the duration of the loan. Perfect competition assures zero ex-ante profits loan-by-loan. For the duration of the paper, I denote the current market (inverse) fixed rate for new mortgages as \( q_m \) and the rate for an individual existing borrower as \( \bar{q}_m \). No meaningful distinction exists in the steady state.

To capture all forms of mortgage debt—second liens, HELOCs, etc.—I assume mortgage contracts have no predefined maturity date. Instead, homeowners gradually accumulate equity at their own pace. However, homeowners that want to tap into their equity must refinance by paying off their old mortgage and taking out a new, re-priced mortgage.\(^8\)

Banks incur a proportional origination cost \( \zeta \) and servicing costs \( \phi \) over the life of each mortgage. During the repayment phase, banks face three sources of risk. First, if

\(^8\)By contrast, Chatterjee and Eyigungor (2015) construct a model where mortgage contracts specify an infinite sequence of geometrically declining payments. Two advantages to the approach here are that households may choose the speed of total deleveraging—either by prepaying or by paying down more slowly (equivalent to paying down a first mortgage while simultaneously extracting equity via a HELOC or second mortgage)—and that computation does not require interpolation along the mortgage debt dimension. Furthermore, I can analyze the effect of fixed-rate mortgages vs. adjustable-rate mortgages.
the house depreciates, the bank must forgive the loan balance.\(^9\) Second, homeowners can decide to default in a given period by not making a payment. In this situation, with probability \(\varphi\), the lender forecloses on the borrower and repossesses the house. With probability \(1 - \varphi\), the lender ignores the skipped payment until the next payment comes due.\(^\text{10}\) Inflation \(\pi\) represents the last source of risk to banks by eroding the real value of repayments.

Banks front-load all borrower-specific default risk into the price \(q_m^0\) borrowers receive at origination, but the fixed rate set at origination reflects depreciation risk and long-run inflation risk. To summarize, a borrower with existing contract \((q_m, M)\) that chooses a new balance of \(M'\) owes \(M - q_m^0 M'\) if \(M' \leq M\) or else \(M - q_m^0 ((q_m, M'), b', h, s) M'\) if \(M' > M\), where \((q_m, M')\) is the refinanced contract at the new prevailing rate \(q_m\).

The fixed rate \(r_m\) set at origination satisfies
\[
1 + r_m = \frac{1 + \phi}{1 - \delta_h} (1 + r^*) (1 + \pi^*),
\]
where \(r^*\) is the spread between the fixed rate and the long-run nominal risk-free rate.

Mortgage prices for contract \((q_m, M')\) satisfy the following recursive relationship:
\[
q_m^0((q_m, M'), b', h, s) M' = (1 - \delta_h) \left(1 + \zeta(1 + \phi)(1 + r)(1 + \pi)\right) \mathbb{E} \left[\begin{array}{c}
\text{sell + repay} \\
\text{no sale (do not try/fail)}
\end{array}\right]
\]
\[
\times \left[\begin{array}{c}
d' \varphi \min \{P' J_{\text{REO}}(h), M'\} \\
\text{default + repossession} \\
\end{array}\right] + d'(1 - \varphi) \left[\begin{array}{c}
-\phi M' + (1 + \zeta)(1 + \phi)q_m^0 ((q_m, M'), b', h, s') M' \\
\text{no repossession} \\
\end{array}\right]
\]
\[
+ (1 - d') \left[\begin{array}{c}
M' - (1 + \phi)q_m M'' 1_{[M'' \leq M]} \\
\text{borrower payment net of servicing costs} \\
\end{array}\right] + (1 + \zeta)(1 + \phi)q_m^0 ((q_m, M''), b', h, s') M'' 1_{[M'' \leq M']}
\]
\[
\right] \]
\[
\]
By defining $m' = \frac{M'}{P}$ and $m'' = \frac{M''}{P'}$ and dividing through by $Pm'$, $q^0_m$ becomes

$$q^0_m((\bar{\eta}_m, m'), b', h, s) = \frac{1 - \delta_h}{(1 + \zeta)(1 + \phi)(1 + r)(1 + \pi)} \mathbb{E} \left\{ p_s(\theta_s(x'_s, h)) + [1 - p_s(\theta_s(x'_s, h))] \right\}$$

$$\times \left\{ d'\phi \min\left\{ \frac{(1 + \pi)J_{REO}(h)}{m'}, 1 \right\} + d'(1 - \phi) (1 + \phi) q^0_m((\bar{\eta}_m, m'), b'', h, s') \right\}$$

$$+ (1 - d') \left(1 - (1 + \phi) \left[ \frac{(1 + \pi)J_{REO}(h)}{m'} \mathbb{1}_{[(1 + \pi) m'' \leq m']} \right] \right) \right\}$$

If the borrower never sells or defaults, mortgage prices in the steady state reduce to

$$q^0_m((\bar{\eta}_m, m'), b', h, s) = \frac{1 - \delta_h}{(1 + \zeta)(1 + \phi)(1 + r)(1 + \pi)} \frac{\bar{\eta}_m}{1 + \zeta},$$

where $\zeta$ is the origination cost and $\bar{\eta}_m = q_m$. We can see that higher inflation $\pi$ reduces mortgage prices. Intuitively, for a given promised sequence of nominal repayments, banks reduce lending as expected inflation increases.\(^{11}\)

### 2.4.2 Foreclosure Process

As just discussed, banks foreclose on defaulting borrowers with probability $\phi$. In this event, borrowers lose their house, have their debt erased, and have a flag $f = 1$ placed on their credit record. Borrowers with a credit flag lose access to the mortgage market. Credit flags persist to the following period with probability $\gamma_f \in (0, 1)$. The house repossession and borrowing exclusion represent the only costs of foreclosure to borrowers.\(^{12}\)

Banks sell repossessed houses (REO properties) in the decentralized housing market. Banks lose a proportion $\chi$ of sales revenue to the various costs of selling foreclosed houses. The bank absorbs all losses but must pass along profits to the borrower in the unlikely event that sales revenues exceed the remaining mortgage balance.

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\(^{11}\)Section 4.2 discusses more in depth the relationship between inflation and credit supply.

\(^{12}\)See Jones (1993), Bhutta, Dokko and Shan (2010), Solomon and Minnes (2011), and Pence (2006) on the rarity of deficiency judgments, even in recourse states.
The value to a lender in repossessing a house $h$ is

$$J_{REO}(h) = R_{REO}(h) - \eta h + \frac{1 - \delta_h}{1 + r} J_{REO}(h)$$

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

where $\eta$ is the cost of holding onto the house (maintenance, property taxes, etc.) and $R_{REO}(h)$ is the option value of trying to sell the house.

### 2.5 Household Problem

Each period contains three subperiods. At the beginning of subperiod 1, households learn their labor efficiency components, $e$ and $s$, and their credit score $f \in \{0, 1\}$. The individual state of a homeowner is cash at hand $y$, inverse mortgage rate $q_m$ and balance $m \equiv \frac{M}{\bar{M}}$, house $h$, and persistent labor component $s$. The individual state of a renter is simply $(y, s, f)$.

Now I work backwards to describe the household problem.

#### 2.5.1 Consumption/Saving

End-of-period homeowner expenditures consist of the consumption good, bond purchases, and mortgage payments. In nominal terms, homeowners face the following constraint:

$$Pc + P\eta h + Pq_bb' + M - \widehat{q_m}M' \leq Py$$

where $\widehat{q_m} = \overline{q_m}1_{[m' \leq \frac{m}{1+\pi}]} + q_0^m((q_m, M'), b', h, s)1_{[m' > \frac{m}{1+\pi}]}$. 

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Dividing through by $P$ and replacing $\frac{M}{P}$ with $\frac{P^*}{P} \frac{M}{P} = \frac{P^*}{P} = \frac{m}{1+\pi}$ gives the budget constraint in terms of the numeraire consumption good,

$$c + \eta h + q_b b' + \frac{m}{1+\pi} - \tilde{q}_m m' \leq y.$$

The constraint makes one effect of inflation clear: higher inflation $\pi$ reduces the value of outstanding debt. In the stationary environment, owners with good credit have value function

$$V_{own}(y, (\bar{q}_m, m), h, s, 0) = \max_{m', b', c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (1 - \delta_h)(W_{own} + R_{sell})(y', (\bar{q}_m, m'), h, s', 0) \\
+ \delta_h (V_{rent} + R_{buy})(y', s', 0) \right]$$

subject to

$$c + \eta h + q_b b' + \frac{m}{1+\pi} - \tilde{q}_m m' \leq y$$

$$q_m^0 ((q_m, m'), b', h, s)m'1_{m' > \frac{m}{1+\pi}} \leq \vartheta_p h$$

$$y' = wc's' + b'$$

(12)

where $\vartheta$ is an exogenous upper bound on LTV for new loans. The terms $W_{own} + R_{sell}$ and $V_{rent} + R_{buy}$ are subperiod 1 utilities for homeowners and apartment-dwellers, respectively.

The problem for homeowners with bad credit is analogous, except that they lack access to the mortgage market. Apartment-dwellers replace mortgage payments with period-by-period purchases of apartment space $a \leq \bar{a}$. Therefore, apartment-dwellers face the following constraint:

$$c + r_h a + q_b b' \leq y.$$
2.5.2 House Buying

Prospective buyers (including successful home sellers from subperiod 1) direct their search to a submarket \((x_b, h)\) of their choice. Buyers with bad credit are bound by the constraint \(y - x_b \geq 0\), while buyers with good credit are bound by the constraint \(y - x_b \geq y(s, (h, 1))\), where \(y < 0\) captures the ability of new buyers to take out a mortgage in subperiod 3. The option value \(R_{buy}\) of attempting to buy is as follows:

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

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

2.5.3 Mortgage Default

The value function for a homeowner deciding whether to default is

\[
W(y, (\overline{q}_m, m), h, s, 0) = \max \left\{ \varphi(V_{rent} + R_{buy}) \left( y + \max \left\{ 0, J_{REO}(h) - \frac{m}{1+\pi} \right\} \right), s, 1 \right\} \\
+ (1 - \varphi)V_{own}^d(y, (\overline{q}_m, m), h, s, 0), V_{own}(y, (\overline{q}_m, m), h, s, 0) \right\}
\]

where the value function associated with defaulting but not being foreclosed on is

\[
V_{own}^d(y, (\overline{q}_m, m), h, s, 0) = \max_{b',c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (1 - \delta_h)(W_{own} + R_{sell})(y', (\overline{q}_m, m), h, s', 0) \right. \\
+ \delta_h(V_{rent} + R_{buy})(y', s', 0) \left. \right] \\
\text{subject to} \\
c + \eta h + q_b b' \leq y \\
y' = w e' s' + b'
\]

\[
(16)
\]
2.5.4 House Selling

Owners of house size \( h \) who want to sell choose a list price \( x_s \) and direct their search to submarket \( (x_s, h) \). The option value \( R_{sell} \) for a homeowner with good credit is

\[
R_{sell}(y, (\bar{q}_m, m), h, s, 0) = \max\{0, \max_{x_s} p_s(\theta_s(x_s, h)) \left[ (V_{rent} + R_{buy}) \left( y + x_s - \frac{m}{1 + \pi}, s, 0 \right) \right.
\]

\[-W_{own}(y, (\bar{q}_m, m), h, s, 0)] + [1 - p_s(\theta_s(x_s, h))] (-\xi) \}

\text{subject to } y + x_s \geq \frac{m}{1 + \pi}
\]

where the constraint reflects the mortgage repayment requirement. By reducing the value of outstanding debt, inflation fights debt overhang and allows sellers to price their houses more competitively, thereby shrinking time on the market and reducing the probability that distressed borrowers fail to sell and end up in foreclosure.

2.6 Equilibrium

A stationary equilibrium consists of value/policy functions for households and banks; market tightnesses \( \theta_s \) and \( \theta_b \); prices \( w, p_h, q^0_h, q_m, q_b \), and \( r_h \); stationary distributions \( \Phi \) of households and \( \{H_{REO}\}_{h \in H} \) of REO houses such that households optimize, firms and banks maximize profits, market tightnesses satisfy \((7) - (8)\), and the labor and housing markets clear.\(^{13}\)

3 Bringing the Model to the Data

I calibrate the model to match selected features of the U.S. economy during 2003 – 2005, prior to the tightening of monetary policy and the subsequent Great Recession. In particular, I pay careful attention to ensuring that the model successfully matches key housing moments related to sales, time on the market, and foreclosures, as well as important dimensions of the joint distribution of assets, housing wealth, and mortgage

\(^{13}\)Housing market clearing refers to the market where seller-brokers, buyer-brokers, and construction firms trade housing. The appendix provides more details.
debt. Some model parameters I calibrate ex ante from the literature or from direct observation of the data. The remaining parameters I calibrate jointly. Below, I discuss the calibration in greater detail.

3.1 Independent Parameters

**Households** Following Storesletten, Telmer and Yaron (2004), I assume that the log of the persistent component of labor efficiency follows an AR(1) process, while the transitory component is log-normal. I discretize the persistent component using a 3-state Markov chain. However, in the spirit of Castañeda, Díaz-Giménez and Ríos-Rull (2003), I add a state corresponding to the top 1%, because I assume that these households bear the brunt of the banking losses caused by the unanticipated spike in foreclosures during the Great Recession.

For preferences, households have CES period utility with an intratemporal elasticity of substitution of $\nu = 0.13$. I set risk aversion to $\sigma = 2$, while I determine the consumption share $\omega$ and discount factor $\beta$ in the joint calibration.

**Technology** I normalize steady state TFP in the consumption good sector to normalize mean quarterly earnings to 0.25. Meanwhile, I assume Cobb-Douglas housing construction with a structures share of $\alpha_S = 0.3$ and a land share of $\alpha_L = 0.33$, based on data from the Lincoln Institute of Land Policy. Housing depreciates at an annual rate of 1.4%. Lastly, I set the apartment technology $A_h$ to generate an annual rent-price ratio of 3.5%.

\footnote{The appendix explains the procedure to convert the annual estimates from Storesletten et al. (2004) to quarterly values.}
Housing Market  Matching is Cobb Douglas, i.e. $p_s(\theta_s) = \min\{\theta^{\gamma_s}, 1\}$ and $p_b(\theta_b) = \min\{\theta^{\gamma_b}, 1\}$. Substituting in (7) and (8) gives

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

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

The joint calibration determines the parameters $\kappa_b, \kappa_s, \gamma_s, \gamma_b$, and disutility $\xi$. I set holding costs (maintenance, property taxes, etc.) to $\eta = 0.007$.

Financial Markets  To match values in the U.S. during 2003 – 2005, I set the inflation rate to 1.9%, the real risk-free rate to $-1\%$, and the mortgage origination cost to 0.4%. I set the mortgage servicing cost $\phi$ such that the nominal mortgage rate is 5.5%. Lastly, I impose an exogenous upper bound on leverage for new mortgages of $\vartheta = 1.25$ (125%), although this constraint is non-binding in the steady state.\textsuperscript{15}

Lastly, I set the persistence of bad credit flags to $\gamma_f = 0.95$, and I determine the REO discount factor $\chi$ in the joint calibration.

3.2 Joint Calibration and Model Fit

I determine the remaining parameters to fit the model to certain aspects of U.S. macroeconomic data in the 2003 – 2005 period. First, the calibration targets select household portfolio moments calculated from the 2004 Survey of Consumer Finances (SCF). Specifically, the calibration aims to match average housing wealth and the proportion of borrowers with leverage exceeding 90%, because these households have the highest likelihood of ending up underwater on their mortgages and in danger of foreclosure during the Great Recession.\textsuperscript{16} I also target certain key moments of...

\textsuperscript{15}At the peak of the housing boom in 2005, the popularity of cash-out refinancing led to many instances of new mortgages with loan-to-value ratios in excess of 100%. See Herkenhoff and Ohanian (2015).

\textsuperscript{16}I include only households that are in the bottom 95% of the earnings and net worth distributions. Net worth is liquid assets + housing – mortgages. Liquid assets is financial wealth – quasi-liquid retirement.
the housing market such as sales volume, average search duration for buyers and mismatched sellers, and maximum price spreads. Lastly, I calibrate the model to match the average foreclosure price discount and the rate of foreclosure starts.

Table 1 shows that the model successfully matches the targets and nearly replicates other untargeted portfolio statistics from the 2004 SCF. Notably, the model generates an appropriate quantity of liquid assets and an empirically accurate LTV distribution.

4 Results

This section begins by describing the approach used to simulate the Great Recession. Next, I go into detail regarding the equilibrium effects of inflation, and I show that the model exhibits approximate superneutrality in the steady state. The main quantitative exercise evaluates how different counterfactual inflationary policies alter the trajectory of key macroeconomic variables during the crisis and recovery. Lastly, I look at how these results vary with the presence of sticky wages and with adjustable rate mortgages instead of fixed rate mortgages.

4.1 Simulating the Great Recession

In this section, I simulate a Great Recession and recovery that takes place in three phases. I compute a perfect foresight transition path that starts from the original steady state and moves through each phase. In other words, the onset of the recession catches households completely by surprise, but households have rational expectations regarding the progression of the recession and the subsequent recovery. Banks experience ex-post losses because of the surprise nature of the recession. I assume that these losses fall disproportionately on the top 1% of households by earnings (those with the highest persistent labor efficiency state), motivated by the highly skewed ownership of financial institution equity in the data.\(^\text{17}\)

\(^\text{17}\)Specifically, I assume that the government levies a flat tax on the liquid assets of the top 1% over the course of the transition path which it uses to finance a bailout of bank losses.
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>Calibration: Independent 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 et al. (2004)</td>
</tr>
<tr>
<td>SD of Persistent Shock</td>
<td>$\sigma_\epsilon$</td>
<td>0.17</td>
<td></td>
<td></td>
<td>Storesletten et al. (2004)</td>
</tr>
<tr>
<td>SD of Transitory Shock</td>
<td>$\sigma_e$</td>
<td>0.49</td>
<td></td>
<td></td>
<td>Storesletten et al. (2004)</td>
</tr>
<tr>
<td>Top 1% Labor Efficiency*</td>
<td>$s_4/s_3$</td>
<td>4</td>
<td></td>
<td></td>
<td>Kuhn and Rios-Rull (2013)</td>
</tr>
<tr>
<td>Prob. of Top 1%*</td>
<td>$\pi_{3,4}$</td>
<td>0.0041</td>
<td></td>
<td></td>
<td>Kuhn and Rios-Rull (2013)</td>
</tr>
<tr>
<td>Persistence of Top 1%*</td>
<td>$\pi_{4,4}$</td>
<td>0.9</td>
<td></td>
<td></td>
<td>Kuhn and Rios-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>Various</td>
<td></td>
</tr>
<tr>
<td>Structure Share</td>
<td>$\alpha_S$</td>
<td>30%</td>
<td></td>
<td></td>
<td>Favilukis et al. (2015)</td>
</tr>
<tr>
<td>Land Share</td>
<td>$\alpha_L$</td>
<td>33%</td>
<td></td>
<td></td>
<td>Lincoln Inst Land Policy</td>
</tr>
<tr>
<td>Holding Costs</td>
<td>$\eta$</td>
<td>0.7%</td>
<td></td>
<td></td>
<td>Moody's</td>
</tr>
<tr>
<td>Depreciation (Annual)</td>
<td>$\delta_h$</td>
<td>1.4%</td>
<td></td>
<td></td>
<td>BEA</td>
</tr>
<tr>
<td>Rent-Price Ratio (Annual)</td>
<td>$r_h$</td>
<td>3.5%</td>
<td></td>
<td></td>
<td>Sommer et al. (2013)</td>
</tr>
<tr>
<td>Risk-Free Rate (Annual)</td>
<td>$r$</td>
<td>$-1.0%$</td>
<td></td>
<td>Federal Reserve Board</td>
<td></td>
</tr>
<tr>
<td>Servicing Cost (Annual)</td>
<td>$\phi$</td>
<td>3.2%</td>
<td></td>
<td></td>
<td>5.5% Nominal Mortgage Rate</td>
</tr>
<tr>
<td>Mortgage Origination Cost</td>
<td>$\zeta$</td>
<td>0.4%</td>
<td></td>
<td></td>
<td>FHFA</td>
</tr>
<tr>
<td>Maximum LTV</td>
<td>$\vartheta$</td>
<td>125%</td>
<td></td>
<td></td>
<td>Fannie Mae</td>
</tr>
<tr>
<td>Prob. of Repossession</td>
<td>$\varphi$</td>
<td>0.5</td>
<td></td>
<td></td>
<td>2008 OCC Mortgage Metrics</td>
</tr>
<tr>
<td>Credit Flag Persistence</td>
<td>$\lambda_f$</td>
<td>0.9500</td>
<td></td>
<td></td>
<td>Fannie Mae</td>
</tr>
<tr>
<td><strong>Calibration: Jointly Determined Parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeownership Rate</td>
<td>$\pi$</td>
<td>3.2840</td>
<td>69.0%</td>
<td>68.9%</td>
<td>Census</td>
</tr>
<tr>
<td>Starter House Value</td>
<td>$h_1$</td>
<td>2.7100</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>0.8159</td>
<td>3.99</td>
<td>3.99</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Borrowers with $LTV \geq 90%$</td>
<td>$\beta$</td>
<td>0.9737</td>
<td>11.40%</td>
<td>11.47%</td>
<td>2004 SCF</td>
</tr>
<tr>
<td>Months of Supply**</td>
<td>$\xi$</td>
<td>0.0013</td>
<td>4.90</td>
<td>4.90</td>
<td>Nat’l Assoc of Realtors</td>
</tr>
<tr>
<td>Avg. Buyer Search (Weeks)</td>
<td>$\gamma_b$</td>
<td>0.0940</td>
<td>10.00</td>
<td>10.03</td>
<td>Nat’l Assoc of Realtors</td>
</tr>
<tr>
<td>Maximum Bid Premium</td>
<td>$\kappa_b$</td>
<td>0.0209</td>
<td>2.5%</td>
<td>2.5%</td>
<td>Gruber and Martin (2003)</td>
</tr>
<tr>
<td>Maximum List Discount</td>
<td>$\kappa_s$</td>
<td>0.1256</td>
<td>15%</td>
<td>15%</td>
<td>RealtyTrac</td>
</tr>
<tr>
<td>Foreclosure Discount</td>
<td>$\chi$</td>
<td>0.1370</td>
<td>20%</td>
<td>20%</td>
<td>Pennington-Cross (2006)</td>
</tr>
<tr>
<td>Foreclosure Starts (Annual)</td>
<td>$\gamma_s$</td>
<td>0.6550</td>
<td>1.20%</td>
<td>1.25%</td>
<td>Nat’l Delinquency Survey</td>
</tr>
</tbody>
</table>

**Model Fit**

| Borrowers with $LTV \geq 80\%$          | 21.90% | 27.45% | 2004 SCF |
| Borrowers with $LTV \geq 95\%$          | 7.10%  | 6.63%  | 2004 SCF |
| Median Owner Liq. Assets                | 0.19   | 0.26   | 2004 SCF |
| Mean Owner Liq. Assets                  | 0.78   | 0.90   | 2004 SCF |
| Mean Net Worth                          | 2.34   | 2.21   | 2004 SCF |

*The ratio $s_4/s_3 = 4$ corresponds roughly to the earnings ratio $earn_{99-100}/earn_{95-99}$ in 2004 reported by Kuhn and Rios-Rull (2013). The transition probabilities resemble the values in table 20 but have been adjusted to ensure that exactly 1% of households at any point in time have $s = s_4$. The transition probabilities $\pi_{i,4} = 0$ and $\pi_{4,i} = 0$ for all $i < 3$.

**Months of supply is inventories divided by the sales rate and proxies for time on the market.
4.1.1 Phase 1: The Crash (3 Years)

In phase 1, the risk free rate $r$ jumps from $-1\%$ to $3\%$ for eight quarters corresponding to the hike in rates in 2006 and 2007. Given that the mortgage rate $r_m$ on new loans depends on \textit{long term} nominal rates, the adjustment in the mortgage market takes place through changes in mortgage prices $q_m^0((q_m, m'), b', h, s)$ rather than in the continuation $q_m$. Furthermore, rates for existing borrowers do not change at all because of the long term, \textit{fixed rate} nature of mortgage contracts in the model.

A decrease of $5\%$ in TFP—and therefore equilibrium wages—that lasts for 12 quarters accompanies the increase in the risk-free rate.$^{18}$ I also simulate a credit crunch that increases the mortgage origination cost from $0.4\%$ to $1.2\%$ and tightens the exogenous maximum loan-to-value on new mortgages to $90\%$. To engineer a $6.2\%$ drop in aggregate labor consistent with the deterioration in employment from 2007 to 2010, I replace the labor efficiency transition matrix $\pi_s$ with new transition probabilities $\tilde{\pi}_s^1(s'|s)$. I adjust the transitions in a way that has little impact on upper-income households but increases downside risk for the middle class.$^{20}$

Lastly, to prevent excessive foreclosures and an exaggerated drop in the home-ownership rate, I assume that the probability of repossession $\phi$ decreases from $50\%$ to $20\%$ and that banks seek deficiency judgments with a probability of $50\%$. To provide more detail, I set $\tilde{\pi}_s^1(s_2|s) = (1 - 0.028)\pi_s(s_2|s)$ for all $s$, $\tilde{\pi}_s^1(s_3|s) = \pi_s(s_3|s)$ for all $s$, and $j = 3, 4$, and I increase $\tilde{\pi}_s^1(s_1|s)$ sufficiently to ensure $\sum_{s'} \tilde{\pi}_s^1(s'|s) = 1$ for all $s$.


4.1.2 Phase 2: The Slow Recovery (4 Years)

The risk-free rate, TFP, and probability of repossession all return to their steady state levels in phase 2. In addition, I generate a gradual labor market recovery by replacing the labor transition probabilities with yet a new matrix $\tilde{\pi}_s^2$.

$^{18}$See Fernald (2014) for evidence on TFP during the Great Recession.

$^{19}$Source: Monthly Interest Rate Survey.

$^{20}$To provide more detail, I set $\tilde{\pi}_s^1(s_2|s) = (1 - 0.028)\pi_s(s_2|s)$ for all $s$, $\tilde{\pi}_s^1(s_3|s) = \pi_s(s_3|s)$ for all $s$, and $j = 3, 4$, and I increase $\tilde{\pi}_s^1(s_1|s)$ sufficiently to ensure $\sum_{s'} \tilde{\pi}_s^1(s'|s) = 1$ for all $s$.

4.1.3 Phase 3: Return to Normalcy

In phase 3, labor market transitions return to normal and the credit crunch ends, which causes the origination cost to drop back down to 0.4% and the maximum LTV on new loans to rise to 125%. Admittedly, the liberalized credit conditions at the height of the housing boom may never return. However, extremely low down payments appear to be making a comeback, and it may be only a matter of time before cash-out refinancing resumes its previous popularity. Either way, the results change little if I assume a perpetual 90% LTV limit, as it has a negligible effect on long run house prices. Lastly, the probability that a bank seeks a deficiency judgment in the event of foreclosure drops back to 0%.

4.1.4 Baseline Results

The model economy responds to the aforementioned shocks in a way that closely mimics the performance of the U.S. economy from 2006 onward. Of particular importance, the model generates a 25% drop in real house prices similar to that in the data, although the perfect foresight assumption exaggerates the speed of the decline. Furthermore, sales fall by over 50%, compared to the actual 40% drop, and average time on the market skyrockets from 22 weeks to over 52 weeks, just as in the empirical results shown in figure 1.

The annualized foreclosure rate jumps to 5.6%, which mirrors the 5.2% peak foreclosure rate in 2009 reported by the Mortgage Bankers Association. In response to the initial spike in foreclosures, the inventory of repossessed houses rapidly escalates and only gradually falls as banks attempt to sell their stock of REO properties in the decentralized market. Panel 5 shows that the REO share of housing sales increases from 10% to 25% and remains elevated for multiple years. In the data, the REO sales 22Fannie Mae and Freddie Mac recently announced they will accept minimum down payments of 3%. See http://blogs.wsj.com/totalreturn/2014/10/22/low-down-payments-are-coming-back/ and http://themortgagereports.com/16976/97-mortgage-low-downpayment-3-mortgage-rates.
Figure 2: The baseline simulated Great Recession. The series for real house prices, sales, and consumption are normalized by their initial, pre-recession values.

Inspection of the series for leverage, time on the market, and consumption reveals that the economy suffers from severe debt overhang during the Great Recession. First, the drop in house prices causes a rapid rise in median leverage from 69% to over 90%. Employing a model with long-term mortgages proves key to generating the increase in leverage, because in models with short-term debt, a tightening of binding borrowing constraints forces households to immediately deleverage. By contrast, figure 2 shows that, while some homeowners immediately deleverage by going into foreclosure, most borrowers continue to make mortgage payments. For those homeowners who try to sell, the spike in average time on the market shows the extent to which liquidity dries up in the housing market.
Consistent with previous work by Hedlund (2015a) that examines the significant spillover effects of housing illiquidity, increased selling delays contribute both to an elevated foreclosure rate and to a sharper cutback in consumption relative to a benchmark with perfectly Walrasian housing markets. In a Walrasian economy, homeowners can always instantly escape the burden of their mortgage debt by selling their house at the market clearing price, provided that said price (plus any accessible savings) exceeds the outstanding debt balance. The landscape changes once one recognizes that having housing equity on paper differs materially from the ability to actually extract the equity in a timely manner by selling or refinancing. For now, I focus on the difficulty of selling in an illiquid housing market. However, the difficulty of refinancing also increased dramatically during the Great Recession because of higher perceived default risk owing to concerns about the future path of housing equity and liquidity. The credit crunch also reduced mortgage lending for reasons not covered in this paper, such as bank balance sheet concerns.

In the model, the drop in the shadow price $p_h$ reduces tightness $\theta_s(x_s, h; p_h)$ and, therefore, equilibrium selling probabilities $p_s(\theta_s(x_s, h; p_h))$. Unconstrained households can militate against this decline by cutting their list price $x_s$ and entering a submarket with a higher selling probability. However, homeowners with debt face the constraint $y + x_s \geq \frac{m}{1+\pi}$. As a result, debt generates stickiness in list prices, which creates debt overhang when an increase in economy-wide leverage fuels longer average time on the market. With their houses experiencing longer on the market, these homeowners face the lose-lose proposition of either defaulting or significantly reducing consumption. Panel 7 of figure 2 shows that non-housing consumption drops by an average of 14% and 9% during the first and second years of the Great Recession, respectively. Recall that wages only drop by 5% during phase 1 of the simulated recession, and the deterioration in labor market transitions only gradually reduces earnings. Instead, the drop in consumption comes largely from homeowners committing greater resources to deleveraging and increasing precautionary saving.
4.2 The Economic Consequences of Inflation

Because banks issue nominal mortgages, inflation emerges as a potential policy tool to mitigate housing-induced recessions by eroding the value of outstanding debt. I turn now to the description of the different channels of inflation in the model.

4.2.1 Inflation and Debt Erosion

Recall that homeowners face the following budget constraint when making their consumption, borrowing, and savings decisions in subperiod 3:

\[ c + \eta h + q_0 b' + \frac{m}{1+\pi} - \tilde{q}_m m' \leq y. \]

Inflation has a direct effect on the household budget by eroding the value of outstanding debt. Higher inflation \( \pi \) reduces \( \frac{m}{1+\pi} \), which gives the household more budgetary flexibility. This debt erosion channel of inflation fueled William Jennings Bryan and the “free silver” movement in the 19th century in the United States, which sought higher inflation to reduce the debt burden on farmers. Here, however, the benefits accrue to indebted homeowners.

4.2.2 Inflation and Credit

As described in section 2.4.1, steady state mortgage prices absent default risk are

\[
q_m^0((\tilde{q}_m, m'), b', h, s) = \frac{1 - \delta_h}{(1 + \zeta)(1 + \phi)(1 + r)(1 + \pi)}
\]

When I allow for the risk-free rate and inflation to vary deterministically during the Great Recession, the price of contract \((\tilde{q}_m, m')\) satisfies\(^{23}\)

\[
q_m^0((\tilde{q}_m, m'), b', h, s) = \left(\frac{1}{1 + \zeta}\right) \left(\frac{1 - \delta_h}{1 + \phi}\right) [1 - (1 + \phi)\tilde{q}_m] \sum_{t=0}^{\infty} \frac{(1 - \delta_h)^t}{\prod_{\tau=0}^{t}(1 + r_{\tau+1})(1 + \pi_{\tau+1})}
\]

\(^{23}\)Recall that mortgages have flexible duration in the model. For this calculation, I assume that borrowers make interest-only payments in perpetuity.
Both of these equations show that higher inflation contracts the supply of credit by reducing equilibrium mortgage prices. That said, economists typically focus on the real interest rate—which in many models without nominal rigidities does not respond to changes in inflation—as the sole determinant of the cost of credit. I shall return to the issue of nominal rigidities momentarily, but first, inspection of a model with short-term debt provides useful intuition regarding the debt erosion and credit contraction effects of inflation.

Continuing the abstraction away from default risk, suppose that banks only issue one-period mortgage contracts. In such a setting, mortgage prices satisfy

$$q_{m,\text{short-term}}^0 = \frac{1 - \delta_h}{(1 + \phi)(1 + r)(1 + \pi)}$$

Therefore, homeowners that choose $m'$ receive $q_{m,\text{short-term}}^0 m'$ at origination and must repay $\frac{m'}{1 + \pi}$ next period. The gross real interest rate equals the ratio of the repayment amount to the amount received at origination, which comes out to

$$1 + r_{m,\text{short-term}} = \frac{\frac{m'}{1 + \pi}}{q_{m,\text{short-term}}^0 m'} = \frac{1}{\frac{1 + \pi}{1 - \delta_h}} = \left(\frac{1 + \phi}{1 - \delta_h}\right)(1 + r)$$

In other words, in the model with one-period debt, the cost of credit depends quite intuitively on the real interest rate and not on inflation. When higher anticipated inflation reduces mortgage prices, borrowers must choose a higher $m'$ to receive the same amount of resources $q_{m,\text{short-term}}^0 m'$ at origination. However, in the subsequent repayment period, the elevated inflation erodes the higher $m'$. These effects exactly cancel in the model with one-period debt. In short, the statement that the cost of credit depends only on real interest rates is tantamount to saying that the credit contraction and debt erosion channels of inflation exactly offset each other.

This result changes upon either the introduction of long-term, fixed rate mortgage contracts or the emergence of unanticipated higher inflation. First, when banks issue long-term mortgage contracts, they price long-run inflation into rates. Therefore, the
Figure 3: The response of nominal 30-year mortgage rates and the effective real rate to an anticipated spike of inflation from 1.9% to 7.9% that lasts for one year.

The nominal mortgage rate responds less than one-for-one to anticipated temporary changes in inflation. Figure 3 shows how 30-year mortgage rates in a stylized model must respond to a one-period anticipated spike in inflation to maintain zero profits.

The nominal rate increases noticeably less than inflation but remains elevated for the entire 30-year period. As a result, the effective real rate at which borrowers can roll-over balances drops dramatically upon impact of the inflation spike. However, the effective real rate later returns to and surpasses the level that prevails absent the jump in inflation. In other words, the debt erosion and credit contraction effects of temporary, anticipated inflation do not cancel period-by-period with long-term loans.

Long-term, fixed rate mortgages make a bigger difference with the arrival of unanticipated inflation, however. As explained earlier, many classical models without nominal rigidities exhibit some form of monetary superneutrality where real interest rates do not depend on the inflation rate. Indeed, permanent, anticipated changes in inflation cause approximate superneutrality in this model, which I discuss later. However, if inflation increases unexpectedly, the vast majority of homeowners experience no change in their interest rates. Borrowers with contract \((\bar{q}_m, m)\) can always roll over existing balances at cost \(1/\bar{q}_m\) as long as they choose \(M' \leq M\), i.e. \(m' \leq \frac{m}{1+\pi}\). In other words, fixed rate mortgages are a manifestation of nominal rigidities. Therefore, unanticipated higher inflation causes a one-for-one drop in the effective real rate for existing borrowers without any corresponding future increase.
4.2.3 Inflation, Lender Losses, and Redistribution

The temporary drop in effective real mortgage rates created by higher inflation has the potential to stimulate the housing market during episodes like the Great Recession characterized by a deep recession, housing slump, and debt overhang. However, just as existing borrowers benefit from an unanticipated devaluation of their future obligations, lenders potentially lose from the devaluation in repayments. In this sense, inflation has a distinctly redistributive impact, which Doepke and Schneider (2006) and Doepke et al. (2015) discuss extensively. In this model, all ex-post losses from either higher-than-expected foreclosures or inflation fall on the top 1% of earners. However, because any household may draw the highest labor efficiency shock and enter the top 1%, all households have potential exposure to these losses.

Even so, the magnitude (and, technically, even the sign) of these losses remains uncertain. On the one hand, higher unanticipated inflation devalues the stream of repayments to the lender, which causes unexpected losses. On the other hand, higher inflation relaxes the budget constraint of borrowers and increases housing liquidity—a subject I turn to next—which mitigates foreclosure-induced losses.

4.2.4 Inflation, Selling Behavior, and Housing Liquidity

The baseline results in section 4.1.4 clearly highlight the deleterious effects of excessive mortgage debt on housing liquidity. To review, higher mortgage debt tightens the list price constraint $y + x_s \geq \frac{m}{1+\pi}$, which forces homeowners to overprice their houses and wait longer to sell. With an abundance of highly indebted homeowners, debt overhang puts significant upward pressure on average time on the market. Furthermore, increased selling delays push financially distressed borrowers into defaulting on their debt and entering foreclosure. Inflation counteracts the effect of debt on selling behavior by directly eroding the value of homeowners’ outstanding balances.

Figure 4 shows how inflation impacts list prices and time on the market. Panel 1 shows the choice of list price as a function of leverage for a financially vulnerable
homeowner (one with low assets and low income). At relatively modest values of leverage, the homeowner sets a price that leads to a typical expected selling time. However, as debt approaches 80%-85% loan-to-value (LTV), the homeowner loses the ability to extract equity through refinancing to smooth consumption. Banks view these households as high default risks and curtail their access to affordable credit. Absent the ability to borrow, these households post low “fire sale” list prices to sell their houses quickly, which their modest amount of equity allows them to do. As leverage increases still further to greater than 90% loan-to-value, homeowners can neither borrow nor post low list prices because the selling price constraint starts to bind. As a result, indebted, financially distressed homeowners face long selling delays.

However, panel 1 shows that higher inflation $\pi$ relaxes the list price constraint and allows sellers to post lower prices. Panel 2 shows time on the market for sellers under low and high inflation, and panel 3 plots the difference in TOM. Clearly, inflation reduces selling time more dramatically for the most indebted sellers. Panel 4 shows
the distribution of time on the market in the original steady state. Average time on the market comes out to 22 weeks, but the heterogeneity in homeowner income, debt, and asset positions translates into considerable variation in selling time. Once higher inflation enters the picture, the erosion of debt noticeably reduces the number of homeowners who sit on the market for more than 30 weeks, as panel 5 demonstrates.

Thus far, the description of how inflation influences selling behavior has focused on the static effect upon impact. However, the ability of inflation to reduce selling time emerges more potently over time as inflation gradually eats away at the value of outstanding debt. Panel 6 shows the monthly selling probability for a sample homeowner under both baseline 1.9% inflation and higher 7.9% inflation. Initially, the sales probability barely differs between the two environments. However, with the high inflation, the homeowner gradually reduces the real list price and experiences a rapid increase in the probability of selling.

Lastly, Hedlund (2015a) points out the important connection between housing liquidity and the supply of credit. Lower housing liquidity increases selling delays and fuels higher foreclosures. In anticipation of higher default risk, credit supply shrinks because of lower mortgage prices. The converse occurs with greater housing liquidity. Therefore, because inflation reduces selling delays, it can actually improve access to credit by reducing the default premia priced into new mortgages.

4.2.5 Long-Run Effects of Higher Inflation

Table 2 shows the overall long-run effects of higher inflation. Column 3 shows the effect of increasing inflation from 1.9% to 4.9% permanently, while column 4 shows the effect of increasing inflation to 7.9%. Note that the model exhibits approximate monetary superneutrality. Neither the homeownership rate, housing wealth, liquid assets, nor equilibrium real house prices differ appreciably across the three regimes. However, the percentage of high leverage borrowers decreases with the inflation rate, as does the rate of foreclosure starts.
Table 2: The Effects of Higher Long-Run Inflation

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Baseline</th>
<th>$\pi = 4.9%$</th>
<th>$\pi = 7.9%$</th>
<th>$\pi = 4.9%^*$</th>
<th>$\pi = 7.9%^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real House Prices</td>
<td>1.000</td>
<td>0.999</td>
<td>0.997</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Homeownership Rate</td>
<td>68.9%</td>
<td>68.9%</td>
<td>68.8%</td>
<td>70.9%</td>
<td>74.2%</td>
</tr>
<tr>
<td>Housing Wealth</td>
<td>3.99</td>
<td>3.98</td>
<td>3.96</td>
<td>4.25</td>
<td>4.77</td>
</tr>
<tr>
<td>Homeowner Liquid Assets</td>
<td>0.26</td>
<td>0.24</td>
<td>0.26</td>
<td>0.05</td>
<td>0.89</td>
</tr>
<tr>
<td>Median Borrower LTV</td>
<td>69.2%</td>
<td>67.8%</td>
<td>67.6%</td>
<td>68.8%</td>
<td>86.5%</td>
</tr>
<tr>
<td>Borrowers with LTV $\geq 80%$</td>
<td>27.5%</td>
<td>23.5%</td>
<td>24.9%</td>
<td>20.4%</td>
<td>99.9%</td>
</tr>
<tr>
<td>Borrowers with LTV $\geq 90%$</td>
<td>11.5%</td>
<td>6.8%</td>
<td>6.9%</td>
<td>2.1%</td>
<td>33.2%</td>
</tr>
<tr>
<td>Borrowers with LTV $\geq 95%$</td>
<td>6.6%</td>
<td>4.2%</td>
<td>3.3%</td>
<td>0.8%</td>
<td>23.6%</td>
</tr>
<tr>
<td>Annual Foreclosure Starts</td>
<td>1.25%</td>
<td>0.87%</td>
<td>0.79%</td>
<td>0.47%</td>
<td>0.11%</td>
</tr>
</tbody>
</table>

$^*$Partial equilibrium with mortgage prices $q_m^0$ from the baseline steady state.

To understand the reason behind this neutrality result, first recall that ex-post losses do not exist in any of the long-run steady state equilibria. As a result, the debt erosion, credit contraction, and housing liquidity channels remain as the only operative consequences of inflation. Furthermore, the analysis in section 4.2.2 shows that the debt erosion and credit contraction channels exactly offset each other in their long run response to permanently higher inflation. In other words, the real interest rate, and not inflation, determines the long-run cost of credit in this economy. Only the housing liquidity channel remains. As predicted, higher inflation reduces foreclosures by allowing homeowners to sell their houses more quickly. The more rapid selling time also explains the lower prevalence of high leverage borrowers because it allows these homeowners to more quickly escape from their debt.

The last two columns show the long-run partial equilibrium impact of higher inflation if banks do not re-price mortgages. As inflation increases, housing wealth and the homeownership rate both climb, but financial portfolios exhibit non-monotonic behavior. In response to moderately higher inflation, homeowners reduce their asset holdings and fewer homeowners take out high LTV loans. However, in the highest inflation regime, homeowners take advantage of the under-priced mortgages and greatly increase both their borrowing and their buffer-stock saving.
Figure 5: The effect of 3 different inflationary policies: (1) 4.9% inflation for 4 years, (2) 7.9% inflation for 2½ years, (3) 7.9% inflation for 4 years.

4.3 Inflation and the Great Recession

The central research question in this paper asks whether temporary inflationary policies can effectively combat deep recessions characterized by a severe housing bust and significant debt overhang. Therefore, I turn now to the main quantitative exercise, which simulates how the economy would have responded during the Great Recession to a range of changes to the level and duration of inflation. For now, I take as given that the U.S. government has the tools to engineer such inflation. However, section 5 addresses concerns about implementation.

4.3.1 Temporary Higher Inflation Targets

I first consider a set of policies that most closely mirrors the proposals advocated by the diverse group of economists that includes Ken Rogoff, Robert Engle, Paul Krugman, and others. Specifically, I analyze the effects of a temporary increase in the inflation target followed by a reversion to the original steady state target. I consider
three variants of this policy. The first two implementations lead to approximately the same aggregate change in the nominal price level but over different time horizons: 4.9% inflation (a 3 percentage point (pp) increase in the target) for four years vs. 7.9% inflation (a 6pp increase) for two and a half years. Next, I prolong the higher 7.9% inflation target to last for four years to allow for greater debt erosion.

Figure 5 plots the response of nominal house prices and several real variables under the different policies. Unsurprisingly, nominal house prices recover from their recession-induced trough much more rapidly in the presence of greater inflation. In fact, under the highest inflation target, nominal house prices recover in less than two years, which effectively wipes out much of the negative equity created by the recession. Moreover, a positive response of real house prices magnifies this nominal increase. Table 3 reports that all three variants of the policy increase real house prices upon impact by approximately three and a half to four percent. However, consistent with the discussion in section 4.2.4, the full potency of inflation emerges over time. Under the 4.9% inflation target, real house prices increase from 79.4% of their steady state value to 90.3% after only two years. By comparison, real house prices with the 1.9% inflation target only reach 86.6% of their steady state level after two years. This gap of 3.9% increases to 4.2% for the 7.9% inflation target implemented over two and a half years. Further strengthening the response, the 7.9% inflation target implemented for four years increases real house prices by a sizable 6.2% after two years. In turn, this faster recovery in house prices fuels an almost 20% resurgence in residential investment.

Of utmost importance, inflation drastically reduces the bite of debt overhang by shaving up to 9 weeks off of average selling time. The reduced frequency of underwater borrowers combined with greater liquidity in the housing market from faster sales causes the peak foreclosure rate to plummet from 5.7% to just over 2%—a more than 60% reduction. As a result, two years into the implementation, the homeownership rate sits at approximately 67.3% under each of the three policies.
compared to only 65.6% in the baseline. Spurred by a higher homeownership rate, a more rapid mechanical deleveraging from inflation, and a faster recovery in real house prices, net worth nearly returns to its steady state level after only two years under the two 7.9% inflation target policies. For comparison, baseline net worth sits at only 86% of its steady state value after two years.

Lastly, the real effects of the temporary raising of inflation targets spill over to higher real non-housing consumption. Although households still face the strong precautionary savings motive that arises from the deterioration in the labor market, higher inflation adds anywhere from 1.8% to 3.6% to consumption after two years. Interestingly, the greatest gap between the baseline and inflationary economies occurs earlier for the two and a half year 7.9% inflation policy compared to the four year 7.9% inflation policy. The 4.9% inflation policy generates a relatively constant estimated 2% increase in consumption during the first four years. Two lessons emerge from this analysis. First, the increase in consumption upon initial announcement of the policy is not monotonic in the declared target. Second, longer expected durations of the higher target postpone the peak increase in consumption.

4.3.2 Isolating the Debt Erosion and Liquidity Channels

The results in table 3 and figure 5 indicate that temporarily raising the inflation target could have demonstrably reduced the severity of the Great Recession and accelerated the recovery. In particular, such a policy could have single-handedly cut the foreclosure rate by more than half and prevented millions of homeowners from losing their houses. However, the results thus far obscure the true strength of the debt erosion and liquidity channels of inflation by entangling them with the headwinds created by reduced mortgage prices. To isolate the debt erosion and liquidity channels, I conduct a counterfactual where the government raises the inflation target and banks naively neglect to directly price the temporary higher inflation into new mortgages.\footnote{Inflation still \textit{indirectly} alters mortgage prices through changes to default/repayment behavior.}
Table 3: The Effects of Temporary Higher Inflation Targets

<table>
<thead>
<tr>
<th>Policy</th>
<th>$t = 0$</th>
<th>$t = 2$</th>
<th>$t = 4$</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
<th>$\Delta_{t=4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real House Prices</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>76.5</td>
<td>86.6</td>
<td>92.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>79.1</td>
<td>90.0</td>
<td>94.8</td>
<td>+3.4%</td>
<td>+3.9%</td>
<td>+2.0%</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>79.4</td>
<td>90.3</td>
<td>95.1</td>
<td>+3.8%</td>
<td>+4.2%</td>
<td>+2.3%</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>79.4</td>
<td>92.0</td>
<td>96.5</td>
<td>+3.8%</td>
<td>+6.2%</td>
<td>+3.8%</td>
</tr>
<tr>
<td><strong>Residential Investment</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>47.8</td>
<td>69.7</td>
<td>80.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>52.9</td>
<td>78.3</td>
<td>85.1</td>
<td>+10.6%</td>
<td>+12.4%</td>
<td>+6.2%</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>53.5</td>
<td>78.9</td>
<td>85.8</td>
<td>+11.8%</td>
<td>+13.2%</td>
<td>+7.1%</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>53.5</td>
<td>83.5</td>
<td>89.7</td>
<td>+12.0%</td>
<td>+19.9%</td>
<td>+11.9%</td>
</tr>
<tr>
<td><strong>Average TOM (Weeks)</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Baseline</td>
<td>52.6</td>
<td>32.0</td>
<td>31.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>46.7</td>
<td>31.5</td>
<td>30.4</td>
<td>-5.9</td>
<td>-0.4</td>
<td>-0.9</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>43.4</td>
<td>30.4</td>
<td>30.7</td>
<td>-9.2</td>
<td>-1.5</td>
<td>-0.6</td>
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<tr>
<td>7.9% Target II (4 Years)</td>
<td>43.8</td>
<td>29.2</td>
<td>28.5</td>
<td>-8.7</td>
<td>-2.8</td>
<td>-2.9</td>
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<tr>
<td><strong>Foreclosure Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Baseline</td>
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<td>0.1%</td>
<td>-</td>
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<tr>
<td>4.9% Target (4 Years)</td>
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<td>0.2%</td>
<td>0.0%</td>
<td>-3.6pp</td>
<td>-0.5pp</td>
<td>-0.1pp</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>2.3%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>-3.4pp</td>
<td>-0.6pp</td>
<td>-0.1pp</td>
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<tr>
<td>7.9% Target II (4 Years)</td>
<td>2.3%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>-3.4pp</td>
<td>-0.6pp</td>
<td>-0.1pp</td>
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<tr>
<td><strong>Homeownership Rate</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Baseline</td>
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<td>64.7%</td>
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<tr>
<td>4.9% Target (4 Years)</td>
<td>68.5%</td>
<td>67.2%</td>
<td>65.7%</td>
<td>+0.5pp</td>
<td>+1.6pp</td>
<td>+1.0pp</td>
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<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>68.5%</td>
<td>67.3%</td>
<td>65.6%</td>
<td>+0.5pp</td>
<td>+1.6pp</td>
<td>+0.8pp</td>
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<td>7.9% Target II (4 Years)</td>
<td>68.5%</td>
<td>67.3%</td>
<td>65.7%</td>
<td>+0.5pp</td>
<td>+1.7pp</td>
<td>+1.0pp</td>
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<td><strong>Consumption (Non-Housing)</strong></td>
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<tr>
<td>Baseline</td>
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<td>93.0</td>
<td>96.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>84.2</td>
<td>94.6</td>
<td>98.7</td>
<td>+1.9%</td>
<td>+1.8%</td>
<td>+1.9%</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>84.1</td>
<td>96.3</td>
<td>98.9</td>
<td>+1.9%</td>
<td>+3.6%</td>
<td>+2.1%</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>83.6</td>
<td>95.4</td>
<td>100.0</td>
<td>+1.3%</td>
<td>+2.6%</td>
<td>+3.2%</td>
</tr>
<tr>
<td><strong>Net Worth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>66.1</td>
<td>86.4</td>
<td>93.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>70.4</td>
<td>93.7</td>
<td>99.6</td>
<td>6.4%</td>
<td>8.3%</td>
<td>7.1%</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
<td>71.3</td>
<td>97.7</td>
<td>100.2</td>
<td>7.8%</td>
<td>13.0%</td>
<td>7.7%</td>
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<tr>
<td>7.9% Target II (4 Years)</td>
<td>71.3</td>
<td>98.2</td>
<td>105.6</td>
<td>7.9%</td>
<td>13.6%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

*Steady state = 100. I use values from the first quarter for each $t$. $\Delta_t$ indicates the difference at time $t$ (years) between the baseline Great Recession and the simulation under each policy.
Figure 6: Isolating the debt erosion and liquidity channels with $\pi = 7.9\%$ for 4 years.

Figure 6 shows the resulting dynamics for the 7.9% inflation target that lasts for four years. As I have already pointed out, this policy increases real house prices by 3.8% upon impact and by 6.2% relative to the baseline two years later. However, when I strip out the effect of reduced mortgage prices, this policy almost completely eliminates the drop in real house prices. Upon impact, house prices fall by only 4% compared to the nearly 25% decline that occurs in the baseline Great Recession simulation. Furthermore, consumption and net worth barely fall and completely recover to their pre-recession levels two years into the policy implementation.

This experiment reveals the extent to which inflation relaxes household budget constraints and improves the liquidity of the housing market. The policy almost completely blunts the initial spike in average time on the market upon impact, and the foreclosure rate falls from 5.7% to below 1%. Understandably, panel 7 shows that this mispricing of mortgage contracts induces homeowners to dramatically increase their borrowing, which helps fuel the resurgence in consumption.
Table 4: The Effects of Nominal Price Level Targeting

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<th>Policy</th>
<th>$\Delta_{t=0}$</th>
<th>$\Delta_{t=2}$</th>
<th>$\Delta_{t=4}$</th>
<th>$\Delta_{t=0}$</th>
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</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>+3.4%</td>
<td>+3.9%</td>
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<td>+10.6%</td>
<td>+12.4%</td>
<td>+6.2%</td>
</tr>
<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
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<td>+4.2%</td>
<td>+2.3%</td>
<td>+11.8%</td>
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<td>+0.7%</td>
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<td>-4.5%</td>
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</tr>
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<td>-0.4</td>
<td>-0.9</td>
<td>-3.6</td>
<td>-0.5</td>
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<td>-0.1</td>
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<tr>
<td>4.9% Target (4 Years)</td>
<td>+0.5</td>
<td>+1.6</td>
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<td>+1.9%</td>
<td>+1.8%</td>
<td>+1.9%</td>
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<td>+0.8</td>
<td>+1.9%</td>
<td>+3.6%</td>
<td>+2.1%</td>
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<tr>
<td>Price Level Targeting: 4.9%</td>
<td>+0.5</td>
<td>+1.4</td>
<td>+1.0</td>
<td>+1.1%</td>
<td>+1.2%</td>
<td>+1.0%</td>
</tr>
<tr>
<td>Price Level Targeting: 7.9%</td>
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<td>+1.3</td>
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<td>+2.7%</td>
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</tr>
<tr>
<td><em><em>Foreclosure Rate (pp</em>)</em>*</td>
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<td>4.9% Target (4 Years)</td>
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<tr>
<td>7.9% Target I (2 $\frac{1}{2}$ Years)</td>
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<tr>
<td>Price Level Targeting: 4.9%</td>
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<tr>
<td>Price Level Targeting: 7.9%</td>
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</table>

*pp = percentage point. $\Delta_t$ represents the policy relative to the baseline $t = 0, 2, 4$ years into the transition. The price level targeting policies are (1) $\pi = 4.9\%$ for 4 years followed by 6 years of $\pi = 0\%$; and (2) $\pi = 7.9\%$ for 2 $\frac{1}{2}$ years followed by 7 $\frac{1}{2}$ years of $\pi = 0\%$.

4.3.3 Nominal Price Level Targeting

Figure 6 clearly demonstrates that the lender response to an anticipated devaluation of future nominal repayments significantly (though only partially) blunts the effectiveness of temporary higher inflation targets. Therefore, an alternative policy of nominal price level targeting has the potential to mitigate the reduction in mortgage prices by replacing the permanent price level increase with a pure redistribution of inflation from the future to the present. I consider two implementations of price level targeting. In the first policy, the government raises the inflation target to 4.9% for four years, and in the second policy, the government raises the inflation target to 7.9% for two and a half years. In each case, the government subsequently commits to zero percent inflation until the price level returns to its baseline trajectory.

Table 4 compares the effects of these two price level targeting policies to their closest counterparts from section 4.3.1. It turns out that, despite mitigating the decline in
mortgage prices, price level targeting actually weakens the response of real variables to temporary higher inflation. At the onset of the recession, an announced policy of temporary current inflation followed by future disinflation increases real house prices relative to the baseline by only 0.1%–0.9% compared to up to 3.8% without future disinflation. Similarly, time on the market falls by a more modest amount under price level targeting, and consumption and net worth experience smaller gains relative to the original higher inflation target policies. That said, the price level still generates a profound drop in the foreclosure rate and props up the homeownership rate by almost one and a half percentage points.

Two lessons emerge from this analysis. First, the future commitment to disinflation partially undermines the initial higher target. As a result, the “forward guidance” dimension of inflationary policies strongly influences their efficacy. Nevertheless, price level targeting remains an effective option if policymakers have concerns about the impact of inflation on fixed-income households or on the future issuance of government debt. Second, to compare the two price level targeting policies, a more rapid initial rise in the price level leads to smaller initial positive effects on real house prices and foreclosures but stronger effects on consumption later in the implementation.

4.3.4 Adjustable Rate vs. Fixed Rate Mortgages

The assumption of fixed-rate mortgage contracts shields most homeowners from changes in credit conditions, which helps mitigate the drag on housing from reduced mortgage prices. By contrast, adjustable rate mortgages act much like one period debt in that they continually adjust the interest rate one-for-one to changes in expected inflation. As a result, the reasoning in section 4.2.2 implies that the debt erosion and credit contraction effects of inflation should exactly offset each other for homeowners with adjustable rate mortgages.

Figure 7 shows the dynamic response of an economy with only adjustable rate mortgages (ARMs) to the same higher inflation target policies from section 4.3.1.
As expected, the inflationary policies have no discernible impact on the path of real house prices, average time on the market, consumption, leverage, or net worth. By reversing the benefits of debt erosion, the reduction in mortgage prices also prevents the liquidity benefits of inflation from taking place.

In fact, only the foreclosure and homeownership rates respond to the inflationary policies, and they deteriorate. Recall that, unlike one period debt, ARMs evaluate and price default risk only at origination. In other words, ARMs prevent banks from demanding a margin call from homeowners that suddenly present a higher default risk. However, in the model, homeowners who wish to increase their debt can only do so by paying off their existing loan and taking out a new, re-priced higher LTV mortgage. By tightening the constraint \( m' \leq \frac{m}{1+\pi} \) (in nominal terms, \( M' \leq M \)) for how much real debt borrowers can roll over with their existing mortgage, higher inflation pressures more households to refinance. However, during a recession with higher mortgage default risk, many homeowners find themselves uncreditworthy. Some of these households enter foreclosure and lose their houses as a result.
Figure 8: Nominal and real wages with nominal wage stickiness and inflation.

4.3.5 Sticky Wages

Lastly, I deviate from flexible wages by imposing nominal wage stickiness. In general, wage stickiness both helps and hurts the case for inflation. However, as a worst case scenario, I ignore any new positive effects of inflation for this experiment and I focus only on the fact that inflation reduces real wages and earnings.

I impose ad hoc wage stickiness by assuming that the nominal take-home wage evolves according to $W_t = (1 - \lambda)(1 + \pi_{steady})W_{t-1} + \lambda W_t^*$, where $W_t^*$ is the flexible nominal wage and $\lambda = 0.16$ is the extremely low degree of wage flexibility. Figure 8 shows how nominal and real wages evolve with and without stickiness.

Even with sticky wages, temporary higher inflation has positive effects, as shown in table 6 and figure 9. Real house prices increase by approximately 2% relative to the baseline after two years, and net worth jumps by as much as 7.3%. Perhaps more importantly, higher inflation cuts the spike in the foreclosure rate from 5.2% to 2.3%–2.9%, which helps prop up homeownership. Mostly, wage stickiness attenuates the magnitude of the benefits of higher inflation and makes the case for implementing higher inflation at a more moderate level over an extended period of time. Unsurprisingly, given that inflation has no real effects with flexible wages and ARMs other than on foreclosures, table 7 in the appendix shows that introducing sticky wages into an economy with ARMs generates a negative response to higher inflation.
5 Discussion

Thus far, I have set aside concerns about how to generate higher inflation. In normal times, this issue does not prove difficult. However, when the economy sits in a liquidity trap at the zero lower bound for short-term nominal rates, concerns about the government’s capacity to generate inflation take on greater salience. Thankfully, a growing body of literature sheds light on which tools the government has at its disposal after its usual ammunition runs dry.

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

Historically, central banks have expressed reluctance to undertake such an endeavor, fearing that public skepticism about the central bank’s ability to attain the higher target would undermine credibility. Bernanke (2000) addresses these concerns by pointing out that central banks have more tools at their disposal than they would like to admit and by stressing the importance of transparent communication. Woodford (2012) reiterates and expands upon both of these points. In recent work, Benigno et al. (2014) shows that future inflation commitments have considerably larger effects on current inflation in economies experiencing dynamic debt deleveraging at the zero lower bound. However, what if the government cannot “credibly promise to be irresponsible”? As one way to demonstrate commitment, the central bank can announce a target path for the price-level, rather than inflation. Eggertsson and Woodford (2003) suggest this course of action, and Sheedy (2014) goes a step further by advocating nominal GDP targeting. Meanwhile, Svensson (2003) explains that a currency
depreciation followed by a peg at the lower rate serves as a “conspicuous commitment to a higher price level in the future.” Bhattari, Eggertsson and Gafarov (2015) also make the important point that, by lowering the duration of government debt, quantitative easing creates the future incentive to pursue higher inflation.

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

6 Conclusions

Debt, deleveraging, and default remain issues of interest as the economy moves beyond the Great Recession. This paper sheds light on the role inflation can play in mitigating some of the deleterious effects of mortgage debt overhang. In particular, temporarily raising the inflation target reduces the magnitude of the recession and speeds up the recovery. By eroding the real value of debt, inflation relaxes budget constraints and creates home equity that increases housing liquidity, reduces foreclosures, and fuels an increase in real house prices, net worth, 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, how do inflationary interventions stack up against fiscal policy and direct mortgage market interventions? Much work also remains on exploring heterogeneity in the response of regional U.S. housing markets to different policy interventions.
References


A Supplementary Figures

Figure 9: Higher inflation targets with very sticky wages.

Figure 10: Higher inflation targets with adjustable rate mortgages and sticky wages.
## B Supplementary Tables

Table 5: The Effects of Nominal Price Level Targeting

<table>
<thead>
<tr>
<th>Policy</th>
<th>$t = 0$</th>
<th>$t = 2$</th>
<th>$t = 4$</th>
<th>$\Delta_{t=0}$</th>
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<td>4.9% (4 Years)</td>
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<td>+0.7%</td>
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</tr>
<tr>
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<td>76.6</td>
<td>86.2</td>
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*Steady state = 100. I use values from the first quarter for each $t$. $\Delta_t$ indicates the difference at time $t$ (years) between the baseline Great Recession and the simulation under each policy. The two different price level targeting regimes are (1) $\pi = 4.9\%$ for 4 years followed by 6 years of $\pi = 0\%$; and (2) $\pi = 7.9\%$ for 2½ years followed by 7½ years of $\pi = 0\%$. 

52
Table 6: Temporary Higher Inflation Targets with Very Sticky Wages

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<td>69.9</td>
<td>79.3</td>
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<td>50.8</td>
<td>73.8</td>
<td>80.7</td>
<td>+4.9%</td>
<td>+5.6%</td>
<td>+1.8%</td>
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<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
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<td>73.1</td>
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<td>50.9</td>
<td>32.2</td>
<td>31.2</td>
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</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>47.9</td>
<td>32.8</td>
<td>31.0</td>
<td>–3.0</td>
<td>+0.6</td>
<td>–0.2</td>
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<tr>
<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
<td>44.8</td>
<td>31.5</td>
<td>31.6</td>
<td>–6.2</td>
<td>–0.7</td>
<td>+0.3</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>47.1</td>
<td>31.3</td>
<td>29.9</td>
<td>–3.9</td>
<td>–0.9</td>
<td>–1.3</td>
</tr>
<tr>
<td><strong>Foreclosure Rate</strong></td>
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<td></td>
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</tr>
<tr>
<td>Baseline</td>
<td>5.2%</td>
<td>0.6%</td>
<td>0.1%</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>2.3%</td>
<td>0.2%</td>
<td>0.0%</td>
<td>–3.0pp</td>
<td>–0.4pp</td>
<td>–0.0pp</td>
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<tr>
<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
<td>2.7%</td>
<td>0.2%</td>
<td>0.0%</td>
<td>–2.5pp</td>
<td>–0.5pp</td>
<td>–0.0pp</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>2.9%</td>
<td>0.2%</td>
<td>0.0%</td>
<td>–2.3pp</td>
<td>–0.5pp</td>
<td>–0.1pp</td>
</tr>
<tr>
<td><strong>Homeownership Rate</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>68.1%</td>
<td>65.9%</td>
<td>64.8%</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>68.5%</td>
<td>67.2%</td>
<td>65.7%</td>
<td>+0.4pp</td>
<td>+1.3pp</td>
<td>+0.9pp</td>
</tr>
<tr>
<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
<td>68.4%</td>
<td>67.2%</td>
<td>65.5%</td>
<td>+0.4pp</td>
<td>+1.3pp</td>
<td>+0.7pp</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>68.4%</td>
<td>67.1%</td>
<td>65.5%</td>
<td>+0.3pp</td>
<td>+1.2pp</td>
<td>+0.7pp</td>
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<td><strong>Consumption (Non-Housing)</strong></td>
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<tr>
<td>Baseline</td>
<td>83.5</td>
<td>93.2</td>
<td>96.7</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>84.2</td>
<td>94.6</td>
<td>98.7</td>
<td>+1.9%</td>
<td>+1.8%</td>
<td>+1.9%</td>
</tr>
<tr>
<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
<td>83.0</td>
<td>94.5</td>
<td>97.5</td>
<td>–0.6%</td>
<td>+1.4%</td>
<td>+0.8%</td>
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<tr>
<td>7.9% Target II (4 Years)</td>
<td>82.0</td>
<td>92.8</td>
<td>97.5</td>
<td>–1.8%</td>
<td>–0.4%</td>
<td>+0.8%</td>
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<tr>
<td><strong>Net Worth</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>67.1</td>
<td>88.5</td>
<td>93.2</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>69.4</td>
<td>92.7</td>
<td>96.1</td>
<td>+3.4%</td>
<td>+4.8%</td>
<td>+3.1%</td>
</tr>
<tr>
<td>7.9% Target I (2 ( \frac{1}{2} ) Years)</td>
<td>69.2</td>
<td>94.9</td>
<td>95.7</td>
<td>+3.2%</td>
<td>+7.3%</td>
<td>+2.6%</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>68.1</td>
<td>94.7</td>
<td>98.6</td>
<td>+1.6%</td>
<td>+7.0%</td>
<td>+5.7%</td>
</tr>
</tbody>
</table>

*Steady state = 100. I use values from the first quarter for each \( t \). \( \Delta t \) indicates the difference at time \( t \) (years) between the baseline Great Recession and the simulation under each policy.
Table 7: Temporary Higher Inflation Targets with ARMs and Very Sticky Wages

<table>
<thead>
<tr>
<th>Policy</th>
<th>$t = 0$</th>
<th>$t = 2$</th>
<th>$t = 4$</th>
<th>$\Delta t=0$</th>
<th>$\Delta t=2$</th>
<th>$\Delta t=4$</th>
</tr>
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<tbody>
<tr>
<td><strong>Real House Prices</strong></td>
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<td></td>
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<tr>
<td>Baseline</td>
<td>74.9</td>
<td>85.7</td>
<td>92.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4.9% Target (4 Years)</td>
<td>73.8</td>
<td>84.7</td>
<td>91.1</td>
<td>-1.4%</td>
<td>-1.2%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>7.9% Target I (2 1/2 Years)</td>
<td>72.9</td>
<td>84.5</td>
<td>91.0</td>
<td>-2.7%</td>
<td>-1.5%</td>
<td>-1.2%</td>
</tr>
<tr>
<td>7.9% Target II (4 Years)</td>
<td>72.0</td>
<td>83.3</td>
<td>90.1</td>
<td>-3.8%</td>
<td>-2.9%</td>
<td>-2.2%</td>
</tr>
</tbody>
</table>

| **Residential Investment**  |         |         |         |              |              |              |
| Baseline                    | 44.8    | 67.5    | 78.0    | -            | -            | -            |
| 4.9% Target (4 Years)       | 42.8    | 65.0    | 75.3    | -4.3%        | -3.6%        | -3.4%        |
| 7.9% Target I (2 1/2 Years) | 41.2    | 64.5    | 75.2    | -7.9%        | -4.4%        | -3.6%        |
| 7.9% Target II (4 Years)    | 39.8    | 61.7    | 72.9    | -11.1%       | -8.5%        | -6.5%        |

| **Average TOM (Weeks)**     |         |         |         |              |              |              |
| Baseline                    | 49.6    | 33.1    | 30.4    | -            | -            | -            |
| 4.9% Target (4 Years)       | 50.2    | 33.2    | 29.8    | +0.7         | +0.1         | -0.6         |
| 7.9% Target I (2 1/2 Years) | 52.1    | 31.9    | 29.0    | +2.5         | -1.2         | -1.3         |
| 7.9% Target II (4 Years)    | 52.7    | 32.4    | 28.7    | +3.1         | -0.7         | -1.7         |

| **Foreclosure Rate**        |         |         |         |              |              |              |
| Baseline                    | 15.0%   | 0.7%    | 0.1%    | -            | -            | -            |
| 4.9% Target (4 Years)       | 19.3%   | 0.7%    | 0.0%    | +4.3pp       | +0.9pp       | +0.0pp       |
| 7.9% Target I (2 1/2 Years) | 26.3%   | 0.9%    | 0.0%    | +11.3pp      | +0.1pp       | +0.0pp       |
| 7.9% Target II (4 Years)    | 28.3%   | 1.3%    | 0.0%    | +13.3pp      | +0.6pp       | +0.0pp       |

| **Homeownership Rate**      |         |         |         |              |              |              |
| Baseline                    | 66.6%   | 62.6%   | 63.3%   | -            | -            | -            |
| 4.9% Target (4 Years)       | 65.9%   | 61.4%   | 62.7%   | -0.7pp       | -1.3pp       | -0.6pp       |
| 7.9% Target I (2 1/2 Years) | 64.7%   | 59.0%   | 61.5%   | -1.9pp       | -3.7pp       | -1.8pp       |
| 7.9% Target II (4 Years)    | 64.4%   | 57.6%   | 60.5%   | -2.2pp       | -5.1pp       | -2.8pp       |

| **Consumption (Non-Housing)**|         |         |         |              |              |              |
| Baseline                    | 81.9    | 91.4    | 95.8    | -            | -            | -            |
| 4.9% Target (4 Years)       | 80.7    | 90.0    | 94.6    | -1.4%        | -1.5%        | -1.2%        |
| 7.9% Target I (2 1/2 Years) | 79.4    | 89.3    | 94.5    | -3.0%        | -2.2%        | -1.3%        |
| 7.9% Target II (4 Years)    | 78.7    | 88.0    | 93.4    | -3.8%        | -3.7%        | -2.5%        |

| **Net Worth**               |         |         |         |              |              |              |
| Baseline                    | 64.0    | 84.6    | 91.2    | -            | -            | -            |
| 4.9% Target (4 Years)       | 62.9    | 83.7    | 89.3    | -1.8%        | -1.1%        | -2.1%        |
| 7.9% Target I (2 1/2 Years) | 61.7    | 82.2    | 88.5    | -3.5%        | -2.8%        | -2.9%        |
| 7.9% Target II (4 Years)    | 60.6    | 82.0    | 87.0    | -5.2%        | -3.1%        | -4.6%        |

*Steady state = 100. I use values from the first quarter for each $t$. $\Delta t$ indicates the difference at time $t$ (years) between the baseline Great Recession and the simulation under each policy.
C Household Value Functions

C.1 Subperiod 3 Value Functions

Homeowners with good credit:

\[
V_{own}(y, (\overline{q_m}, m), h, s, 0) = \max_{m', \nu', c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (1 - \delta_h)(W_{own} + R_{sell})(y', (\overline{q_m}, m'), h, s', 0) \right. \\
\left. + \delta_h (V_{rent} + R_{buy})(y', s', 0) \right]
\]

subject to
\[
c + \eta h + q_b b' + \frac{m}{1 + \pi} - \overline{q_m} m' \leq y \\
q_m^0 ((q_m, m'), b', h, s)m' \mathbb{1}_{m' > \frac{m}{1 + \pi}} \leq \vartheta p_h \\
y' = w e's' + b'
\]

Homeowners with bad credit:

\[
V_{own}(y, 0, h, s, 1) = \max_{\nu', c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (1 - \delta_h)(W_{own} + R_{sell})(y', 0, h, s, f') \right. \\
\left. + \delta_h (V_{rent} + R_{buy})(y', s', f') \right]
\]

subject to
\[
c + \eta h + q_b b' \leq y \\
y' = w e's' + b'
\]

Apartment-dwellers with good credit:

\[
V_{rent}(y, s, 0) = \max_{\nu', c \geq 0, a \leq \pi} u(c, a) + \beta \mathbb{E} [(V_{rent} + R_{buy})(y', s', 0)]
\]

subject to
\[
c + q_b b' + r_h a \leq y \\
y' = w e's' + b'
\]
Apartment-dwellers with bad credit:

\[ V_{\text{rent}}(y, s, 1) = \max_{b', c \geq 0, a \leq \pi} u(c, a) + \beta \mathbb{E} \left[ (V_{\text{rent}} + R_{\text{buy}})(y', s', f') \right] \]

subject to

\[ c + q_b b' + r_h a \leq y \]
\[ y' = we's' + b' \]

C.2 Subperiod 2 Value Functions

The option value of searching to buy a house:

\[ R_{\text{buy}}(y, s, 0) = \max \{ 0, \max_{h \in H, x_b \leq y} p_h(\theta_h(x_b, h))[V_{\text{own}}(y - x_b, 0, h, s, 0) - V_{\text{rent}}(y, s, 0)] \} \]
\[ R_{\text{buy}}(y, s, 1) = \max \{ 0, \max_{h \in H, x_b \leq y} p_h(\theta_h(x_b, h))[V_{\text{own}}(y - x_b, 0, h, s, 1) - V_{\text{rent}}(y, s, 1)] \} \]

C.3 Subperiod 1 Value Functions

The utility associated with the default decision:

\[ W(y, (\bar{q}_m, m), h, s, 0) = \max \left\{ \varphi(V_{\text{rent}} + R_{\text{buy}}) \left( y + \max \left\{ 0, J_{\text{REO}}(h) - \frac{m}{1 + \pi} \right\}, s, 1 \right) \right. \]
\[ + (1 - \varphi) V_{\text{own}}^d(y, (\bar{q}_m, m), h, s, 0), V_{\text{own}}(y, (\bar{q}_m, m), h, s, 0) \} \]

Utility of default conditional on no repossession:

\[ V_{\text{own}}^d(y, (\bar{q}_m, m), h, s, 0) = \max_{b', c \geq 0} u(c, h) + \beta \mathbb{E} \left[ (1 - \delta_h)(W_{\text{own}} + R_{\text{sell}})(y', (\bar{q}_m, m), h, s', 0) \right. \]
\[ \left. + \delta_h(V_{\text{rent}} + R_{\text{buy}})(y', s', 0) \right] \]

subject to

\[ c + \eta h + q_b b' \leq y \]
\[ y' = we's' + b' \]
The option value of attempting to sell a house for a (possibly indebted) homeowner:

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

The option value of attempting to sell a house for a homeowner with bad credit:

\[
R_{sell}(y, 0, h, s, 1) = \max \left\{ 0, \max_{x_s} p_s(\theta_s(x_s, h)) \left[ (V_{rent} + R_{buy}) (y + x_s, s, 1) \right. \right.
\]
\[
- W_{own}(y, 0, h, s, 1) + \left[1 - p_s(\theta_s(x_s, h))\right] (-\xi) \left. \right\}
\]

\section{D Determining the Shadow Housing Price}

Housing supply \( S_h(p_h) \) equals the sum of new and existing sold housing,

\[
S_h(p_h) = Y_h(p_h) + S_{REO}(p_h) + \int h p_s(\theta_s(x_s^*, h; p_h)) d\Phi_{own}.
\]

Housing demand \( D_h(p_h) \) equals housing purchased by matched buyers,

\[
D_h(p_h) = \int h^* p_h(\theta_b(x_b^*, h^*; p_h)) d\Phi_{rent}.
\]

The shadow housing price \( p_h \) equates these Walrasian-like equations,

\[
D_h(p_h) = S_h(p_h).
\]

\section{E Calibrating Labor Efficiency}

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

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

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

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

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

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

\[ \ln(e \cdot s) = \ln(s) + \ln(e) \]

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

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

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.