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

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Abstract

Can inflating away nominal mortgage liabilities help 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. I show that temporarily raising the inflation target would have cut foreclosures by over 60% and led to a more robust recovery. Price-level targeting that offsets this temporary inflation with future disinflation has more modest effects. Higher inflation loses its potency with adjustable rate mortgages but is effective even in the presence of sticky wages. Partially demand-determined output magnifies the effects of inflation.

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

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

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1 Introduction

In response to the Great Recession and the unprecedented collapse in the housing market, 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.[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:

"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."

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.

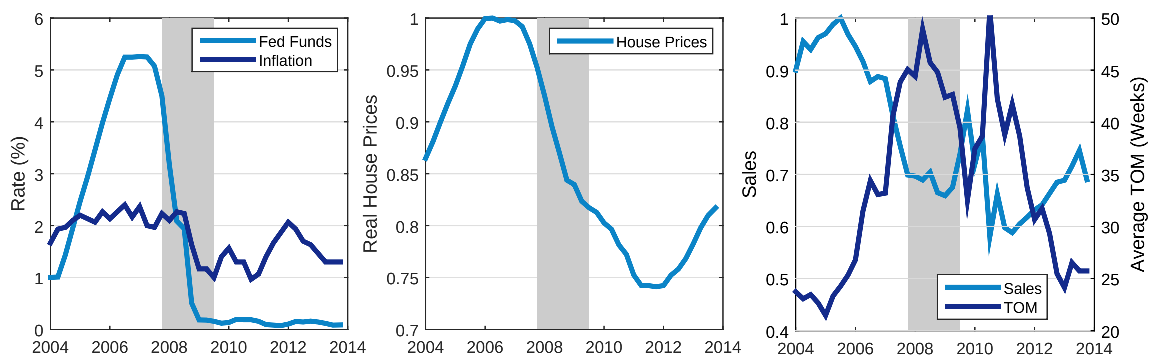


Figure 1: Fed funds rate and inflation rate; real house prices; existing sales and time on the market

[1]See 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 á 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 superneutrality. 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. The foreclosure rate peaks at 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, respectively, up to 6.2%, 13.6%, and 3.6% higher in absolute terms and 23%, 34.8%, and 19% higher when scaled by their recessionary troughs. Impressively, the economy achieves 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 check the robustness of the baseline inflation experiment results to three model modifications. First, I replace fixed rate mortgages (FRMs) with adjustable rate mortgages (ARMs) and show that, as expected, removing the nominal mortgage rigidity causes the credit contraction and debt erosion effects to exactly cancel. Alternatively, with FRMs and nominal wage stickiness, higher inflation targets continue to demonstrate remarkable, though diminished, effectiveness. However, the combination of ARMs *and* nominal wage stickiness makes higher inflation harmful. Lastly, I introduce an aggregate demand externality that causes output to be partially demand-determined. Here, inflationary policies demonstrate greater potency. Temporary higher inflation stimulates consumption, and the resulting increase in aggregate demand fuels higher output that amplifies the effects of the policy.

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 positive role for inflation during times of high debt. Sheedy (2014) makes the case for nominal GDP targeting to improve risk-sharing from the presence of noncontingent nominal debt. Lessard and Modigliani (1975), Kearl (1979), and Piazzesi and Schneider (2012) study the real effects of high 1970s inflation. In the recent sovereign debt literature, 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, they employ a representative agent model with fully amortizing mortgages, whereas I study an economy with the option to refinance and an endogenous distribution of assets, debt, and housing. Furthermore, search frictions make housing illiquid in this paper. These added features allow me to study the effect of inflation on household portfolios, housing liquidity, foreclosures, and credit pricing during the Great Recession.

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

Midrigan and Philippon (2016) and Garriga and Hedlund (2016) study the role of house prices and deleveraging during the Great Recession, while Gorea and Midrigan (2015) also analyze the importance of housing illiquidity. However, to the best of my understanding, no other paper has examined the potential of inflation to combat economic crises characterized by a deep housing slump and foreclosure crisis.

2 The Model

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 β 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 $a \leq \overline{a}$ 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 $h \in H = \{\underline{h}, h_2, h_3\}$ 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 $\overline{a} \leq \underline{h}$, 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

$$w = A_c. \tag{1}$$

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

$$r_h = \frac{1}{A_h} \tag{2}$$

[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 $\overline{L} > 0$ 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 δ_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

$$1 = p_h \frac{\partial F_h(\overline{L}, S_h, N_h)}{\partial S_h} \tag{3}$$

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

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 $p_b(0) = 0$; α_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 $\kappa_b h$,[5] 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*

[5]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.[6] Brokers find sellers with probability α_s, where p_s and α_s are analogous to p_b and α_b, respectively. Each broker incurs an entry cost $\kappa_s h$, and owners that try and fail to sell pay a small utility cost ξ.[7] Both sides of the market take $\theta_s(x_s, h)$ parametrically.

The profit maximization conditions of the real estate brokers are

$$\kappa_b h \geq \overbrace{\alpha_b(\theta_b(x_b, h))}^{\text{prob of match}} \overbrace{(x_b - p_h h)}^{\text{broker revenue}} \tag{5}$$

$$\kappa_s h \geq \underbrace{\alpha_s(\theta_s(x_s, h))}_{\text{prob of match}} \underbrace{(p_h h - x_s)}_{\text{broker revenue}} \tag{6}$$

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 $p_h h - x_s$. 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 income, assets, and debt. Instead, $\theta_s(x_s, h)$ and $\theta_b(x_b, h)$ depend only on p_h, as in Hedlund (2015a) and Hedlund (2015b):

$$\theta_b(x_b, h) = \alpha_b^{-1}\left(\frac{\kappa_b h}{x_b - p_h h}\right) \tag{7}$$

$$\theta_s(x_s, h) = \alpha_s^{-1}\left(\frac{\kappa_s h}{p_h h - x_s}\right) \tag{8}$$

This *block recursivity* greatly increases tractability without altering the substance of the frictional buying and selling problems. Solving for the dynamics of market tightnesses reduces to finding the path of p_h and substituting into (7) – (8).

[6] Short sales create the potential for moral hazard, which I abstract from here.

[7] 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.

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 $q_m^0((q_m, M'), b', h, s)M'$ 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 $\overline{q_m}$. 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 ζ and servicing costs ϕ over the life of each mortgage. During the repayment phase, banks face three sources of risk. First, if 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,

[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.

[9]This assumption prevents the model from generating artificially high foreclosure rates.

with probability φ, 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.[10] Inflation π 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 $(\overline{q_m}, M)$ that chooses a new balance of M' owes $M - \overline{q_m}M'$ 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 $1+r_m = \underbrace{\left(\frac{1+\phi}{1-\delta_h}\right)}_{\text{spread}} \underbrace{(1+r^*)(1+\pi^*)}_{\text{long-run nominal risk-free rate}}.$

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

$$q_m^0((\overline{q_m}, M'), b', h, s)M' = \frac{1-\delta_h}{(1+\zeta)(1+\phi)(1+r)(1+\pi)} \mathbb{E} \Bigg\{ \overbrace{p_s(\theta_s(x_s', h))M'}^{\text{sell + repay}} + \overbrace{[1 - p_s(\theta_s(x_s', h))]}^{\text{no sale (do not try/fail)}}$$
$$\times \Bigg[\underbrace{d'\varphi \min\left\{P' J_{REO}(h), M'\right\}}_{\text{default + repossession}} + \underbrace{d'(1-\varphi)}_{\text{no repossession}} \Bigg(-\phi M' + \underbrace{(1+\zeta)(1+\phi)q_m^0((\overline{q_m}, M'), b'', h, s')M'}_{\text{continuation value of current } M'} \Bigg)$$
$$+(1-d') \Bigg(\underbrace{M' - (1+\phi)\overline{q_m}M''\mathbf{1}_{[M'' \leq M']}}_{\text{borrower payment net of servicing costs}} + \underbrace{(1+\zeta)(1+\phi)q_m^0((\overline{q_m}, M''), b'', h, s')M''\mathbf{1}_{[M'' \leq M']}}_{\text{continuation value of new } M''} \Bigg) \Bigg] \Bigg\} \tag{9}$$

where P' is the price level and x_s', d', b'', and M'' are the policy functions for list price, mortgage default ($\in \{0, 1\}$), bonds, and new mortgage balance next period, respectively.

[10] I calibrate the model with period length one quarter. Therefore, one skipped payment in the model means 3 months of skipped payments in the data. Many of these mortgages do not end up in foreclosure.

By defining $m' = \frac{M'}{P}$ and $m'' = \frac{M''}{P'}$ and dividing through by Pm', q^0_m becomes

$$
\begin{aligned}
q^0_m((\overline{q_m}, m'), b', h, s) = & \frac{1-\delta_h}{(1+\zeta)(1+\phi)(1+r)(1+\pi)} \mathbb{E}\left\{p_s(\theta_s(x'_s, h)) + [1 - p_s(\theta_s(x'_s, h))]\right. \\
& \times \left[d'\varphi \min\left\{\frac{(1+\pi)J_{REO}(h)}{m'}, 1\right\} + d'(1-\varphi)\left(-\phi + (1+\zeta)(1+\phi)q^0_m((\overline{q_m}, m'), b'', h, s')\right)\right. \\
& \left.\left. +(1-d')\left(1 - (1+\phi)\left[\overline{q_m} - (1+\zeta)q^0_m((\overline{q_m}, m''), b'', h, s')\right]\frac{(1+\pi)m''}{m'}\mathbf{1}_{[(1+\pi)m'' \leq m']}\right)\right]\right\}
\end{aligned} \tag{10}
$$

If the borrower never sells or defaults, mortgage prices in the steady state reduce to $q^0_m((\overline{q_m}, m'), b', h, s) = \frac{1-\delta_h}{(1+\zeta)(1+\phi)(1+r)(1+\pi)} = \frac{\overline{q_m}}{1+\zeta}$, where ζ is the origination cost and $\overline{q_m} = q_m$. We can see that higher inflation π 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 φ. 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 χ 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.

[11]Section 4.1 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.

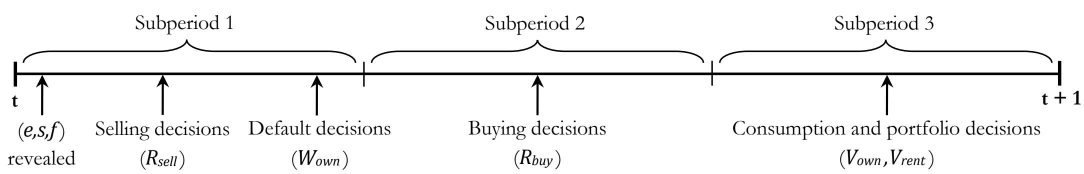
The value to a lender in repossessing a house h is

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

$$R_{REO}(h) = \max\left\{0, \max_{x_s \geq 0} p_s(\theta_s(x_s, h)) \left[(1-\chi)x_s - \left(-\eta h + \frac{1-\delta_h}{1+r} J_{REO}(h)\right)\right]\right\} \tag{11}$$

where η 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 $\overline{q_m}$ and balance 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:

$$Pc + P\eta h + Pq_b b' + M - \widetilde{q_m} M' \leq Py$$

where $\widetilde{q_m} = \overline{q_m}\mathbf{1}_{[m' \leq \frac{m}{1+\pi}]} + q_m^0((q_m, M'), b', h, s)\mathbf{1}_{[m' > \frac{m}{1+\pi}]}$.

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

$$c + \eta h + q_b b' + \frac{m}{1+\pi} - \widetilde{q_m} m' \leq y.$$

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

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

$$\begin{gathered} \text{subject to} \\ c + \eta h + q_b b' + \frac{m}{1+\pi} - \widetilde{q_m} m' \leq y \\ q_m^0((q_m, m'), b', h, s) m' \mathbf{1}_{[m' > \frac{m}{1+\pi}]} \leq \vartheta p_h \\ y' = w e' s' + b' \end{gathered} \tag{12}$$

where ϑ 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 $a \leq \overline{a}$. 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 $y - x_b \geq \underline{y}(s,(h,1))$, where $\underline{y} < 0$ 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:

$$R_{buy}(y,s,0) = \max\{0, \max_{\substack{h\in H,\\ x_b \leq y-\underline{y}}} p_b(\theta_b(x_b,h))[V_{own}(y-x_b,0,h,s,0) - V_{rent}(y,s,0)]\} \tag{13}$$

$$R_{buy}(y,s,1) = \max\{0, \max_{\substack{h\in H,\\ x_b \leq y}} p_b(\theta_b(x_b,h))[V_{own}(y-x_b,0,h,s,1) - V_{rent}(y,s,1)]\} \tag{14}$$

2.5.3 Mortgage Default

The value function for a homeowner deciding whether to default is

$$\begin{aligned} W_{own}(y,(\overline{q_m},m),h,s,0) = \max\Bigg\{&\varphi(V_{rent}+R_{buy})\left(y+\max\left\{0, J_{REO}(h) - \frac{m}{1+\pi}\right\}, s, 1\right) \\ &+(1-\varphi)V^d_{own}(y,(\overline{q_m},m),h,s,0), V_{own}(y,(\overline{q_m},m),h,s,0)\Bigg\} \end{aligned} \tag{15}$$

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

$$V^d_{own}(y,(\overline{q_m},m),h,s,0) = \max_{b',c\geq 0} u(c,h) + \beta\mathbb{E}\begin{bmatrix} (1-\delta_h)(W_{own}+R_{sell})(y',(\overline{q_m},m),h,s',0) \\ +\delta_h(V_{rent}+R_{buy})(y',s',0) \end{bmatrix}$$

subject to

$$c + \eta h + q_b b' \leq y$$

$$y' = we's' + b' \tag{16}$$

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

$$R_{sell}(y, (\overline{q_m}, m), h, s, 0) = \max\{0, \max_{x_s} p_s(\theta_s(x_s, h)) \left[(V_{rent} + R_{buy}) \left(y + x_s - \frac{m}{1+\pi}, s, 0 \right) \right. \\ \left. - W_{own}(y, (\overline{q_m}, m), h, s, 0) \right] + [1 - p_s(\theta_s(x_s, h))] (-\xi)\} \text{ subject to } y + x_s \geq \frac{m}{1+\pi} \tag{17}$$

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 θ_s and θ_b; prices w, p_h, q_m^0, q_m, q_b, and r_h; stationary distributions Φ 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.[14] 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 ω and discount factor β 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%.

[14] 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

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

The joint calibration determines the parameters κ_b, κ_s, γ_s, γ_b, and disutility ξ. 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 ϕ 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.[15] Lastly, I set the persistence of bad credit flags to $\gamma_f = 0.95$, and I determine the REO discount χ 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.[16] I also target certain key moments of

[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).

[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 different channels through which inflation operates and shows that the model exhibits approximate superneutrality in the steady state. Next, the main quantitative exercise simulates the Great Recession and 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, the nature of mortgage contracts (fixed rate vs. adjustable rate), and the presence of aggregate demand externalities.

4.1 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.

4.1.1 Inflation and Debt Erosion

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

$$c + \eta h + q_b b' + \frac{m}{1+\pi} - \widetilde{q_m} m' \leq y.$$

Table 1: Model Calibration

Description	Parameter	Value	Target	Model	Source/Reason
		Calibration: Independent Parameters			
Autocorrelation	ρ	0.952			Storesletten et al. (2004)
SD of Persistent Shock	σ_ϵ	0.17			Storesletten et al. (2004)
SD of Transitory Shock	σ_e	0.49			Storesletten et al. (2004)
Top 1% Labor Efficiency*	s_4/s_3	4			Kuhn and Ríos-Rull (2013)
Prob. of Top 1%*	$\pi_{3,4}$	0.0041			Kuhn and Ríos-Rull (2013)
Persistence of Top 1%*	$\pi_{4,4}$	0.9			Kuhn and Ríos-Rull (2013)
Intratemp. Elas. of Subst.	ν	0.13			Flavin and Nakagawa (2008)
Risk Aversion	σ	2			Various
Structure Share	α_S	30%			Favilukis et al. (2015)
Land Share	α_L	33%			Lincoln Inst Land Policy
Holding Costs	η	0.7%			Moody's
Depreciation (Annual)	δ_h	1.4%			BEA
Rent-Price Ratio (Annual)	r_h	3.5%			Sommer et al. (2013)
Risk-Free Rate (Annual)	r	-1.0%			Federal Reserve Board
Servicing Cost (Annual)	ϕ	3.2%			5.5% Nominal Mortgage Rate
Mortgage Origination Cost	ζ	0.4%			FHFA
Maximum LTV	ϑ	125%			Fannie Mae
Prob. of Repossession	φ	0.5			2008 OCC Mortgage Metrics
Credit Flag Persistence	λ_f	0.9500			Fannie Mae
		Calibration: Jointly Determined Parameters			
Homeownership Rate	$\overline{a}$	3.2840	69.0%	68.9%	Census
Starter House Value	h_1	2.7100	2.75	2.75	Corbae and Quintin (2015)
Housing Wealth (Owners)	ω	0.8159	3.99	3.99	2004 SCF
Borrowers with $LTV \geq 90\%$	β	0.9737	11.40%	11.47%	2004 SCF
Months of Supply**	ξ	0.0013	4.90	4.90	Nat'l Assoc of Realtors
Avg. Buyer Search (Weeks)	γ_b	0.0940	10.00	10.03	Nat'l Assoc of Realtors
Maximum Bid Premium	κ_b	0.0209	2.5%	2.5%	Gruber and Martin (2003)
Maximum List Discount	κ_s	0.1256	15%	15%	RealtyTrac
Foreclosure Discount	χ	0.1370	20%	20%	Pennington-Cross (2006)
Foreclosure Starts (Annual)	γ_s	0.6550	1.20%	1.25%	Nat'l Delinquency Survey
		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 $\text{earn}_{99-100}/\text{earn}_{95-99}$ in 2004 reported by Kuhn and Ríos-Rull (2013). The transition probabilities resemble the values in table 20 but have been adjusted to ensure that exactly 1% of households at any point in time have $s = s_4$. The transition probabilities $\pi_{i,4} = 0$ and $\pi_{4,i} = 0$ for all $i < 3$.

**Months of supply is inventories divided by the sales rate and proxies for time on the market.

Inflation has a direct effect on the household budget by eroding the value of outstanding debt. Higher inflation π 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.

4.1.2 Inflation and Credit

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

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

When I allow for the risk-free rate and inflation to vary deterministically during the Great Recession, the price of contract $(\overline{q_m}, m')$ satisfies[17]

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

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

[17] Recall that mortgages have flexible duration in the model. For this calculation, I assume that borrowers make interest-only payments in perpetuity.

one-period mortgage contracts. In such a setting, mortgage prices satisfy

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

Therefore, homeowners that choose m' receive $q^0_{m,\text{short-term}} m'$ 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

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

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 $q^0_{m,\text{short-term}} m'$ 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 fixed mortgage rate responds less than one-for-one to anticipated temporary changes in inflation. Figure 2 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

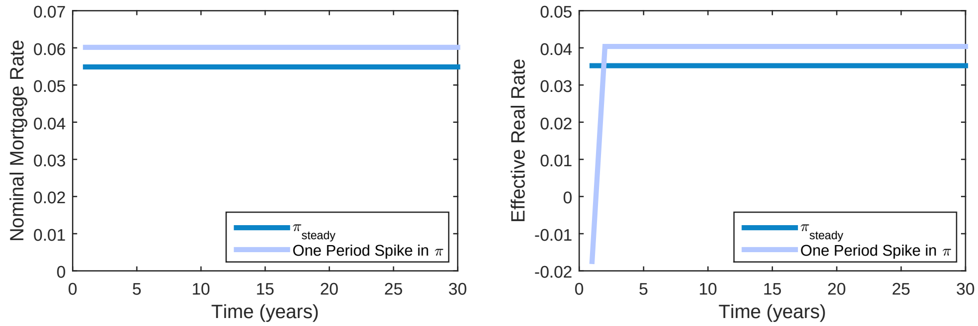


Figure 2: The response of nominal 30-year mortgage rates and the effective real rate to an anticipated spike of inflation from 1.9% to 7.9% that lasts for one year.

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 $(\overline{q_m}, m)$ can always roll over existing balances at cost $1/\overline{q_m}$ 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.

4.1.3 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)

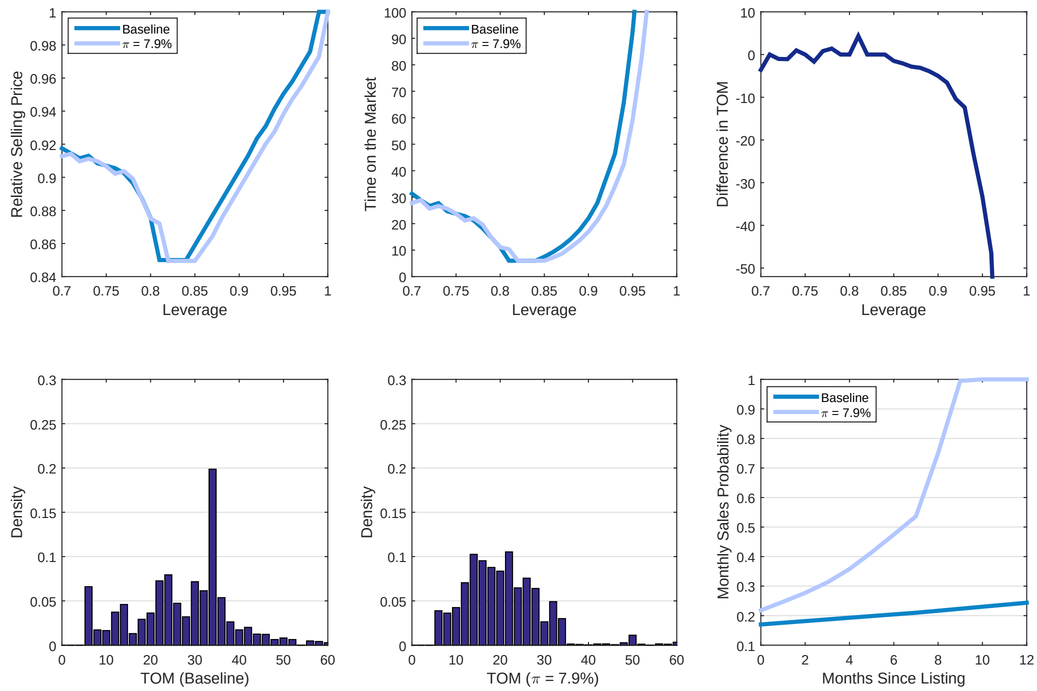


Figure 3: (1) List price; (2) expected TOM; (3) difference in TOM; (4) baseline distribution of TOM; (5) the effect of debt erosion on TOM; (6) monthly sales probabilities.

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.

4.1.4 Inflation, Selling Behavior, and Housing Liquidity

Excessive mortgage debt also has deleterious effects on housing liquidity by tightening 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 debt.

Figure 3 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 π 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

Table 2: The Effects of Higher Long-Run Inflation

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

*Partial equilibrium without correcting for the response of default premia in mortgage prices.

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.

4.1.5 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.

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 4.1.2 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.

4.2 Inflation and the Great Recession

The central question in this paper asks whether temporary inflation 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 the Great Recession and how the economy would have responded 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 implementation.

4.2.1 Establishing the Baseline Great Recession

To analyze the impact of counterfactual inflationary policies, I first establish a baseline by simulating the Great Recession following the approach in Garriga and Hedlund (2016). The onset of the crisis occurs by surprise when the model economy gets hit by a combination of real and financial shocks, but then households and banks have rational expectations about the dynamics of the recession and recovery. Note that banks experience ex-post losses because of the surprise recession. Given the highly skewed ownership of financial institution equity in the data, I assume that these losses are borne by the top 1% of households by earnings.[18]

Real and Financial Shocks On the financial side, the short term real rate r jumps from -1% to 3% for eight quarters, corresponding to the Fed rate hikes in 2006 and 2007. However, there is minimal pass-through into long-term mortgage rates, and existing (fixed rate) borrowers experience no change in rates. At the same time, the initially non-binding down-payment constraint tightens to 10%, and mortgage origination costs increase temporarily from 0.4% to 1.2%.[19]

On the real side, productivity in the consumption sector declines by 5% for 12 quarters, and the economy gets hit by a left tail shock to labor market risk in such a way as to replicate the gradual 6.2% decline in aggregate hours from 2007 to 2010.[20]

Lastly, recent evidence points to increased foreclosure delays and instances of banks pursuing the non-housing assets of delinquent borrowers.[21] To capture these features, the repossession probability φ decreases from 50% to 20% and the probability of a deficiency judgment rises to 50%, both for 3 years. After this crisis phase, the shocks revert and the economy gradually returns to its pre-crisis equilibrium.

[18] Specifically, I assume that the government levies a flat tax on the liquid assets of the top 1% over the course of the transition path that it uses to finance a bailout of bank losses.

[19] Source: Monthly Interest Rate Survey.

[20] See Fernald (2014) for evidence on productivity during the Great Recession. For the left tail shock, I set $\widetilde{\pi}_s^1(s_2|s) = (1-0.028)\pi_s(s_2|s)$ for all s, $\widetilde{\pi}_s^1(s_j|s) = \pi_s(s_j|s)$ for all s and j =3, 4, and I increase $\widetilde{\pi}_s^1(s_1|s)$ sufficiently to ensure $\sum_{s'} \widetilde{\pi}_s^1(s'|s) = 1$ for all s.

[21] See Herkenhoff and Ohanian (2015) for evidence of increasing foreclosure delays.

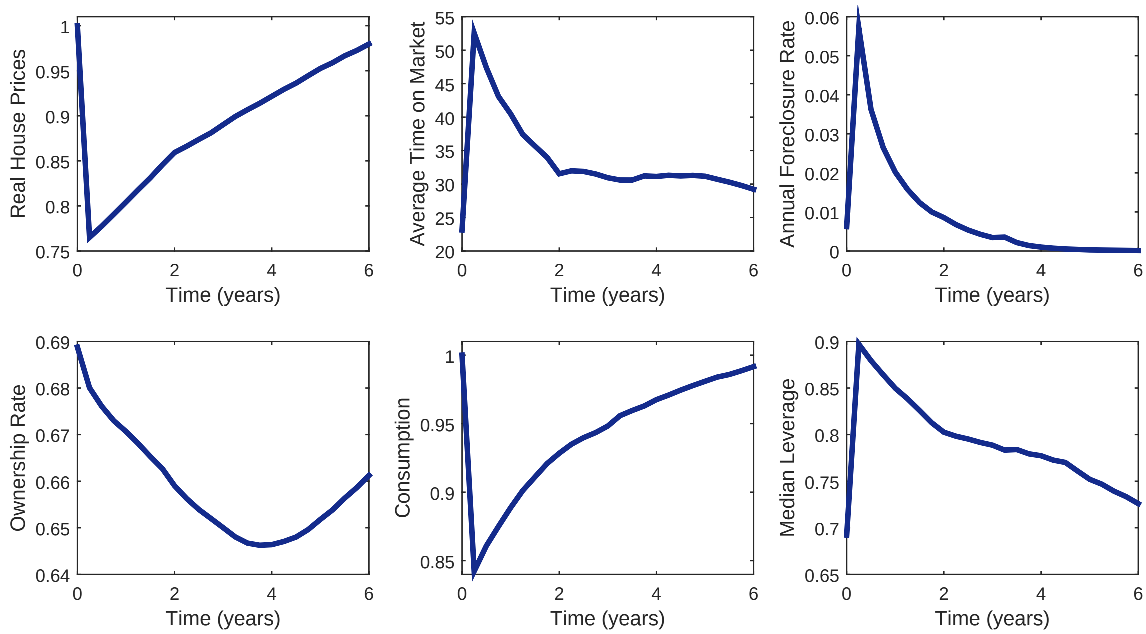


Figure 4: The baseline simulated Great Recession. The series for real house prices and consumption are normalized by their initial, pre-recession values.

4.2.2 The Great Recession without Inflation Interventions

The model economy responds to these shocks in a way that closely resembles the housing crash, Great Recession, and slow recovery. Of particular importance, the model replicates the 25% drop in real house prices and the rise in time on the market from 22 weeks to over 52 weeks shown in figure 1. Furthermore, the peak annualized foreclosure rate of 5.6% mirrors the 5.2% rate in 2009 reported by the Mortgage Bankers Association, which largely accounts for the gradual fall in homeownership from 69% to under 65%. Lastly, the model captures the steep consumption decline described in Pistaferri (2015), Berger, Guerrieri, Lorenzoni and Vavra (2016), Huo and Ríos-Rull (2016), and Kaplan, Mitman and Violante (2016).

The role of each shock and the underlying mechanisms are described in detail by Garriga and Hedlund (2016). Importantly, inspection of the series for leverage, time on the market, and consumption reveals that the model 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%. This rise in leverage owes to long term mortgage debt, because in models with short-term debt, a tightening of binding borrowing constraints forces households to immediately deleverage.

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), increased selling delays contribute both to an elevated foreclosure rate and to a sharper cutback in consumption relative to a benchmark with 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 housing equity *on paper* differs materially from the ability to extract that 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.

In the model, the deterioration in house prices reduces market tightnesses and, therefore, selling probabilities $\{p_s(\theta_s(x_s, h))\}$. 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, this downward rigidity in list prices creates debt overhang associated with longer time on the market. In turn, homeowners experiencing long selling delays face the lose-lose proposition of either defaulting or significantly reducing consumption. Panel 5 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%, and aggregate earnings decline slowly. Instead, the drop in consumption comes largely from homeowners committing greater resources to deleveraging and increasing precautionary saving.

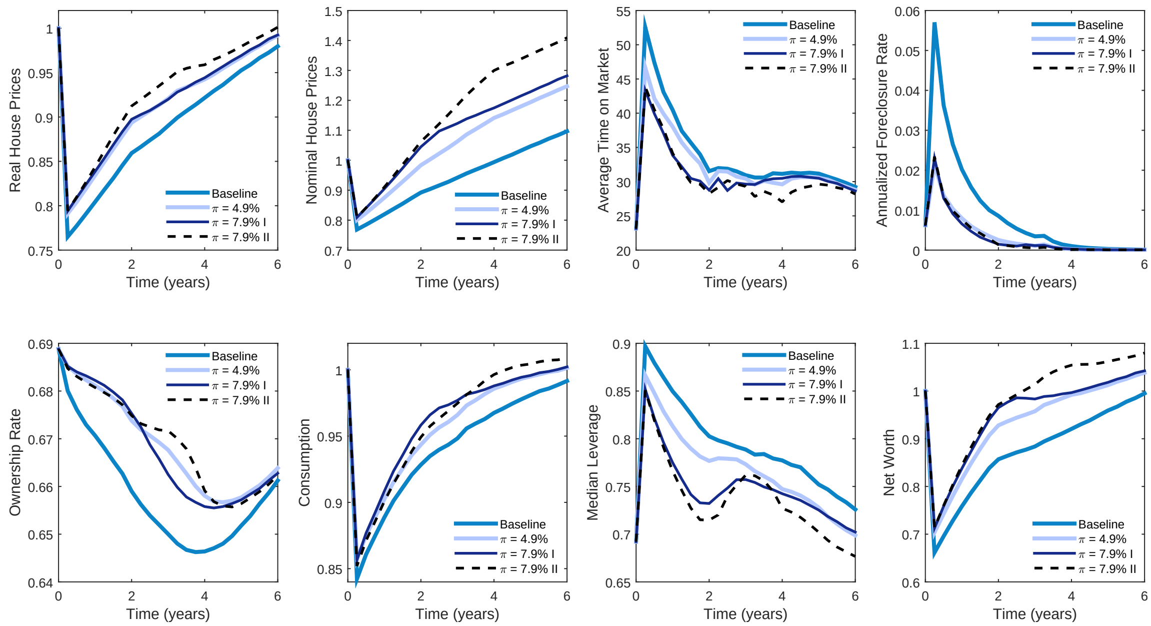


Figure 5: The effect of 3 different inflationary policies: (1) 4.9% inflation for 4 years, (2) 7.9% inflation for $2\frac{1}{2}$ years, (3) 7.9% inflation for 4 years.

4.2.3 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 4.1.4, 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.

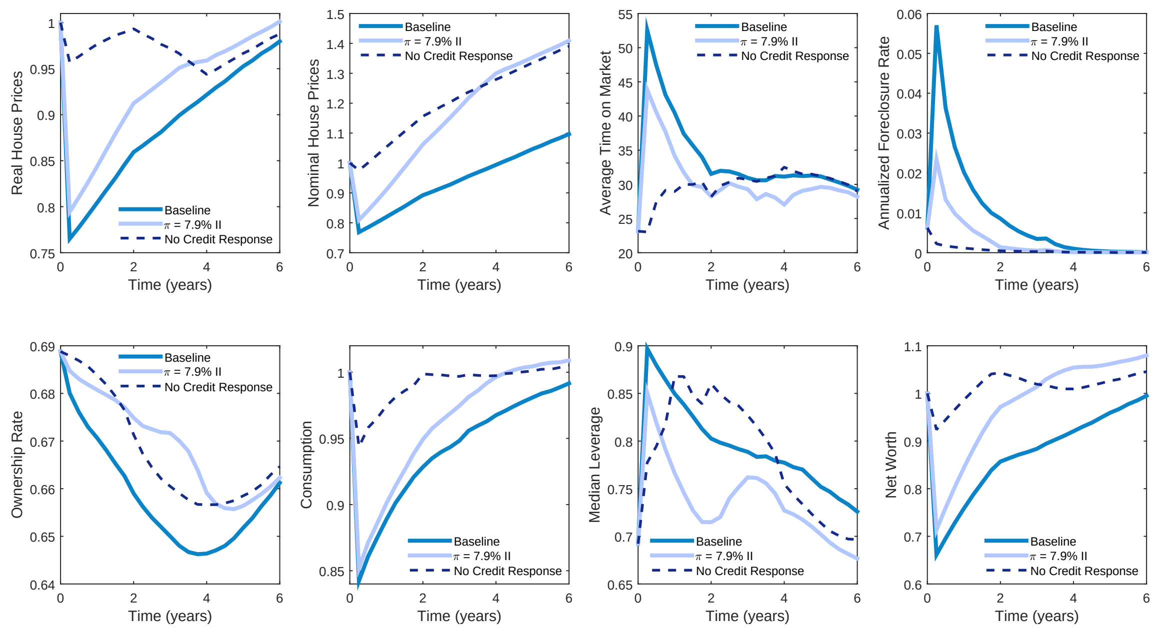


Figure 6: Isolating the debt erosion and liquidity channels with $\pi = 7.9\%$ for 4 years.

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.

4.2.4 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

Table 3: The Effects of Temporary Higher Inflation Targets

Policy	$t = 0$	$t = 2$	$t = 4$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
			*Real House Prices**			
Baseline	76.5	86.6	92.9	–	–	–
4.9% Target (4 Years)	79.1	90.0	94.8	11.1%	14.5%	8.1%
7.9% Target I ($2\frac{1}{2}$ Years)	79.4	90.3	95.1	12.3%	15.7%	9.4%
7.9% Target II (4 Years)	79.4	92.0	96.5	12.3%	23.0%	15.3%
			*Residential Investment**			
Baseline	47.8	69.7	80.2	–	–	–
4.9% Target (4 Years)	52.9	78.3	85.1	9.8%	16.5%	9.4%
7.9% Target I ($2\frac{1}{2}$ Years)	53.5	78.9	85.8	10.9%	17.6%	10.7%
7.9% Target II (4 Years)	53.5	83.5	89.7	10.9%	26.4%	18.2%
			*Consumption (Non-Housing)**			
Baseline	82.6	93.0	96.9	–	–	–
4.9% Target (4 Years)	84.2	94.6	98.7	9.2%	9.2%	10.3%
7.9% Target I ($2\frac{1}{2}$ Years)	84.1	96.3	98.9	8.6%	19.0%	11.5%
7.9% Target II (4 Years)	83.6	95.4	100.0	5.7%	13.8%	17.8%
			*Net Worth**			
Baseline	66.1	86.4	93.0	–	–	–
4.9% Target (4 Years)	70.4	93.7	99.6	12.7%	21.5%	19.5%
7.9% Target I ($2\frac{1}{2}$ Years)	71.3	97.7	100.2	15.3%	33.3%	21.2%
7.9% Target II (4 Years)	71.3	98.2	105.6	15.3%	34.8%	37.2%
			*Average TOM (Weeks)***			
Baseline	52.6	32.0	31.3	–	–	–
4.9% Target (4 Years)	46.7	31.5	30.4	−5.9	−0.4	−0.9
7.9% Target I ($2\frac{1}{2}$ Years)	43.4	30.4	30.7	−9.2	−1.5	−0.6
7.9% Target II (4 Years)	43.8	29.2	28.5	−8.7	−2.8	−2.9
			*Foreclosure Rate***			
Baseline	5.7%	0.7%	0.1%	–	–	–
4.9% Target (4 Years)	2.1%	0.2%	0.0%	−3.6pp	−0.5pp	−0.1pp
7.9% Target I ($2\frac{1}{2}$ Years)	2.3%	0.1%	0.0%	−3.4pp	−0.6pp	−0.1pp
7.9% Target II (4 Years)	2.3%	0.1%	0.0%	−3.4pp	−0.6pp	−0.1pp
			*Homeownership Rate***			
Baseline	68.0%	65.6%	64.7%	–	–	–
4.9% Target (4 Years)	68.5%	67.2%	65.7%	0.5pp	1.6pp	1.0pp
7.9% Target I ($2\frac{1}{2}$ Years)	68.5%	67.3%	65.6%	0.5pp	1.6pp	0.8pp
7.9% Target II (4 Years)	68.5%	67.3%	65.7%	0.5pp	1.7pp	1.0pp

*Steady state = 100. Δ_t scales the difference between policy and baseline by the size of the baseline trough and indicates how much each policy accelerates the recovery. **Here, Δ_t measures the level difference.

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.[22]

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.

4.2.5 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

[22] Inflation still *indirectly* alters mortgage prices through changes to default/repayment behavior.

Table 4: The Effects of Nominal Price Level Targeting

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
	*Real House Prices**			*Residential Investment**		
4.9% Target (4 Years)	11.1%	14.5%	8.1%	9.8%	16.5%	9.4%
7.9% Target I ($2\frac{1}{2}$ Years)	12.3%	15.7%	9.4%	10.9%	17.6%	10.7%
Price Level Targeting: 4.9%	3.0%	2.6%	−8.1%	2.7%	2.7%	−9.6%
Price Level Targeting: 7.9%	0.4%	−1.7%	−6.0%	0.2%	−2.1%	−7.1%
	*Consumption**			*Average TOM (Weeks)***		
4.9% Target (4 Years)	9.2%	9.2%	10.3%	−5.9	−0.4	−0.9
7.9% Target I ($2\frac{1}{2}$ Years)	8.6%	19.0%	11.5%	−9.2	−1.5	−0.6
Price Level Targeting: 4.9%	5.2%	5.7%	5.7%	−4.1	1.1	2.1
Price Level Targeting: 7.9%	1.7%	14.4%	7.5%	−6.4	−0.7	1.5
	*Foreclosure Rate***			*Homeownership Rate***		
4.9% Target (4 Years)	−3.6pp	−0.5pp	−0.1pp	0.5pp	1.6pp	1.0pp
7.9% Target I ($2\frac{1}{2}$ Years)	−3.4pp	−0.6pp	−0.1pp	0.5pp	1.6pp	0.8pp
Price Level Targeting: 4.9%	−3.2pp	−0.4pp	−0.1pp	0.5pp	1.4pp	1.0pp
Price Level Targeting: 7.9%	−2.7pp	−0.5pp	−0.0pp	0.4pp	1.3pp	0.7pp

*Δ_t scales the difference between policy and baseline by the baseline trough. **Here, Δ_t measures the level difference. 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 $\pi = 0\%$.

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 4.2.3. 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.

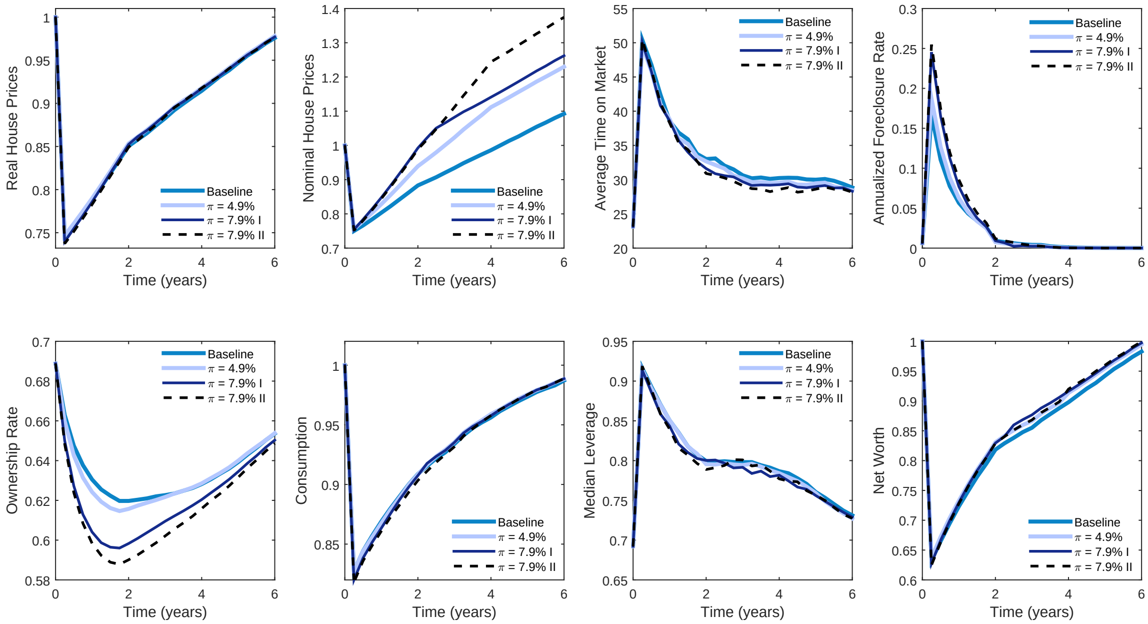


Figure 7: Higher inflation targets with adjustable rate mortgages.

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.

4.2.6 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 4.1.2 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 4.2.3. 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.

4.2.7 Sticky Wages

This section deviates 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 $W_t = (1-\lambda)(1+\pi_{\text{steady}})W_{t-1} + \lambda W_t^*$, where W_t^* is the flexible nominal wage and $\lambda = 0.16$ is the extremely low degree of wage flexibility. Figure 8

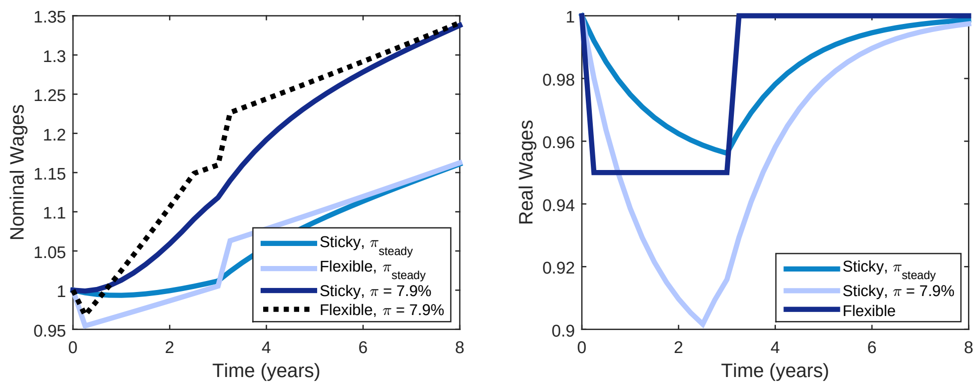


Figure 8: Nominal and real wages with nominal wage stickiness and inflation.

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 7 and figure 10. 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 8 in the appendix shows that introducing sticky wages into an economy with ARMs generates a *negative* response to higher inflation.

4.2.8 Aggregate Demand Externalities

Despite its impact on house prices and aggregate consumption, inflation has no output effects in the model studied so far because aggregate demand plays no role in output determination. This section follows Krueger and Mitman (2016) and introduces endogenous TFP that depends on aggregate consumption: $A_c = A_{c,\text{exog}} C^{\omega}$, where $\omega = 0.367$. This reduced form aggregate demand externality mirrors the micro-founded ones found in Bai, Ríos-Rull and Storesletten (2012), Huo and Ríos-Rull

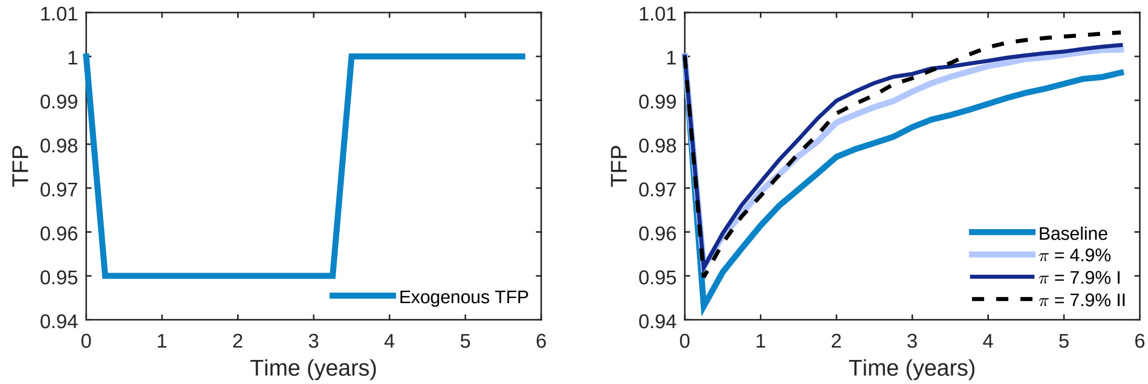


Figure 9: TFP in the models with (right) and without (left) demand externalities. Inflation in the model with externalities boosts TFP through higher consumption.

(2013), and Kaplan and Menzio (2014).

I modify the simulated recession by removing the exogenous 5% drop in TFP and allowing TFP to move purely endogenously. Figure 9 shows that baseline TFP drops by 6% at the trough before slowly recovering to its initial level after six years. As in the model without the demand externality, temporary higher inflation boosts house prices, residential investment, and consumption while reducing time on the market and foreclosures. Table 5 shows that the first variant of the high inflation surge policy raises house prices by 5% relative to the baseline trajectory and increases consumption by 3 – 4%. Furthermore, TFP endogenously increases by over 2%. In summary, the feedback from higher inflation into higher consumption and TFP significantly enhances the effectiveness of these policies.

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

Table 5: Inflationary Policies with Aggregate Demand Externalities

Policy	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
	Real House Prices*			*Residential Investment**		
7.9% Target I (Baseline)	12.3%	15.7%	9.4%	10.9%	17.6%	10.7%
7.9% Target II (Baseline)	12.3%	23.0%	15.3%	10.9%	26.4%	18.2%
7.9% Target I (Externality)	16.2%	19.7%	13.1%	13.5%	19.6%	14.5%
7.9% Target II (Externality)	16.6%	28.8%	20.5%	14.3%	31.1%	23.2%
	Consumption*			*Average TOM (Weeks)***		
7.9% Target I (Baseline)	8.6%	19.0%	11.5%	−7.9	−1.3	−0.2
7.9% Target II (Baseline)	5.7%	13.8%	17.8%	−7.4	−2.5	−2.5
7.9% Target I (Externality)	14.1%	22.9%	15.9%	−10.0	−1.8	−1.1
7.9% Target II (Externality)	10.6%	17.6%	21.8%	−9.9	−3.3	−3.1
	Foreclosure Rate**			*Homeownership Rate***		
7.9% Target I (Baseline)	−3.0pp	−0.5pp	−0.0pp	0.4pp	1.6pp	1.0pp
7.9% Target II (Baseline)	−3.4pp	−0.4pp	−0.1pp	0.5pp	1.7pp	1.1pp
7.9% Target I (Externality)	−3.3pp	−0.5pp	−0.1pp	0.5pp	1.6pp	0.8pp
7.9% Target II (Externality)	−3.3pp	−0.5pp	−0.1pp	0.4pp	1.7pp	1.0pp

$^*\Delta_t$ scales the difference between policy and baseline by the baseline trough. **Here, Δ_t measures the level difference.

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.

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A Supplementary Tables

Table 6: The Effects of Nominal Price Level Targeting

Policy	$t = 0$	$t = 2$	$t = 4$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
	*Real House Prices**					
Baseline	76.5	86.6	92.9	–	–	–
4.9% (4 Years)	77.2	87.2	91.0	3.0%	2.6%	−8.1%
7.9% ($2\frac{1}{2}$ Years)	76.6	86.2	91.5	0.4%	−1.7%	−6.0%
	*Residential Investment**					
Baseline	47.8	69.7	80.2	–	–	–
4.9% Target (4 Years)	49.2	71.1	75.2	2.7%	2.7%	−9.6%
7.9% Target I ($2\frac{1}{2}$ Years)	47.9	68.6	76.5	0.2%	−2.1%	−7.1%
	*Consumption (Non-Housing)**					
Baseline	82.6	93.0	96.9	–	–	–
4.9% (4 Years)	83.5	94.0	97.9	5.2%	5.7%	5.7%
7.9% ($2\frac{1}{2}$ Years)	82.9	95.5	98.2	1.7%	14.4%	7.5%
	*Net Worth**					
Baseline	66.1	86.4	93.0	–	–	–
4.9% (4 Years)	67.6	90.9	96.8	4.4%	13.3%	11.2%
7.9% ($2\frac{1}{2}$ Years)	67.2	94.1	97.7	3.2%	22.7%	13.9%
	*Average TOM (Weeks)***					
Baseline	52.6	32.0	31.3	–	–	–
4.9% (4 Years)	48.4	33.1	33.4	−4.1	1.1	2.1
7.9% ($2\frac{1}{2}$ Years)	46.1	31.3	32.8	−6.4	−0.7	1.5
	*Foreclosure Rate***					
Baseline	5.7%	0.7%	0.1%	–	–	–
4.9% (4 Years)	2.5%	0.3%	0.0%	−3.2pp	−0.4pp	−0.1pp
7.9% ($2\frac{1}{2}$ Years)	3.0%	0.2%	0.0%	−2.7pp	−0.5pp	−0.0pp
	*Homeownership Rate***					
Baseline	68.0%	65.6%	64.7%	–	–	–
4.9% (4 Years)	68.5%	67.0%	65.7%	0.5pp	1.4pp	1.0pp
7.9% ($2\frac{1}{2}$ Years)	68.4%	66.9%	65.4%	0.4pp	1.3pp	0.7pp

*Steady state = 100. Δ_t scales the difference between policy and baseline by the size of the baseline trough and indicates how much each policy accelerates the recovery. **Here, Δ_t measures the level difference. 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 $2\frac{1}{2}$ years followed by $7\frac{1}{2}$ years of $\pi = 0\%$.

Table 7: Temporary Higher Inflation Targets with Very Sticky Wages

Policy	$t=0$	$t=2$	$t=4$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
			*Real House Prices**			
Baseline	76.8	86.8	92.6	–	–	–
4.9% Target (4 Years)	78.1	88.3	93.2	5.6%	6.5%	2.6%
7.9% Target I ($2\frac{1}{2}$ Years)	77.6	88.1	93.4	3.4%	5.6%	3.4%
7.9% Target II (4 Years)	76.9	88.6	93.7	0.4%	7.8%	4.7%
			*Residential Investment**			
Baseline	48.5	69.9	79.3	–	–	–
4.9% Target (4 Years)	50.8	73.8	80.7	4.5%	7.6%	2.7%
7.9% Target I ($2\frac{1}{2}$ Years)	50.0	73.1	81.3	2.9%	6.2%	3.9%
7.9% Target II (4 Years)	48.5	74.5	82.2	0.0%	8.9%	5.6%
			*Consumption (Non-Housing)**			
Baseline	83.5	93.2	96.7	–	–	–
4.9% Target (4 Years)	84.2	94.6	98.7	2.4%	1.8%	3.6%
7.9% Target I ($2\frac{1}{2}$ Years)	83.0	94.5	97.5	−3.0%	7.9%	4.8%
7.9% Target II (4 Years)	82.0	92.8	97.5	−9.1%	−2.4%	4.8%
			*Net Worth**			
Baseline	67.1	88.5	93.2	–	–	–
4.9% Target (4 Years)	69.4	92.7	96.1	7.0%	12.8%	8.8%
7.9% Target I ($2\frac{1}{2}$ Years)	69.2	94.9	95.7	6.4%	19.5%	7.6%
7.9% Target II (4 Years)	68.1	94.7	98.6	3.0%	18.8%	16.4%
			*Average TOM (Weeks)***			
Baseline	50.9	32.2	31.2	–	–	–
4.9% Target (4 Years)	47.9	32.8	31.0	−3.0	0.6	−0.2
7.9% Target I ($2\frac{1}{2}$ Years)	44.8	31.5	31.6	−6.2	−0.7	0.3
7.9% Target II (4 Years)	47.1	31.3	29.9	−3.9	−0.9	−1.3
			*Foreclosure Rate***			
Baseline	5.2%	0.6%	0.1%	–	–	–
4.9% Target (4 Years)	2.3%	0.2%	0.0%	−3.0pp	−0.4pp	−0.0pp
7.9% Target I ($2\frac{1}{2}$ Years)	2.7%	0.2%	0.0%	−2.5pp	−0.5pp	−0.0pp
7.9% Target II (4 Years)	2.9%	0.2%	0.0%	−2.3pp	−0.5pp	−0.1pp
			*Homeownership Rate***			
Baseline	68.1%	65.9%	64.8%	–	–	–
4.9% Target (4 Years)	68.5%	67.2%	65.7%	0.4pp	1.3pp	0.9pp
7.9% Target I ($2\frac{1}{2}$ Years)	68.4%	67.2%	65.5%	0.4pp	1.3pp	0.7pp
7.9% Target II (4 Years)	68.4%	67.1%	65.5%	0.3pp	1.2pp	0.7pp

*Steady state = 100. Δ_t scales the difference between policy and baseline by the size of the baseline trough and indicates how much each policy accelerates the recovery. **Here, Δ_t measures the level difference.

Table 8: Temporary Higher Inflation Targets with ARMs and Very Sticky Wages

Policy	$t = 0$	$t = 2$	$t = 4$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
	*Real House Prices**					
Baseline	74.9	85.7	92.1	–	–	–
4.9% Target (4 Years)	73.8	84.7	91.1	−4.4%	−4.0%	−4.0%
7.9% Target I ($2\frac{1}{2}$ Years)	72.9	84.5	91.0	−8.0%	−4.8%	−4.4%
7.9% Target II (4 Years)	72.0	83.3	90.1	−11.6%	−9.6%	−8.0%
	*Residential Investment**					
Baseline	44.8	67.5	78.0	–	–	–
4.9% Target (4 Years)	42.8	65.0	75.3	−3.6%	−4.5%	−4.9%
7.9% Target I ($2\frac{1}{2}$ Years)	41.2	64.5	75.2	−6.5%	−5.4%	−5.1%
7.9% Target II (4 Years)	39.8	61.7	72.9	−9.1%	−10.5%	−9.2%
	*Consumption (Non-Housing)**					
Baseline	81.9	91.4	95.8	–	–	–
4.9% Target (4 Years)	80.7	90.0	94.6	−6.6%	−7.7%	−6.6%
7.9% Target I ($2\frac{1}{2}$ Years)	79.4	89.3	94.5	−13.8%	−11.6%	−7.2%
7.9% Target II (4 Years)	78.7	88.0	93.4	−17.7%	−18.8%	−13.3%
	*Net Worth**					
Baseline	64.0	84.6	91.2	–	–	–
4.9% Target (4 Years)	62.9	83.7	89.3	−3.1%	−2.5%	−5.3%
7.9% Target I ($2\frac{1}{2}$ Years)	61.7	82.2	88.5	−6.4%	−6.7%	−7.5%
7.9% Target II (4 Years)	60.6	82.0	87.0	−9.4%	−7.2%	−11.7%
	*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 ($2\frac{1}{2}$ 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	0.0pp	0.0pp
7.9% Target I ($2\frac{1}{2}$ 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 ($2\frac{1}{2}$ 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

*Steady state = 100. Δ_t scales the difference between policy and baseline by the size of the baseline trough and indicates how much each policy accelerates the recovery. **Here, Δ_t measures the level difference..

Table 9: Temporary Higher Inflation Targets with Aggregate Demand Externalities

Policy	$t=0$	$t=2$	$t=4$	$\Delta_{t=0}$	$\Delta_{t=2}$	$\Delta_{t=4}$
	*Real House Prices**					
Baseline	77.1	87.4	93.4	–	–	–
4.9% Target (4 Years)	80.7	91.7	95.9	15.7%	18.8%	10.9%
7.9% Target I ($2\frac{1}{2}$ Years)	80.8	91.9	96.4	16.2%	19.7%	13.1%
7.9% Target II (4 Years)	80.9	94.0	98.1	16.6%	28.8%	20.5%
	*Residential Investment**					
Baseline	49.5	68.5	82.3	–	–	–
4.9% Target (4 Years)	56.0	78.5	88.3	12.9%	19.8%	11.9%
7.9% Target I ($2\frac{1}{2}$ Years)	56.3	78.4	89.6	13.5%	19.6%	14.5%
7.9% Target II (4 Years)	56.7	84.2	94.0	14.3%	31.1%	23.2%
	*Consumption (Non-Housing)**					
Baseline	83.0	93.6	97.0	–	–	–
4.9% Target (4 Years)	85.4	95.8	99.3	14.1%	12.9%	13.5%
7.9% Target I ($2\frac{1}{2}$ Years)	85.4	97.5	99.7	14.1%	22.9%	15.9%
7.9% Target II (4 Years)	84.8	96.6	100.7	10.6%	17.6%	21.8%
	*Net Worth**					
Baseline	66.9	88.0	94.1	–	–	–
4.9% Target (4 Years)	72.6	96.9	102.2	17.2%	26.9%	24.5%
7.9% Target I ($2\frac{1}{2}$ Years)	73.2	101.2	103.6	19.0%	39.9%	28.7%
7.9% Target II (4 Years)	73.4	101.8	109.1	19.6%	41.7%	45.3%
	*Average TOM (Weeks)***					
Baseline	51.3	31.7	31.0	–	–	–
4.9% Target (4 Years)	44.0	30.7	29.9	−7.3	−1.0	−1.1
7.9% Target I ($2\frac{1}{2}$ Years)	41.2	29.9	29.9	−10.0	−1.8	−1.1
7.9% Target II (4 Years)	41.4	28.4	27.9	−9.9	−3.3	−3.1
	*Foreclosure Rate***					
Baseline	5.3%	0.6%	0.1%	–	–	–
4.9% Target (4 Years)	1.9%	0.2%	0.0%	−3.4pp	−0.4pp	−0.1pp
7.9% Target I ($2\frac{1}{2}$ Years)	2.0%	0.1%	0.0%	−3.3pp	−0.5pp	−0.1pp
7.9% Target II (4 Years)	2.0%	0.1%	0.0%	−3.3pp	−0.5pp	−0.1pp
	*Homeownership Rate***					
Baseline	68.1%	65.6%	64.6%	–	–	–
4.9% Target (4 Years)	68.6%	67.2%	65.6%	0.5pp	1.6pp	1.0pp
7.9% Target I ($2\frac{1}{2}$ Years)	68.6%	67.2%	65.4%	0.5pp	1.6pp	0.8pp
7.9% Target II (4 Years)	68.5%	67.3%	65.5%	0.4pp	1.7pp	1.0pp

*Steady state = 100. Δ_t scales the difference between policy and baseline by the size of the baseline trough and indicates how much each policy accelerates the recovery. **Here, Δ_t measures the level difference.

B Supplementary Figures

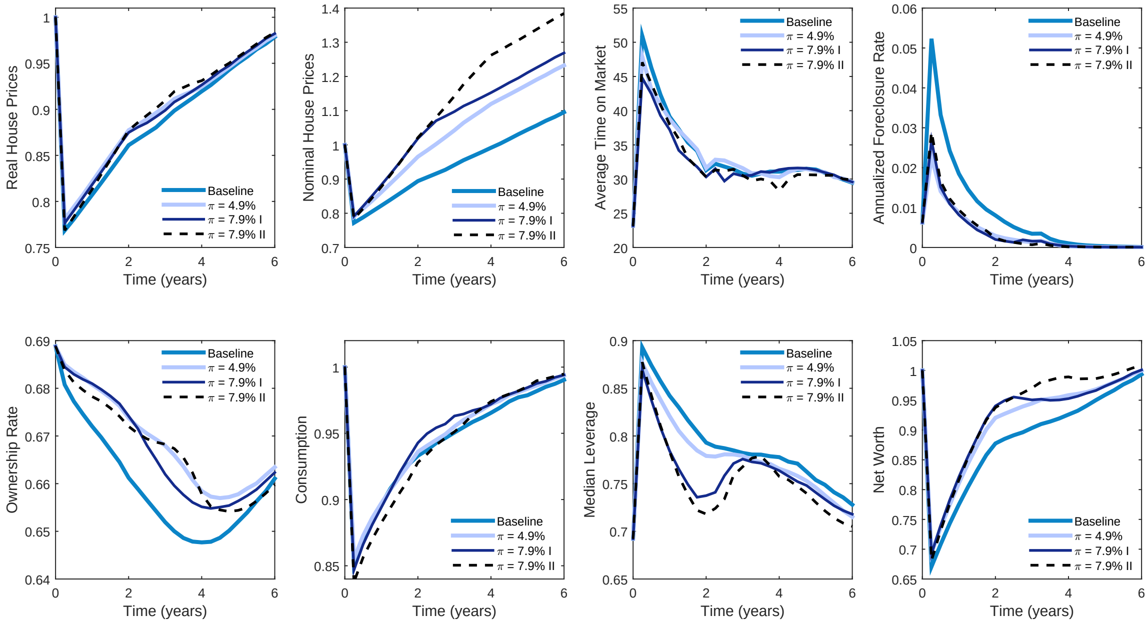

Figure 10: Higher inflation targets with very sticky wages.

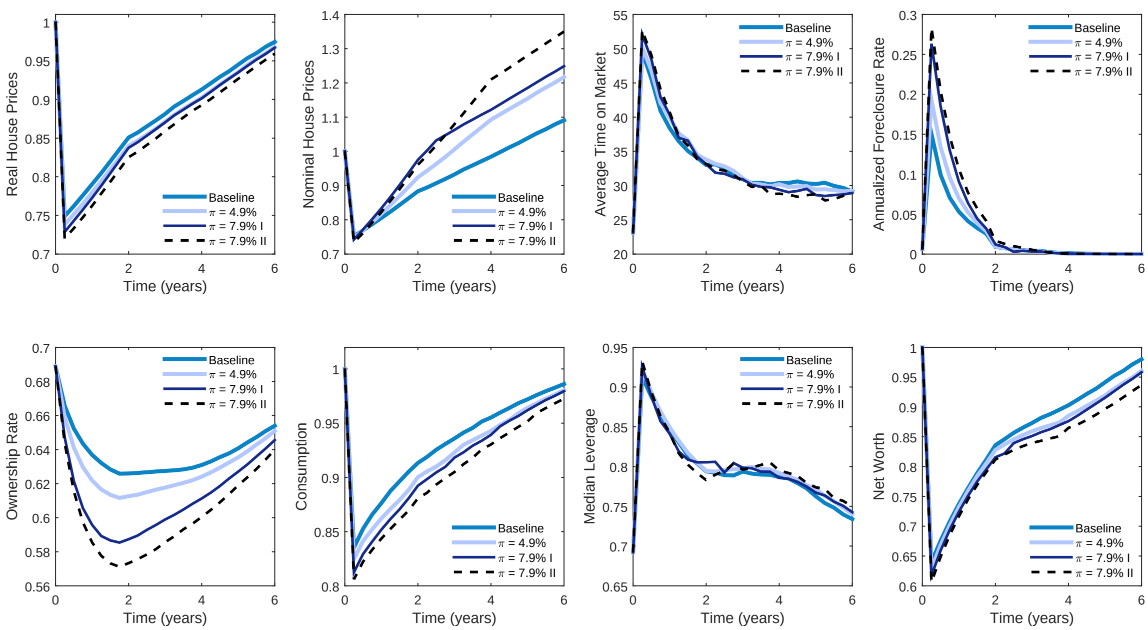

Figure 11: Higher inflation targets with adjustable rate mortgages *and* sticky wages.

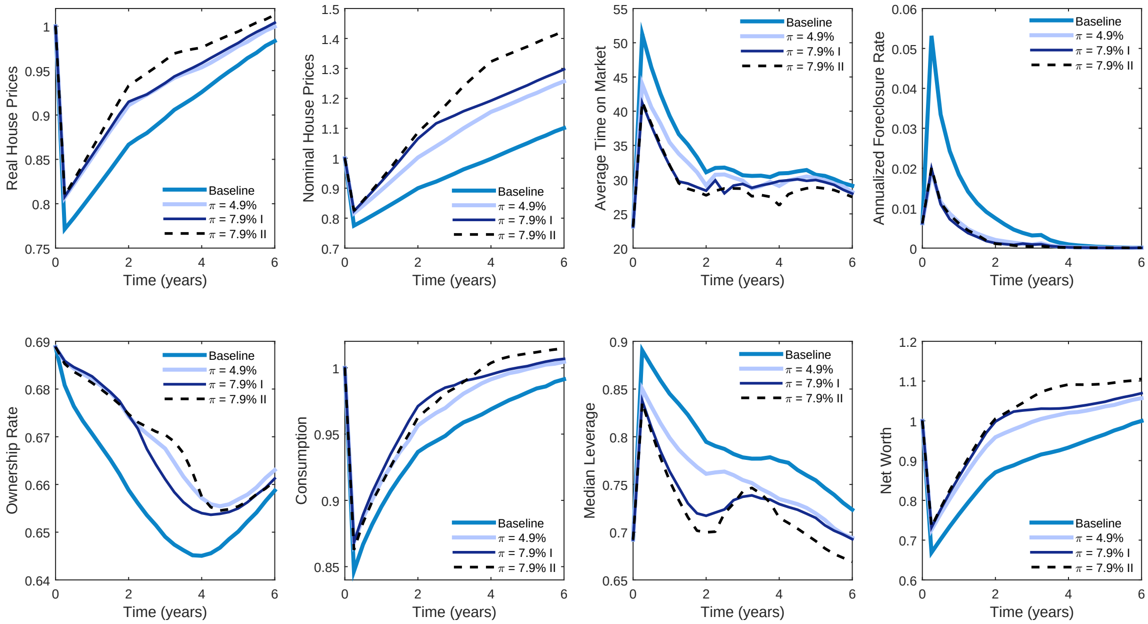

Figure 12: Higher inflation targets with the aggregate demand externality.

C Household Value Functions

C.1 Subperiod 3 Value Functions

Homeowners with good credit:

$$V_{own}(y,(\overline{q_m},m),h,s,0) = \max_{m',b',c\geq 0} u(c,h) + \beta\mathbb{E}\begin{bmatrix} (1-\delta_h)(W_{own}+R_{sell})(y',(\overline{q_m},m'),h,s',0) \\ +\delta_h(V_{rent}+R_{buy})(y',s',0) \end{bmatrix}$$

subject to

$$c + \eta h + q_b b' + \frac{m}{1+\pi} - \widetilde{q_m} m' \leq y$$

$$q_m^0((q_m,m'),b',h,s)m'\mathbf{1}_{[m'>\frac{m}{1+\pi}]} \leq \vartheta p_h$$

$$y' = we's' + b'$$

Homeowners with bad credit:

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

subject to

$$c + \eta h + q_b b' \leq y$$

$$y' = we's' + b'$$

Apartment-dwellers with good credit:

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

subject to

$$c + q_b b' + r_h a \leq y$$

$$y' = we's' + b'$$

Apartment-dwellers with bad credit:

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

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:

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

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

C.3 Subperiod 1 Value Functions

The utility associated with the default decision:

$$W_{own}(y,(\overline{q_m},m),h,s,0) = \max\left\{\varphi(V_{rent}+R_{buy})\left(y+\max\left\{0, J_{REO}(h)-\frac{m}{1+\pi}\right\},s,1\right)\right.$$
$$\left.+(1-\varphi)V^d_{own}(y,(\overline{q_m},m),h,s,0), V_{own}(y,(\overline{q_m},m),h,s,0)\right\}$$

Utility of default conditional on no repossession:

$$V^d_{own}(y,(\overline{q_m},m),h,s,0) = \max_{b',c\geq 0} u(c,h)+\beta\mathbb{E}\left[\begin{array}{l}(1-\delta_h)(W_{own}+R_{sell})(y',(\overline{q_m},m),h,s',0)\\ +\delta_h(V_{rent}+R_{buy})(y',s',0)\end{array}\right]$$

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:

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

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

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

D Determining the Shadow Housing Price

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

$$S_h(p_h) = \overbrace{Y_h(p_h)}^{\text{new housing}} + \overbrace{S_{REO}(p_h)}^{\text{REO housing}} + \overbrace{\int h p_s(\theta_s(x_s^*, h; p_h)) d\Phi_{own}}^{\text{sold by owner}}.$$

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

$$D_h(p_h) = \int h^* p_b(\theta_b(x_b^*, h^*; p_h)) d\Phi_{rent}$$

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

$$D_h(p_h) = S_h(p_h). \tag{18}$$

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

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

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

F Computation

The household problem is solved using value function iteration. The state space (y, m, h, s) for homeowners with good credit standing is discretized using 275 values for y, 131 values for m, 3 values for h, and 4 values for s (the calibration of labor efficiency is described in the previous section). Homeowners with bad credit standing $(f = 1)$ have state (y, h, s), and renters have state (y, s). To compute the equilibrium transition path, the algorithm starts with an initial guess for the path of shadow house prices, $\{p_{h,t}\}_{t=1}^{T}$. The algorithm then does backward induction on the recursive mortgage price equation and the household Bellman equations before forward iterating on the distribution of households and REO properties. Equilibrium house prices (which depend on the current guess for the house price trajectory) are calculated period by period during the forward iteration. The initial guess is then compared with these equilibrium prices, and a convex combination of these two sequences is used for the next guess. This process continues until convergence.