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ABSTRACT

We analyze the impact of fiscal and monetary stimulus in an economy with mortgage debt, where inflation redistributes from savers to borrowers. We show theoretically that fiscal transfers without future tax increases cause a surge in inflation, increasing consumption demand and house prices. The power of fiscal stimulus grows when borrowers are more indebted. We then show quantitatively that transfers followed by easy monetary policy cause a surge in inflation which helps explain features of the post-Covid boom, including a boom in output and house prices. This boom comes with a longer-term contraction, since redistribution reduces borrower labor supply.

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1 Introduction

The US government responded to the 2020 Covid crisis with its largest fiscal and monetary stimulus in history. In response to the recession, the government implemented a range of tranfer and insurance programs resulting in deficits in 2020 and 2021 of \$3.1 trillion and \$2.7 trillion. During the post-Covid recovery from April 2020 up to the start of 2022, unemployment fell rapidly (from over 14% to 4%), house prices surged by 30%, and inflation reached a peak level over 9%. Despite this surge in inflation, the Federal Reserve did not start to raise interest rates until March 2022. This paper shows that such a mix of loose fiscal and monetary policy provides powerful economic stimulus, in large part by causing a surge in inflation that redistributes wealth from savers to borrowers.

We first analyze the impact of fiscal transfers in a simple model with more indebted "borrower" households and less indebted "saver" households. For a given tax rate, the model has a unique steady state equilibrium, with a greater supply of liquid assets in equilibria with higher tax rates backing a larger real supply of government debt. The model's steady state can be solved entirely in real terms, so an increase in nominal transfers without raising taxes only results in inflation. Fiscal transfers either must be backed by an increase in future taxes or are immediately dissipated by inflation with no real effects.

Next, we analyze transfers in this model with downward wage rigidity added, so involuntary unemployment can cause a recession. While involuntary unemployment prevents inflation during a recession, unbacked transfers without future tax increases cause delayed inflation after the recession ends. This delayed inflation, like the rise in inflation in 2021-2022 following transfers in 2020-2021, lowers real interest rates during the recession. This reduction in real rates stimulates consumption demand both by lowering the return on saving and by increasing the borrowing capacity of the most indebted consumers. The stimulus provided by these low real rates increases total economic output and also causes a boom in house prices that disproportionately impacts houses owned by constrained borrowers. Fiscal inflation caused by an unbacked fiscal stimulus therefore is a powerful tool for increasing demand in a recession, and the stimulative impact of this inflation increases with the amount of outstanding household debt.

We formally decompose the impact of fiscal stimulus in this model to three distinct channels, only one of which results in inflation. First, an increase in government debt allows households to hold more liquid assets, allowing for better smoothing of liquidity shocks. Second, if fiscal transfers are targeted at the least patient households, overall consumption demand is increased by redistribution. Third, and most importantly, a fiscal stimulus causes future inflation after a recession only if future taxes are not raised enough to pay for the stimulus. This lack of future taxation requires debt to be inflated away instead. This inflation reduces the real value of outstanding mortgage debt, resulting in additional redistribution from savers to borrowers that causes a boom in house prices. While fiscal stimulus can always increase output in a recession, its power increases when it is not accompanied by future tax increases.

We then simulate the impact of fiscal and monetary stimulus like that after Covid in a richer quantitative model. The model features borrowers and savers with segmented housing markets, an institutionally realistic mortgage market, wage and price rigidities, and fiscal and monetary policy. In this economy, the central bank follows a policy rule to set nominal interest rates, and a fiscal authority sets the magnitude of taxes and transfers, both as a function of the state of the economy. In normal times, monetary policy acts to stabilize inflation and output, while fiscal policy adjusts taxes to ensure the government can service its debt. The policy interventions we consider are: 1. a temporary increase in fiscal transfers, and 2. a temporarily passive monetary policy rule that responds less to inflation and output. Because we solve our model with global nonlinear methods, we can document a strong interaction between these two policies that amplifies their impact on output, inflation, and house prices. A fiscal stimulus followed by easy monetary policy results in a surge in inflation that reduces the need to pay for the fiscal stimulus with future taxes. The existence of mortgage debt in our model implies that this inflation surge also results in redistribution from savers to borrowers.

We first analyze the impact of fiscal/monetary stimulus on the economy starting at its steady state, outside of a recession. Neither fiscal transfers nor passive monetary policy cause much inflation alone, but together they cause a surge in inflation that peaks near 8%. This inflation erodes the real value of nominal debt and therefore redistributes from savers to borrowers, increasing borrower consumption by 4.5% and borrower house prices by 6%. Saver consumption and house prices respectively fall by 4.2% and 9%. After a few quarters of mildly increased output, the redistribution towards borrowers results in a contraction of up to .6% of GDP 2-3 years after the policy. In our model, redistribution that stimulates demand in the short term also causes a longer term reduction in supply. This longer term contraction in output is because redistribution towards borrowers reduces their labor supply due to a wealth effect. We show that this contraction must be due to reduced borrower supply, since it disappears in a modified model where borrower labor supply is held fixed.

Next, we consider the impact of the same policies in response to an exogenous decrease in consumption demand, motivated by the large voluntary drop in consumption during Covid (Chetty et al., 2020). Without emergency policy interventions, the economy would experience a large drop in output, deflation, and a rise in unemployment. These are partially offset by adding emergency unemployment insurance, but only with the jointly loose fiscal/monetary policy in the previous paragraph is there a surge in inflation and a complete prevention of unemployment. As above, this surge of inflation redistributes from savers to borrowers, causing a rise consumption and house prices for borrowers and a fall for savers. This redistribution to borrowers also results in a longer term reduction in output as borrowers reduce their labor supply. If instead the economy had experienced deflation, borrower consumption and house prices would have decreased and long run output would have increased.

We then present two small modifications of our quantitative model to make it more consistent with the data from the recovery after the Covid recession. First, to explain the fact that house prices increased overall from 2020 to 2022 and not just for houses owned by constrained borrowers, we exogenously increase households' preferences for consuming housing. Second, we set the inflation expectations of mortgage lenders to be a weighted average of the rational expectations prediction and the long run inflation target. This "anchoring" of inflation expectations is consistent with data on inflation swap prices. Without this anchoring, agents with rational expectations would anticipate the surge in inflation our policy interventions cause before the inflation occurs. As a result, mortgage rates would rise in anticipation of future inflation, unlike the historically low mortgage rates in 2021. With anchored inflation expectations and an increase in housing demand, our model features a boom in house prices, low real mortgage rates, and a surge in mortgage refinancing (Fuster et al., 2021) in response to the joint fiscal/monetary stimulus we analyze.

Our last policy experiment shows that the stimulative impact of joint fiscal/monetary stimulus is stronger in an economy with more outstanding mortgage debt. If we increase mortgage debt by 30% relative to its steady state level, the surge of inflation caused by our fiscal/monetary stimulus results in more redistribution from savers to borrowers. This leads to a greater increase in borrower consumption and house prices, and a greater reduction in borrower labor supply and output in the longer term. These results show that, like we find in our simpler theoretical model, the power of fiscal inflation to stimulate consumption demand is greater when there is more outstanding household debt.

Our results on the impact of fiscal and monetary policy rely on the realistic details of mortgage markets we embed in a New Keynesian model. First, the model features two distinct groups of saver and borrower households, allowing for the possibility of redistribution. In addition, a financial intermediary provides long-term mortgages with default and prepayment risk. A non-financial sector produces output subject to sticky prices and wages. Our savers are more patient than borrowers, so in equilibrium savers hold most financial assets while borrowers have a sizable mortgage. The financial intermediary finances its mortgage holdings with riskless deposits and risky equity. Borrowers have to fund their consumption and pay their mortgage out of their holdings of riskless deposits and (risky) labor income, and they default on their mortgages if paying it would result in a sufficiently low level of consumption. Our approach to modeling mortgage default matches empirical evidence (Ganong and Noel, 2021) that the vast majority of mortgage defaults are driven by household liquidity shortages rather than by a strategic choice to maximize household wealth. In addition, the model allows the borrowers to refinance their mortgages for a utility cost and to choose between a "rate refi" that lowers their future payments and a "cash out refi" that immediately provides cash.

While our model is motivated by explaining the stylized facts of the unique post-Covid boom, it has two broader lessons for fiscal and monetary policy. First, coordinated easing of fiscal and monetary policy can provide particularly strong stimulus. After a generous fiscal stimulus, a temporarily loose monetary stance that permits transitory inflation makes the stimulus more powerful. Second, a significant share of the power of this joint fiscal/monetary stimulus comes from redistribution between borrowers and savers (Auclert, 2019). As a result, fiscal/monetary policy which can be expansionary in the short term may also lead to a longer term contraction due to reduced borrower labor supply. This redistribution channel relies crucially on a realistic model of mortgage markets, demonstrating the importance of household finance for the transmission of monetary and fiscal policy.

Related Literature Our work primarily relates to three literatures: research on the interaction between fiscal and monetary policy, research on the macroeconomic role of household debt, and research particularly focused on the 2020 Covid crisis and recovery. The first literature is closely related to the fiscal theory of the price level (Leeper, 1991; Woodford, 2001; Sims, 2011; Cochrane, 2001; Bassetto and Cui, 2018; Brunnermeier et al., 2022), which argues that a large outstanding government debt relative to the present value of future tax revenue can cause inflation. Unlike in some emerging economies, immediate US fiscal concerns are not so dire as to require printing money to pay for spending. As a result, our paper differs somewhat from much of this literature by studying the impact of joint fiscal and monetary easing, without any threat of default by the fiscal authority. Our work is closer to Bianchi and Melosi (2022); Bianchi and Ilut (2017); Bianchi, Faccini, and Melosi (2023) who study economies where fiscal policy is only partially paid for with inflation. Also close to us is Angeletos, Lian, and Wolf (2023) who document conditions under which expansionary fiscal policy can pay for itself. We contribute to this literature by documenting the power of a joint easing of fiscal and monetary policy to stimulate demand, with interactive effects missed by common log-linear solution methods.

Our work is also closely related to a recent literature on the role of household debt, heterogeneity, and redistribution in the transmission of macroeconomic policy. Most of this literature (Auclert, 2019; Kaplan et al., 2018) focuses on the impact of monetary policy, with some recent work on the long run sustainability of fiscal policy (Kaplan et al., 2023). The only work we know that examines monetary/fiscal interactions with household heterogeneity is Bhattarai, Lee, and Yang (2022). Because our model features realistic long-term mortgage contracts, we can match evidence that inflation redistributes mostly from old savers to young borrowers (Doepke and Schneider, 2006; Di Maggio et al., 2017). This redistributive effect of inflation is behind our novel result that demand stimulus in a recession can lower labor supply and output later on.

Finally, our paper contributes to a recent literature trying to explain the unusual 2020 Covid recession and the recovery following it (Guerrieri et al., 2021b,a; Faria-e-Castro, 2021; Bhattarai et al., 2021). This literature aims to match a range of unusual empirical facts about the Covid recession. Despite a large drop in consumption in 2020, uniquely generous policy stabilized household income and wealth (Cox et al., 2020; Chetty et al., 2020; Cherry et al., 2021; Ganong et al., 2021a,b). Relative to existing models of the post-Covid recovery, ours is the first to include a realistic financial sector that provides deposits and mortgages. We therefore can explain empirical evidence of an unprecedented boom in bank deposit quantities (Levine et al., 2021) and in mortgage refinancing (Fuster et al., 2021) during the post-Covid recovery as well as an unprecedented housing boom (Gamber et al., 2022; Mondragon and Wieland, 2022; Howard et al., 2023; Gupta et al., 2022; Davis et al., 2023).

The rest of our paper is organized as follows. Section 2 presents key stylized facts about the recovery from the 2020 Covid recession. Section 3 presents a tractable theoretical model of fiscal policy in a realistic financial system. Section 4 presents a larger quantitative model that analyzes the interaction between fiscal and monetary stimulus and confronts macroeconomic and financial data from the post-Covid boom, followed by a conclusion.

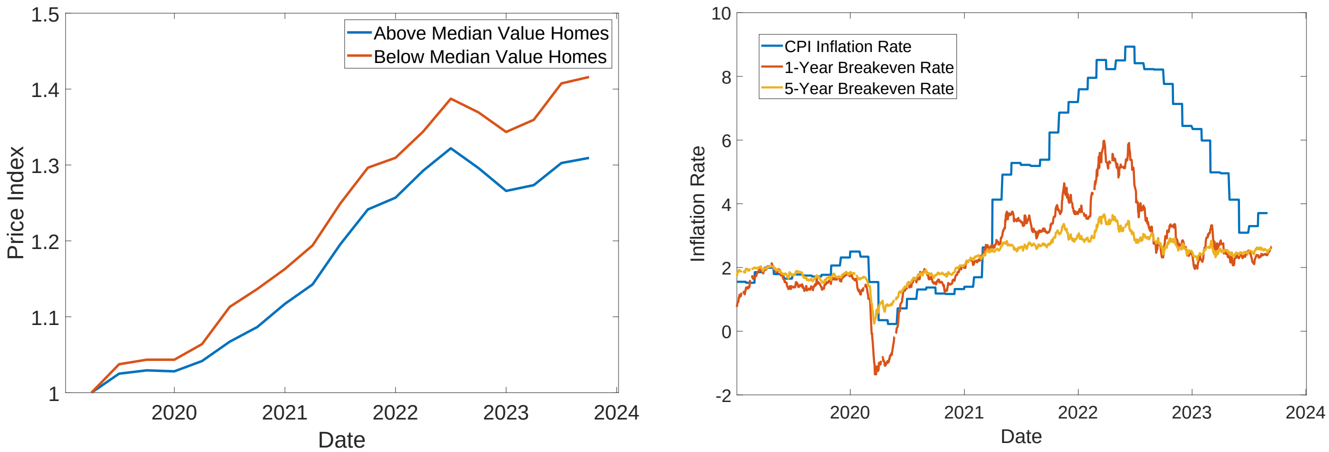
2 Motivating Facts

Three key stylized facts about the recovery from the 2020 Covid recession motivate our analysis. First, we show in figure 1a that this recovery features one of the largest housing booms in history. This chart presents a repeat sales index using Corelogic data for US house prices, separately for those that are above and below the median price in their county.[1] Above median prices grew by roughly 30%, while below median prices (likely owned by more constrained homeowners) grew by over 40%. Second, this housing boom occured during an unprecedented surge in inflation documented in figure 1b. Here, we plot realized CPI inflation as well as inflation swap breakeven rates, which reveal investors' (risk-neutral) expectations of inflation over the next 1 or 5 years. This plot shows that financial institutions believed that the post-Covid surge in inflation was transitory, with 5-year breakeven rates anchored near the 2% long-term inflation target.

Finally, this surge in inflation and house prices followed an unprecedented combination of fiscal and monetary stimulus. The U.S. ran its largest primary deficits (before interest pay-

[1] See appendix C.1 for details.

Figure 1: Inflation and House Prices After the 2020 Covid Recession



(a) Repeated Sales Indices for House Prices

(b) CPI and 1-Year/5-Year Inflation Breakevens

ments) on record in 2020 and 2021 near \$ 2.5 trillion a year, in large part to finance generous unemployment insurance and direct transfers to households. These transfers financed a large increase in the M2 money supply, which increased from roughly \$ 15 trillion at the start of 2020 to over \$21 trillion in 2022. In addition, the federal funds rate was held at zero until early 2022, by which time inflation was already above 8 percent, far below the rate suggested by a standard Taylor rule. To understand the policy response following the Covid recession, this paper analyzes the impact of a combination of loose fiscal and monetary policy and shows that it can help to explain both a surge in inflation and a housing boom that is strongest in the most constrained segments of the housing market.

3 Theoretical Model

We begin with a stylized model with banks, mortgages, and government debt to examine the macroeconomic impact of post-Covid fiscal stimulus. We first examine the impact of the government sending "checks" to households outside of a recession, when an increase in the supply of government-provided liquidity only has real effects when it is backed by future tax increases. Without such backing, the increased nominal liquidity supply is inflated away, yielding the same real allocations. This isolates a key building block for our later results- that fiscal stimulus only causes inflation when it is not combined with future tax increases.

Next, we consider the impact of transfers during a temporary recession with downwardly-rigid wages and involuntary unemployment. Due to this wage rigidity, the price level does not respond to fiscal transfers until after the recession. Sending checks to consumers in a recession therefore increases not only nominal but real liquidity supply, which stimulates consumption demand. In addition, without future tax increases, these transfers cause inflation after the recession. At a given nominal interest rate, this post-recession inflation lowers the real return on savings and reduces the real value of outstanding mortgage debt. By "printing away the mortgages," post-recession inflation results in a boost in real house prices and also increases the power of stimulus to increase consumption demand during the recession. The greater the stock of mortgage debt, the more this post-recession inflation boosts output during the recession.

Households. The main building block of our model are households who hold liquid assets to insure against idiosyncratic shocks, supply labor, make mortgage payments, and consume non-durables and housing. A household's demand for liquidity implies that "printing money" can have real economic effects if it improves the household's ability to insure against liquidity shocks, which is one key transmission channel of fiscal transfers. In addition, households' nominal mortgage debt implies that inflation can redistribute between borrowers and savers. We consider different households indexed by s with different degrees of patience, which ensures that separate borrowers and savers exist in equilibrium.

The representative household of type s begins period t holding a nominal quantity of bank deposits/liquid assets d_t^s. It earns nominal labor income $w_t l_t^s$ from its labor supply l_t^s, gets a transfer (or tax) t_t^s from the government, and starts owns housing h_{t-1}^s at nominal house price $p_t^{h,s}$. It faces a price p_t for consumption goods. In each period t, each member of the household has a probability $1-q$ of a "liquidity shock." After a liquidity shock, consumption $c_t^{s,liq}$ cannot exceed the real deposit holdings $D_t^s = \frac{d_t^s}{p_t}$. Consumption without a liquidity shock is c_t^s. Households can invest in deposits and borrow risk-free mortgages at the nominal interest rate r_t. Their mortgage face value f_t^s is bounded by a fraction λ^s of their house value in the next period, $f_t^s \leq \lambda^s p_{t+1}^{s,h} h_t^s$. The household maximizes a utilitarian objective function over the welfare of all its members, averaging over those that do and do not face liquidity shocks

$$V_t(d_t^s) = \max_{\{c_{t+\tau}^s, c_{t+\tau}^{s,liq}, l_{t+\tau}^s, h_{t+\tau}^s\}} E_t \sum_{\tau \geq 0} \beta_s^\tau [qu(c_{t+\tau}^s) + (1-q)u(c_{t+\tau}^{s,liq}) + v(h_{t+\tau}^s) - kl_{t+\tau}^s]. \tag{1}$$

The household faces a liquidity constraint $c_t^{s,liq} \leq \frac{d_t^s}{p_t}$ and a budget constraint

$$d_{t+1}^s = (1+r_t)\left[d_t^s - p_t(qc_t^s + (1-q)c_t^{s,liq}) - p_t^{s,h}(h_t^s - h_{t-1}^s) + w_t l_t^s - m_t^s - t_t^s\right], \tag{2}$$

where m_t^s is mortgage repayment minus mortgage borrowing at time t

$$m_t^s = f_{t-1}^s - \frac{f_t^s}{1+r_t} = \lambda^s p_t^{s,h} h_{t-1}^s - \frac{\lambda^s p_{t+1}^{s,h} h_t^s}{1+r_t}.$$

If the liquidity constraint does not bind, the optimal consumption level is the same with or without a liquidity shock. If it does bind, then all deposits are consumed in a liquidity shock, so $c_t^{s,liq} = \min(\frac{d_t^s}{p_t}, c_t^s)$. The first-order conditions for the households' labor supply, deposit holdings, and house purchases are

$$u'(c_t^s) = \frac{p_t}{w_t}k, \tag{3}$$

$$u'(c_t^s) = \beta_s R_t \left[qu'(c_{t+1}^s) + (1-q)u'\left(\min\left(D_{t+1}^s, c_{t+1}^s\right)\right)\right], \tag{4}$$

$$u'(c_t^s)\left[P_t^{s,h} - \frac{\lambda^s P_{t+1}^{s,h}}{R_t}\right] = v'(h_t^s) + \beta_s u'(c_{t+1}^s)(1-\lambda^s)P_{t+1}^{s,h}. \tag{5}$$

In these expressions, $R_t = (1+r_t)\frac{p_t}{p_{t+1}}$ is the real interest rate, $P_t^{s,h} = \frac{p_t^{s,h}}{p_t}$ is the real house price, and $D_t^s = \frac{d_t^s}{p_t}$ is real deposit holdings.

Production and Resource Constraint. Firms have a technology which can turn one unit of labor into one unit of consumption goods C_t they can sell. They maximize their profits $max_{\{C_t, L_t\}} p_t C_t - w_t L_t$ subject to $C_t \leq L_t$. Their first-order conditions yield $p_t = w_t$. The total output of the economy is $\sum_s l_t^s$, so the economy therefore has the resource constraint

$$\sum_s l_t^s = \sum_s \left[qc_t^s + (1-q)c_t^{s,liq}\right]. \tag{6}$$

Each household type s has a fixed quantity h^s of housing stock it can own, so $h^s = h_t^s$ for all t.

Supply of Liquid Assets and Market Equilibrium. Deposits are provided by a "bank" that invests all of its assets in central bank reserves and in mortgages, all of which are risk-free. The banking sector is profit maximizing and competitive, so the interest rates on deposits, reserves, and mortgages are the same nominal rate r_t. We state the bank's budget constraint in appendix equation (63), which can be solved forward to get its present value form

$$\sum_s D_t^s = \sum_s \lambda^s h^s P_t^{h,s} + \sum_{\tau=0}^{\infty} \frac{\sum_s T_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}} + \lim_{\tau\to\infty} \frac{\sum_s D_{t+\tau}^s - \lambda^s h^s P_{t+\tau}^{h,s}}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}}. \tag{7}$$

The assets backing deposits $\sum_s D_t^s$ are first mortgages of value $\sum_s \lambda^s h^s P_t^{h,s}$, the present value $G_t = \sum_{\tau=0}^{\infty} \frac{\sum_s T_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1}(R_{t+\theta})}$ of future tax revenue, and a potential rational bubble $\lim_{\tau\to\infty} \frac{\sum_s D_{t+\tau}^s - \lambda^s h^s P_{t+\tau}^{h,s}}{\Pi_{\theta=0}^{\tau-1}(R_{t+\theta})}$. An equilibrium is a sequence of prices, interest rates, and wages and of consumption, investment, and labor decisions where 1. each household maximizes its expected utility subject to its budget and liquidity constraints, 2. firms maximize profits, and 3. the resource constraint is satisfied.

Steady State Equilibria. The model has a continuum of steady state equilibria determined by the level of real tax revenue. When the government raises more future tax revenue, it is able to back a larger stock of government debt now. In addition, a given stream of future tax revenue has a larger present value when real interest rates decrease, so the supply of government debt is decreasing in the real rate. We also show that the demand for government debt, in turn, is increasing in the real rate, since households have greater demand for higher-yielding assets. Given a tax policy, this upward-sloping debt demand curve and downward sloping debt supply curve yield a unique real interest rate and real quantity of outstanding government debt. Because the real quantity and interest rate of government debt are determined by future real tax revenue, it follows that changes in the nominal supply of money/debt have no effect on real variables. Any nominal "helicopter drop" of transfers not financed by future taxes is immediately inflated away, holding real debt fixed.

We derive in appendix A from equation (4) an expression for steady state deposit demand

$$\sum_s (u')^{-1}\left(k\frac{1-q\beta_s R_{ss}}{(1-q)\beta_s R_{ss}}\right) = \sum_s D^s_{ss}. \tag{8}$$

This deposit demand is increasing in the real rate R_{ss} so long as marginal utility $u'(c)$ is decreasing in consumption c. In appendix A, we also use the budget constraint (equation (7)) and the expression for house prices (equation (5)) to derive the steady state deposit supply curve for $R_{ss} > 1$

$$\sum_s D^s_{ss} = \sum_s \lambda^s h_s \frac{v'(h^s)}{(1-\frac{\lambda^s}{R_{ss}} - \beta(1-\lambda^s))k} + \frac{R_{ss}}{R_{ss}-1}\sum_s T^s_{ss}. \tag{9}$$

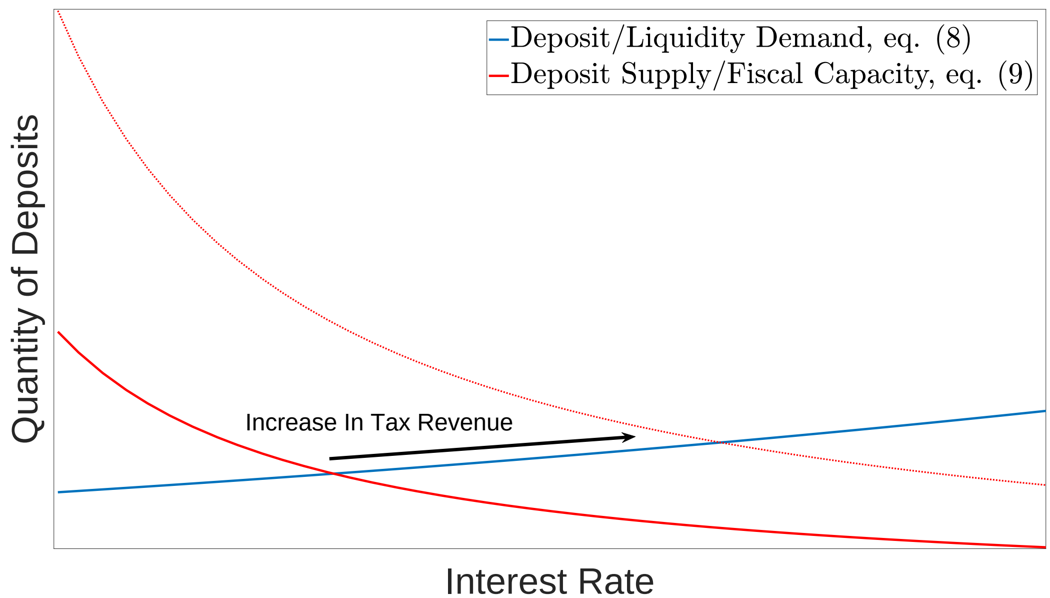
Total deposit supply is equal to the sum of outstanding government debt $\frac{R_{ss}}{R_{ss}-1}\sum_s T^s_{ss}$ and outstanding mortgage debt $\sum_s \lambda^s h_s \frac{v'(h^s)}{(1-\frac{\lambda^s}{R_{ss}}-\beta(1-\lambda^s))k}$. The supply of deposits is increasing in tax revenue $\sum_s T^s_{ss}$ and decreasing in the real rate R_{ss}.

The values of R_{ss} and $\sum_s D^s_{ss}$ that jointly satisfy the demand curve (equation (8)) and deposit supply curve (equation (9)) yield a unique equilibrium if the solution satisfies $\beta_s R_{ss} < 1$ for all households s. As the level of real tax revenue increases, the quantity of deposits supplied at a given real rate goes up, resulting in a higher equilibrium real rate and deposit quantity, as we plot in figure 2. In the appendix, we derive the following characterization of all of the model's steady state equilibria.

Proposition 1. *The model has a family of steady state equilibria, with the equilibrium uniquely determined by the government's chosen quantity of real tax revenue* $\sum_s T^s_{ss}$. *With no tax revenue, the real interest rate is* $R_{ss} = 1$. *As tax revenue* $\sum_s T^s_{ss}$ *increases, real deposit rates and quantities increase to satisfy equations 8 and 9. With sufficiently high tax revenue, the demand for liquidity from the most patient agent is satiated, and real rates cannot increase more.*

One implication of this result is that the model's real variables can be determined without direct reference to nominal quantities. As a result, holding fixed the government's policy for raising real tax revenue, changes in nominal quantities are entirely neutral. A "helicopter drop" that provides nominal deposits to all agents will be entirely dissipated by an increase in the nominal price level, leaving real quantities fixed. Similarly, a change in nominal interest rates

Figure 2: Fiscal capacity and the supply and demand for liquid assets



through conventional monetary policy will have no effect on real interest rates. However, if the government pays for transfers with an increase in future tax revenue, the real supply of liquid assets increases. This shows a key distinction between “funded” fiscal policy that results in an increase in the real supply of liquid assets and “unfunded” fiscal policy without future tax increases that simply results in inflation. The following proposition summarizes this result.

Proposition 2. *Holding fixed real tax revenue, an increase in nominal deposit quantities results in a proportional increase in nominal goods prices to keep real quantities held fixed. An increase in the nominal interest rate results in a higher inflation rate to hold real rates fixed.*

3.1 Nominal Rigidites, Involuntary Unemployment, and Fiscal Stimulus

This section analyzes the impact of fiscal transfers during a recession, when downward nominal wage rigidity results in involuntary unemployment. If the nominal wage level is w_t at time t, we now assume that wages cannot be lowered but can be costlessly increased. We consider the simplest possible case, where wage rigidity is binding at time T but not at any time afterwards. All households are rationed to supply the same quantity of labor when there is unemployment.

Because wages are held fixed by downward nominal wage rigidity, small changes in fiscal policy have no immediate impact on the price level. As a result, nominal government transfers can redistribute real resources without causing inflation, unlike proposition 2 above.

We consider the impact of a policy μ that provides a "helicopter drop" of deposits at time T, potentially raises taxes at time $T+1$, and then keeps taxes at steady state tax levels $T^s_{ss} > 0$ after time T+1. We verify in appendix A that the economy returns to steady state by time T+2, and that real rates, total output, and total real deposit supply return to steady state levels by time T+1. Below, we use these results to characterize the impact of policy in two steps. First, we show how each individual household responds to changes in deposit supply and the real interest rate in partial equilibrium. Second, we provide an expression for how the government budget constraint determines the change in real interest rates and allows us to compute the general equilibrium impact of policy.

The partial equilibrium impact of fiscal stimulus on consumption can be derived using the consumption Euler equation and budget constraint at time T

$$u'(c^s_T) = \beta_s R_T \left[qk + (1-q)u'(D^s_{T+1})\right] \tag{10}$$

$$D^s_{T+1} = R_T[D^s_T - qc^s_t - (1-q)D^s_T + l^s_t - \left(M^s_T - \frac{\lambda^s h^s P^{h,s}_{ss}}{R_T}\right) - T^s_T], \tag{11}$$

which follow from equations (2) and (4), where M^s_T is the real mortgage debt due at time T. If our policy μ provide a transfer that increases D^s_T and changes the real interest rate R_T, the response of consumption satisfies

$$\frac{dc^s_T}{d\mu} = \frac{\partial c^s_t}{\partial R_T}\frac{\partial R_T}{\partial \mu} + MPC^s_T[q\frac{\partial D^s_T}{\partial \mu} + \frac{dl^s_t}{d\mu} - \frac{\lambda^s P^{s,h}_{ss} h^s}{R^2_T}\frac{\partial R_T}{\partial \mu}], \tag{12}$$

where $\frac{\partial c^s_t}{\partial R_T}$ and MPC^s_T are the comparative statics of c^s_t with respect to changes in R_T and D^s_t implied by equations (10)-(11). We provide explicit expressions for the interest rate sensitivity of consumption $\frac{\partial c^s_t}{\partial R_T}$ and the marginal propensity to consume MPC^s_T in equations (76)-(77) of appendix A. In addition, because consumers consume all of their deposits D^s_t when facing a liquidity shock, post-liquidity-shock consumption $c^{s,liq}_T$ increases one-for-one with D^s_t.

Equation 12 illustrates the channels by which fiscal stimulus can impact consumption at time T. First, the most direct channel is that a transfer of deposits D^s_T increases consumption after a liquidity shock one-for-one, $\frac{dc^{s,liq}_T}{d\mu} = \frac{\partial D^s_T}{\partial \mu}$. Because a fraction $1-q$ of consumers face a liquidity shock, this leaves a transfer $q\frac{\partial D^s_T}{\partial \mu}$ for the rest of household s to consume. Given the household's marginal propensity to consume MPC^s_T, this results in an additional increase in consumption of $MPC^s_T q \frac{\partial D^s_T}{\partial \mu}$. The total "direct effect" of a fiscal transfer $\frac{\partial D^s_T}{\partial \mu}$ on consumption is $[qMPC^s_T + (1-q)]\frac{\partial D^s_T}{\partial \mu}$, ignoring changes in real interest rates and labor supply.

Second, fiscal stimulus increases consumption by lowering real interest rates. This occurs through two channels: intertemporal substitution and borrowing capacity. A reduction in real rates incentivizes consumers to substitute present consumption for future consumption. A reduction in R_T holding consumer wealth fixed causes consumers to increase consumption by $-\frac{\partial c^s_t}{\partial R_T}$, resulting in a (positive) consumption boost of $-\frac{\partial c^s_t}{\partial R_T}\frac{\partial R_T}{\partial \mu}$. In addition, because households can borrow at most $\frac{\lambda^s P^{s,h}_{ss} h^s}{R_T}$ against their housing, a reduction in real rates allows them to borrow more at time T. This extra borrowing capacity $-\frac{d}{dR_T}[\frac{\lambda^s P^{s,h}_{ss} h^s}{R_T}]$ is equivalent to an "indirect transfer" proportional to the outstanding mortgage debt $\lambda^s P^{s,h}_{ss} h^s$. Rate reductions therefore stimulate consumption more when there is more outstanding mortgage debt.

Finally, fiscal stimulus increases consumption by endogenously increasing labor supply. A greater quantity of consumption demanded requires a greater quantity of labor to produce consumable goods. In a recession with involuntary unemployment, this results in a greater quantity of labor supplied because workers work less than they would choose at the going wage. For an increase $\frac{dl_t}{d\mu}$ in labor income, household s consumes an additional $MPC^s_T \frac{dl_t}{d\mu}$. The following proposition summarizes these results on the impact of fiscal stimulus in partial equilibrium.

Proposition 3. *If the government provides deposits D^s_T to agents in a recession at time T and potentially raises taxes T^s_{T+1} afterwards at time T+1, the impact of fiscal policy on aggregate consumption is given by equation 12. This consumption response is the sum of:*

1. *The direct effect of providing deposits D^s_T, out of which the total marginal propensity to consume is $qMPC^s_T + (1-q)$ for household s.*

2. *The effect of a reduction in real interest rates. This leads to a boost $\frac{\partial c^s_t}{\partial R_T}\frac{-\partial R_T}{\partial \mu}$ in consumption due to households' intertemporal substitution. In addition, consumption is boosted by $MPC^s_T \frac{\lambda^s P^{s,h}_{ss} h^s}{R^2_T}\frac{-\partial R_T}{\partial \mu}$ due to greater mortgage borrowing capacity.*

3. Endogenous effects on labor income. Each added unit of labor income for household s increases its consumption by MPC^s_T.

Based on our partial equilibrium result in proposition 3, we can characterize the impact of fiscal stimulus once we know how real rates R_T and labor supply l^s_t endogenously respond. The impact the of our policy μ on real rates follows from the government budget constraint, which we derive in equation (79) of appendix A.

$$G_{ss} = G_{T+1} = R_T G_T - \sum_s T^s_{T+1} \tag{13}$$

Government debt G_{T+1} at time T+1 is equal to its steady state level G_{ss} since wage rigidity no longer binds at time T+1, so the steady state results in section 3 apply. The impact of our policy μ on real interest rates is given by

$$\frac{\partial R_T}{\partial \mu} = \frac{R_T \frac{\partial G_T}{\partial \mu} - \sum_s \frac{\partial T^s_{T+1}}{\partial \mu}}{G_T}. \tag{14}$$

Equation 14 shows that real interest rates fall only if the government does not finance its spending at time T with tax raises at time T+1. $R_T \frac{\partial G_T}{\partial \mu}$ is the value at time T+1 of the debt issued at time T to finance increased spending. This increased debt minus the new tax revenue $\sum_s \frac{\partial T^s_{T+1}}{\partial \mu}$ raised at time T+1 determines how much remaining debt must be inflated away to return to steady state debt levels. Because we showed in proposition 3 that lowering real rates increases the impact of fiscal policy on consumption, fiscal stimulus is more stimulative when it is not combined with increases in future taxes $\sum_s T^s_{T+1}$ to pay for it. If our fiscal policy is not accompanied by any change in nominal interest rates due to monetary policy, the reduction in real rates R_T must be entirely due to an increase in the nominal price level at time $T+1$. We summarize our results in the following proposition.

Proposition 4. *1. The impact of fiscal stimulus on real interest rates is given by equation 14. The decrease in real rates R_T is proportional to the amount of added debt $R_T \frac{\partial G_T}{\partial \mu}$ that accrues at time T+1 from transfers at time T minus the taxes $\sum_s \frac{\partial T^s_{T+1}}{\partial \mu}$ raised to pay for this spending.*

2. If the government holds nominal interest rates fixed at time T, the reduction in real interest *rates at time T occurs entirely from an increase in inflation at time T+1. That is, unfunded fiscal transfers during a recession at time T result in future inflation at time T+1.*

Finally, we characterize the impact of our fiscal stimulus μ on the quantity of labor supplied. This follows from the resource constraint in equation 6. Since all agents are assumed to supply equal amounts of labor when there is involuntary unemployment, the resource constraint implies

$$\frac{\partial l_t^s}{\partial \mu} = \frac{1}{S}[\sum_s q\frac{\partial c_T^S}{\partial \mu} + (1-q)\frac{\partial D_T^S}{\partial \mu}]. \tag{15}$$

Using this expression for $\frac{\partial l_t^s}{\partial \mu}$ in equation (12), we get that the aggregate response of consumption to our policy is given by equation (16). We summarize the implications in proposition 5.

$$(\sum_s \frac{dc_T^s}{d\mu})(1-\frac{1}{S}\sum_{s'} MPC_T^{s'})=\sum_s\{\frac{\partial c_t^s}{\partial R_T}\frac{\partial R_T}{\partial \mu}+MPC_T^s[q\frac{\partial D_T^s}{\partial \mu}+\frac{1}{S}\sum_{s'}(1-q)\frac{\partial D_T^{s'}}{\partial \mu} - \frac{\lambda^s P_{ss}^{s,h} h_t^s}{R_T^2}\frac{\partial R_T}{\partial \mu}]\}. \tag{16}$$

Proposition 5. *1. The total impact of fiscal stimulus on consumption at time T is given by equation (16). The right hand side gives the direct impact of transfers $\frac{\partial D_T^s}{\partial \mu}$ and the impact of real interest rate changes $\frac{\partial R_T}{\partial \mu}$ on consumption, as described in proposition 3.*

2. The total response of consumption to fiscal stimulus equals the right hand side divided by $(1-\frac{1}{S}\sum_{s'} MPC_T^{s'})$, reflecting Keynesian multiplier effects. The increase in consumption causes an equal increase in labor income, of which a fraction $\frac{1}{S}\sum_{s'} MPC_T^{s'}$ is consumed too.

House price impact. We finally analyze the impact of fiscal stimulus on house prices. Since house prices and consumption return to their steady state levels at time $T+1$, the first-order condition for house purchases (equation (5)) at time T is

$$u'(c_T^s)\left[P_T^{s,h} - \frac{\lambda^s P_{ss}^{s,h}}{R_T}\right] = v'(h^s) + \beta_s u'(c_{ss}^s)(1-\lambda^s)P_{ss}^{s,h}. \tag{17}$$

Other than house prices $P_T^{s,h}$, the only variables in equation (17) that respond to policy are consumption c_s^T and real rates R_T, whose responses are given by equations (12) and (14). The impact of fiscal stimulus on time T house prices is gven by

$$\frac{\partial P_T^{s,h}}{\partial \mu} = -\frac{\partial c_s^T}{\partial \mu}\frac{u''(c_s^T)}{u'(c_T^s)}\left[P_T^{s,h} - \frac{\lambda^s P_{ss}^{s,h}}{R_T}\right] - \frac{\lambda^s P_{ss}^{s,h}}{R_T^2}\frac{\partial R_t}{\partial \mu}. \tag{18}$$

The house price of group s increases through two channels. First, an increase in consumption c_t^s decreases the marginal disutility of funding the down payment $P_T^{s,h} - \frac{\lambda^s P_{ss}^{s,h}}{R_T}$. For CRRA utility with risk aversion γ, we have that $-\frac{\partial c_T^s}{\partial \mu}\frac{u''(c_T^s)}{u'(c_T^s)} = \frac{\partial c_s^T}{\partial \mu}\frac{\gamma}{c_T^s}$. Second, a reduction in real rates boosts the collateral value of housing, with the price increase proportional to the house's debt capacity $\lambda^s P_{ss}^{s,h}$. If the consumption of the most indebted homeowners grows the most after fiscal transfers, their house prices must increase the most too, as stated in proposition 6.

Proposition 6. *Fiscal stimulus that increases households' consumption c_T^S at time T and lowers the real interest rate R_T boosts time T house prices. This house price increase is greater (under CRRA utility) for those experiencing a larger growth $\frac{\partial c_s^T}{\partial \mu}\frac{1}{c_T^s}$ in consumption and those with higher leverage λ^s.*

Discussion Our model's novel insights come from the interaction between fiscal policy and the private sector financial system. First, we showed that outside a recession, the impact of fiscal policy works by increasing the real supply of liquid bank deposits. Because the supply and demand for deposits can be computed in real terms, a nominal "helicopter drop" without any added tax revenue only causes inflation. Second, we showed that similar unfunded fiscal transfers during a recession both increase output and also cause delayed inflation after the recession ends. This explains why large transfers in 2020 may have contributed to inflation in 2021-2022. Third, our model shows that the impact of unfunded fiscal transfers on both output and on house prices increase with the supply of outstanding mortgage debt. The inflation needed to satisfy the government budget constraint increases output and house prices more when a larger supply of private debt is inflated away too. Qualitatively, the rapid recovery from the 2020 recession, followed by a boom in house prices and inflation is precisely what a generous, unfunded fiscal stimulus causes in our model.

4 Quantitative Model

We next analyze the impact of fiscal and monetary stimulus after a deep recession in a richer quantitative model. The model has separate borrower and saver households, where borrowers finance their consumption with mortgages. A financial intermediary holds both mortgages and government debt to back its issuance of bank deposits. Output is produced by firms that have nominal rigidities in both their price and wage setting, so unemployment occurs when consumption demand is sufficiently low. The central bank sets monetary policy following a Taylor rule, reacting to both inflation and output in its interest rate choices. Finally, a fiscal authority follows a rule by which it raises lump sum taxes (or makes transfers) T_t^B, T_t^S on the borrower and saver.

We use this model to simulate a Covid-induced recession and its policy response. The recession is triggered by all agents temporarily become more patient and wanting to reduce their consumption. This results in deflation, unemployment, a house price crash, and higher mortgage defaults without any government intervention. We then show that with unemployment insurance that fully replaces the income of all unemployed households, the drop in consumption caused by this recession falls by roughly half. We then consider large additional fiscal stimulus in the shape of increased transfer payments. Finally, we show that when this fiscal stimulus is combined with a temporary shift towards a monetary policy rule that is less responsive, consumption recovers more strongly. However, this passive monetary policy also results in a surge of inflation up to a peak of 8% and a real increase in house prices of borrowers beyond the inflation rate.

4.1 Setup

The economy has two types of goods which agents want to consume: housing and non-durables. There are two groups of households in the model, savers and borrowers. The housing stock is segmented, with each group of households trading an exogenous supply $\bar{H}^j$, with $j \in \{B, S\}$, that produces one unit of housing services each period. Each unit of housing requires δ^h units of non-durable consumption spent each period to maintain it.

4.2 Production

Non-durable output is produced as a constant elasticity of substitution aggregate of a continuum of varieties $Y_t(i)$, as is standard in a New Keynesian model. Total output is given by

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}, \tag{19}$$

where $Y_t(i)$ it the quantity of intermediate good i used to produce the final good. Each intermediate good $Y_t(i)$ is produced from labor and capital with a production function

$$Y_t(i) = Z_t n_t(i)^{1-\alpha} k_t(i)^{\alpha} \tag{20}$$

where Z_t is an aggregate productivity level, and $n_t(i)$ and $k_t(i)$ are the quantity of labor and capital, respectively, used to produce variety i. Log-productivity $z_t = \log(Z_t)$ is an exogenous variable that follows an AR(1) process driven by normally distributed productivity shocks ε_t:

$$z_{t+1} = (1 - \rho_z)\bar{z} + \rho_z z_t + \varepsilon_{t+1}. \tag{21}$$

4.3 Households

Borrower households act collectively to maximize their utilitarian welfare across all members i. Borrower i gets utility $U^B(c^B_{i,t}, h^B_t, \ell^B_t)$ at time t from consuming non-durables $c^B_{i,t}$ and housing h^B_t and supplying labor ℓ^B_t where

$$U^B(c^B_{i,t}, h^B_t, \ell^B_t) = u(c^B_{i,t}) + K^B_h u(h^B_t) - \chi^B_0 v(\ell^B_t), \tag{22}$$

with $u(c) = c^{1-\gamma}/(1-\gamma)$ and $v(\ell) = \ell^{1+\chi_1}/(1+\chi_1)$.

Borrowers aim to maximize their lifetime expected utility, which equals

$$\mathrm{E}_0 \sum_t \beta^t_B \int_0^1 U^B(c^B_{i,t}, h^B_t, \ell^B_t) di. \tag{23}$$

net of some costs related to mortgage refinancing specified below.

Savers obtain utility from non-durables c_t^S, housing h_t^S, and their real holdings d_{t+1}^S of bank deposits. They also dislike supplying labor ℓ_t^S to firms. Their utility function is

$$U^S(c_t^S, h_t^S, d_{t+1}^S, n_t^S) = u(c_t^S) + K_h^S u(h_t^S) + K_d u(d_{t+1}^S) - \chi_0^S v(\ell_t^S). \tag{24}$$

Savers aim to maximize their lifetime expected utility

$$\mathrm{E}_0 \sum_t \beta_S^t U^S(c_t^S, h_t^S, d_{t+1}^S, n_t^S). \tag{25}$$

Savers are more patient than borrowers, so $\beta_S > \beta_B$.

4.4 Markets

At each time t, households face a nominal price P_t of buying consumption goods. The inflation rate at time t is given by $\pi_t = \frac{P_t}{P_{t-1}} - 1$.

Our economy has competitive markets where housing trades for price $p_t^{h,j}$ among borrowers $j = B$ and savers $j = S$, respectively. Riskless bank deposits are available with nominal interest rate ${}^{\$}i_t$.[2]

In addition to these markets, borrowers can take out mortgages issued by financial intermediaries. Mortgages are summarized by their remaining nominal principal ${}^{\$}m_t$ at time t. Mortgage payments decline geometrically at a rate $0 < \delta^m < 1$, such that ${}^{\$}m_t = \delta^m {}^{\$}m_{t-1}$. When a borrower takes out a mortgage of nominal face value ${}^{\$}m_t$, it receives a nominal cash flow of $q_t^m {}^{\$}m_t$, where q_t^m is the price of mortgage credit. A borrower with mortgage face value ${}^{\$}m_{t-1}$ at time $t-1$ owes a payment of $(\iota + (1-\delta^m)\bar{q}^m){}^{\$}m_{t-1}^B$ at time t. The variable ι can be seen as the interest payment of the mortgage and $(1-\delta^m)\bar{q}^m$ as the payment towards reducing the principal. Together, parameters ι, δ^m, and $\bar{q}^m$ allow us to mimic the properties of real-world fixed-rate mortgages in a tractable way. To simplify notation going forward, we define the total

[2] The prices of all financial assets will be written in real terms – their nominal prices divided by the price index P_t. We index any nominal variable with a dollar sign as left superscript. The same variable without such a script denotes its real value (the nominal value divided by P_t). For example, the nominal deposit holdings of borrowers are ${}^{\$}d_t^B$ and real deposits are $d_t^B = {}^{\$}d_t^B / P_t$.

mortgage payment

$$Q^m = \iota + (1 - \delta^m)\bar{q}^m.$$

Borrowers can choose to prepay their mortgage, in which case they pay κm_t for a mortgage of real face value $m_t = {}^{\$}m_t / P_t$, where κ is a fixed parameter. Borrowers can also default on their mortgages, in which case their housing is seized and sold, with a fraction ζ of its value lost as a foreclosure discount.

4.5 Borrower's Problem

Borrowers form a household that maximizes their overall welfare. They begin at time t owning housing h_t^B, nominal deposits ${}^{\$}d_t^B$, and owing a mortgage of nominal face value ${}^{\$}m_t$. There are two sub-periods within each period t. First, borrowers begin with a "consumption stage," where they choose how much consumption to allocate to each member and how much labor to supply. In addition, some household members default on their mortgages. Second, the household chooses a subset of members that enter a "mortgage stage." By entering the mortgage stage, a borrower can re-optimize their mortgage terms. All borrowers entering the mortgage stage refinance their balance at the current market price q_t^m. Entering borrowers can further decide to increase their mortgage balance to the maximum LTV ratio, akin to a "cash-out refi."

In each period, the overall utility of the household is, using the utility function $U^B(c_{i,t}^B, h_t^B, \ell_t^B)$ in equation (22),

$$\int_0^1 U^B(c_{i,t}^B, h_t^B, \ell_t^B) di \tag{26}$$

in addition to some utility costs of mortgage refinancing specified below. This cross-sectional integral over all household members i gives their average utility at time t.

Consumption Stage In the consumption stage, the household earns a wage ${}^{\$}w_t$ per unit of labor that is hired by firms. Units of labor hired by firms are $\tilde{\ell}_t^B \leq \ell_t^B$, since the labor market features downward wage rigidity and involuntary unemployment, explained below in Section 4.10. Resulting total labor income is ${}^{\$}w_t \tilde{\ell}_t^B$. Each individual household member i receives labor income ${}^{\$}w_t \tilde{\ell}_t^B \epsilon_i$, where ϵ_i is a mean one idiosyncratic shock that is i.i.d. across borrowers. Each borrower faces a cash-in-advance constraint that it can only consume and make mortgage payments out of its deposit holdings and labor income. Borrower consumption (which equals $c_t^d(\epsilon)$ if it defaults and $c_t^{nd}(\epsilon)$ if not) must therefore satisfy

$$c_t^d(\epsilon) \leq w_t \tilde{\ell}_t^B \epsilon + d_t^B, \tag{27}$$

$$c_t^{nd}(\epsilon) \leq w_t \tilde{\ell}_t^B \epsilon + d_t^B - Q^m m_t. \tag{28}$$

Each borrower is required to consume a minimum quantity $\bar{c}$ before making its mortgage payment and defaults if this is impossible. That is, the borrower defaults if $\bar{c} + Q^m m_t < w_t \tilde{\ell}_t^B \epsilon + d_t^B$. Let $\hat{\epsilon}_t$ be the threshold value of ϵ below which a household defaults, so

$$\hat{\epsilon}_t = \frac{\bar{c} + Q^m m_t - d_t^B}{w_t \tilde{\ell}_t^B}. \tag{29}$$

A fraction $F(\hat{\epsilon}_t)$ of borrowers default at time t, where F is the CDF of the distribution of ϵ. Each borrower that defaults gets its per-capita share of the borrower family's housing seized after the consumption stage.

In addition to these defaults, the borrower family chooses consumption (subject to its cash in advance constraint) and labor supply. The total consumption of the household is given by

$$C_t = \int_0^{\hat{\epsilon}_t} c^d(\epsilon) dF(\epsilon) + \int_{\hat{\epsilon}_t}^{\infty} c^{nd}(\epsilon) dF(\epsilon). \tag{30}$$

Mortgage Stage. The household enters the mortgage stage with a remaining real deposit balance d_t^+ given by

$$d_t^+ = d_t^B + (1 - F(\hat{\epsilon}_t)) h_t (p_t^{h,B} - \delta^h) + w_t \tilde{\ell}_t^B - T_t^B - C_t - (1 - F(\hat{\epsilon}_t)) Q^m m_t. \tag{31}$$

After the consumption stage, each borrower gets a random draw η_t^h that is their utility cost of entering the mortgage stage. By entering the mortgage stage, a borrower refinances their mortgage and prepays the old balance at cost κ per dollar of real face value. The borrower chooses between a "cash out refi" and a "rate refi" for their mortgage. If they choose the cash out refi, they pay an additional (potentially negative) utility penalty η_t^r. A cash out refi takes out a new mortgage that provides a nominal sum of $P_t \theta p_t^{h,B} h_t^B$ today. The face value of this mortgage is $\frac{P_t \theta p_t^{h,B} h_t^B}{q_t^m}$. The parameter θ exogenously sets the down payment on a new mortgage. A rate refi takes out a new mortgage at price q_t^m so that the borrower's current cash balance does not change. The household chooses a threshold $\hat{\eta}_t^h$ for entering the mortgage stage and a threshold $\hat{\eta}_t^{cr}$ for choosing a cash out refi conditional on having entered the mortgage stage. These choices imply the following law of motion for real aggregate mortgage debt

$$m_{t+1} = \frac{1 - F(\hat{\epsilon}_t)}{1 + \pi_{t+1}} \left[\delta^m m_t \left(1 - F_h(\eta_t^h) + F_h(\eta_t^h)(1 - F_{cr}(\eta_t^{cr})) \frac{\kappa}{q_t^m} \right) + F_h(\eta_t^h) F_{cr}(\eta_t^{cr}) \frac{\theta p_t^{h,B} h_t^B}{q_t^m} \right]. \tag{32}$$

Complete Problem. The state variables of the borrower problem are housing h_t^B, and real mortgage debt and deposits (m_t^B, d_t^B). Denoting the aggregate state variables exogenous to borrowers as $\mathcal{Z}_t$, we can write the complete borrower household optimization problem as

$$\begin{aligned} V(h_t^B, m_t^B, d_t^B; \mathcal{Z}_t) = \max_{\substack{c^d(\epsilon), c^{nd}(\epsilon), h_{t+1}^B, \\ \hat{\eta}_t^h, \hat{\eta}_t^{cr}, \ell_t^B}} & \int_0^{\hat{\epsilon}_t} u(c^d(\epsilon)) dF(\epsilon) + \int_{\hat{\epsilon}_t}^{\infty} u(c^{nd}(\epsilon)) dF(\epsilon) + K_h^B u(h_t^B) - \chi_0^B v(\ell_t^B) \\ & - (1 - F(\hat{\epsilon}_t)) F_h(\hat{\eta}_t^h) \mathrm{E}[\eta^h \mid \eta^h < \hat{\eta}_t^h] && (33) \\ & - (1 - F(\hat{\epsilon}_t)) F_h(\hat{\eta}_t^h) F_{cr}(\hat{\eta}_t^{cr}) \mathrm{E}[\eta^{cr} \mid \eta^{cr} < \hat{\eta}_t^{cr}] && (34) \\ & + \beta_B \mathrm{E}_t \left[V(h_{t+1}^B, m_{t+1}^B, d_{t+1}^B; \mathcal{Z}_{t+1}) \right] && (35) \end{aligned}$$

subject to cash in advance constraints (equations (27), (28)) in the consumption stage, the default threshold $\hat{\epsilon}_t$ given in equation (29), the transition law for mortgage debt in (32), and the following law of motion for real deposits with d_t^+ given in equation (31),

$$d_{t+1}^B = \frac{1 + {}^{\$}i_t}{1 + \pi_{t+1}} \left[d_t^+ - p_t^{h,B} h_{t+1}^B + (1 - F(\hat{\epsilon}_t)) F_h(\hat{\eta}_t^h) F_{cr}(\hat{\eta}_t^{cr}) \left(\theta p_t^{h,B} h_t^B - \kappa \delta^m m_t \right) \right]. \tag{36}$$

Lines (33) and (34) are the total utility cost for borrowers entering the mortgage stage and choosing a cash-out refi, respectively. It is important to note that liquid savings d_t^B and mortgages m_t^B are nominal claims; the transition laws for the real value of these assets in (32) and (36) is affected by inflation, a key force in the model.

4.6 Saver's Problem

The representative saver maximizes its lifetime expected utility given in equation (24) depending on consumption c_t^S, housing h_t^S, labor supply ℓ_t^S, and the real value of bank deposits $d_{t+1}^S = \frac{^{\$}d_{t+1}^S}{P_t}$ that savers choose to hold in t, where $^{\$}d_{t+1}^S$ are the saver's nominal deposit holdings. In addition to its labor income, the saver owns the capital stock, all non-financial firms, and all equity issued by the financial intermediary.

Let Y_t^S denote the total capital income of savers from producers, including profits from producing firms and the returns from renting capital to firms. In addition, let div_t^I be the dividend paid by intermediary equity at time t as specified below in equation (41) and equ_t^I be the equity raised by the intermediary at time t. Because the saver has to hold all bank equity and the entire capital stock in equilibrium, we can consider their decision as only optimizing over consumption c_t^S, next period's housing h_{t+1}^S, labor ℓ_t^S, and next period's deposits d_{t+1}^S. Finally, let Reb_t be a payoff to the saver equal to all deadweight losses caused by mortgage defaults, which we include to preserve the simple relation that total consumption equals total output, net of depreciation of capital and housing. We provide an expression for Reb_t in equation (89) in appendix B.

The saver's state at the start of the t can be summarized by its wealth W_t^S and its housing stock h_t^S. The saver's Bellman is

$$V^S(W_t^S, h_t^S; \mathcal{Z}_t) = \max_{c_t^S, h_{t+1}^S, d_{t+1}^S, \ell_t^S} U^S(c_t^S, h_t^S, d_{t+1}^S, \ell_t^S) + \beta_S \mathrm{E}_t V^S(W_{t+1}^S, h_{t+1}^S; \mathcal{Z}_{t+1}) \tag{37}$$

subject to the budget constraint

$$W_t^S + w_t \ell_t^S = c_t^S + p_t^{h,S} h_t^S + equ_t^I + d_{t+1}^S, \tag{38}$$

and the definition of next period's wealth

$$W_{t+1}^S = Y_{t+1}^S + (p_{t+1}^{h,S} - \delta^h) h_{t+1}^S + div_{t+1}^I + Reb_{t+1} + \frac{1 + {}^{\$}i_t}{1 + \pi_{t+1}} d_{t+1}^S, \tag{39}$$

with the utility function given by equation (24).

4.7 Financial Intermediary

The financial intermediary is a profit maximizing firm whose equity is owned by savers. The intermediary holds mortgages to borrowers and government debt. It is financed by issuing a mix of riskless deposits and loss-bearing equity. For simplicity, the intermediary pays out all remaining cash flows generated by its portfolio every period in the trading stage and then raise new deposits and equity to fund more loans. The intermediary lends a nominal payment $q_t^m {}^{\$}m_{t+1}^I$ when it issues mortgages of nominal face value ${}^{\$}m_{t+1}^I$. It also holds central bank reserves ${}^{\$}B_{t+1}^I$, which pay the nominal interest rate ${}^{\$}i_t^B$, at the central bank. When intermediaries issue new mortgages and invest in reserves, these investments are funded with a combination of equity equ_t^I and promising a nominal payment of $(1 + {}^{\$}i_t){}^{\$}D_{t+1}^I$ to depositors at time $t+1$. Thus, the intermediary faces the budget constraint

$$equ_t^I + D_{t+1}^I = q_t^m m_{t+1}^I + B_{t+1}^I. \tag{40}$$

Suppose the intermediary issues mortgages of total nominal face value ${}^{\$}m_t^I$ at time t which generate a repayment $\mathcal{P}_{t+1}$ per dollar of face value. The intermediary first owes the nominal payment $(1 + {}^{\$}i_t){}^{\$}D_{t+1}^I$ to its depositors before equity holders can be paid. A fraction ν of the cash flows to be paid to equity holders are lost, as a measure of the cost of financial intermediation. The equity holders get the residual payment of div_{t+1}^I given by

$$div_{t+1}^I = (1-\nu)\left(\mathcal{P}_{t+1} m_{t+1}^I - \frac{1 + {}^{\$}i_t}{1+\pi_{t+1}} D_{t+1}^I\right). \tag{41}$$

The intermediary also faces a regulatory capital requirement that requires in all states of the world its equity is worth at least a fraction $\bar{e}$ of the value of its assets. This capital requirement can be written as

$${}^{\$}D_{t+1}^I \leq (1-\bar{e}^R){}^{\$}B_{t+1}^I + (1-\bar{e}) \min_{z_{t+1}|\mathcal{Z}_t} \mathcal{P}_{t+1} {}^{\$}m_{t+1}^I \tag{42}$$

where $\min_{z_{t+1}|\mathcal{Z}_t} \mathcal{P}_{t+1}$ denotes the lowest possible realization of $\mathcal{P}_{t+1}$ given information available at time t. The capital requirement for mortgages and reserves are $\bar{e}$ and $\bar{e}^R$, respectively.

The intermediary's equity is priced by the saver's stochastic discount factor $\mathcal{M}_{t,t+1}^S$(given in equation (86)), so at time t it maximizes

$$\max_{m_{t+1}^I, D_{t+1}^I, B_{t+1}^I} - equ_t^I + \mathrm{E}_t \mathcal{M}_{t,t+1}^S div_{t+1}^I \tag{43}$$

subject to equations (40), (41) and inequality (42). Because the saver gets utility directly from holding deposits, the deposit rate will always be strictly below the risk-free rate implied by $\mathcal{M}_{t,t+1}^S$. The intermediary therefore always issues the maximum quantity of deposits and its leverage constraint in (42) is always binding.

With $F(\hat{\epsilon}_t)$ denoting the probability of borrower default, the real value $\mathcal{P}_t$ of the intermediary's mortgage portfolio per dollar of face value is given by

$$\mathcal{P}_t = \frac{1 - F(\hat{\epsilon}_t)}{1 + \pi_t} [Q^m + \delta^m q_t^m] + F(\hat{\epsilon}_t) \frac{h_t^B}{m_t^B} \left((1 - \zeta) p_t^{h,B} - \delta^h \right). \tag{44}$$

If a borrower does not default, the intermediary receives a cash payment of Q^m per dollar of face value and the remaining mortgage has a fraction δ^m of its previous face value. The market value of this remaining mortgage is $\delta^m q_t^m$. If the borrower does default, the intermediary seizes $\frac{h_t^B}{m_t^B}$ units of housing collateral per dollar of mortgage face value. The intermediary has to make a real payment of $\delta^h \frac{h_t^B}{m_t^B}$ to maintain this housing stock and resells each unit of housing for $p_t^{h,B}$, after the foreclosure loss ζ. Weighting the default and no-default payoffs by their probabilities as the intermediary diversifies across many mortgages yields the portfolio's payoff per dollar of face value.

4.8 Production Sector

This section describes how the economy's non-durable consumption output is produced by profit maximizing firms. In each sector a, b, there is a final consumption good that is produced using a continuum of intermediate goods specific to that sector. The intermediate goods are then produced by firms which use capital and labor for production. Intermediate goods produces have nominal rigidities in both their wage and price setting while final goods produces have flexible prices.

Final goods. The final goods producer maximizes its profits

$$\max_{Y_t, Y_t(i)} P_t Y_t - \left(\int_0^1 Y_t(i) P_t(i) di \right). \tag{45}$$

subject to equation (19) that ensures it produces as much as it sells. The final goods sector is competitive with free entry so zero profits are earned in equilibrium. Standard results (Appendix B.5.1) imply that a profit maximizing final goods producer has demand for intermediate goods given by

$$Y_t(i) = Y_t \left(\frac{P_t(i)}{P_t} \right)^{-\eta}, \tag{46}$$

where

$$P_t = \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{1}{1-\eta}}.$$

Equation (46) determines the demand curve that intermediate goods producers face when maximizing their profits.

Intermediate Goods. Intermediate good firms maximize the present value of their profits subject to constraints that make their prices sticky. Following Rotemberg (1982), firms face a quadratic cost of moving the growth rate in their prices from an exogenous inflation target of $\bar{\Pi}$. We take as a state variable today's level of their individual nominal goods price p_{t-1}^j as well as all aggregate states $\mathcal{Z}_t$. The firm faces a demand curve $y_j(p_t^j)$ for its intermediate good given by equation (46). The intermediate good firm's Bellman equation is (suppressing j subscripts)

$$\begin{aligned} V^W(p_{t-1}, \mathcal{Z}_t) = \max_{p_t, n_t, k_t} \frac{p_t}{P_t} y(p_t) - (w_t n_t + r_t^K k_t) - \frac{\xi}{2} \left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1 \right)^2 \\ + \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^S V^W(p_t, \mathcal{Z}_{t+1}) \right], \end{aligned} \tag{47}$$

subject to the constraint that it produces as much as it sells

$$(Z_t n_t)^\alpha k_t^{1-\alpha} \geq y(p_t).$$

In this Bellman equation, P_t is the overall price index, w_t and r_t^K are the real wage and real rental rate of capital for the firm. The ratio $\frac{p_t}{P_t}$ between the firm's price and the overall price level gives the real value of the firm's output. ξ is a constant that determines the severity of price stickiness, and $\bar{\Pi}$ is a constant that determines the long-run inflation rate in the economy (equal to the central bank's inflation target). $\mathcal{M}_{t,t+1}^S$ is the stochastic discount factor of the firm's shareholders (who in equilibrium are the savers).

Because all intermediate goods producers are identical, they choose the same price $p_t = P_t$. In appendix B.5.2, we derive a standard forward-looking price setting condition for firms.

4.9 Monetary and Fiscal Authority

Monetary. The central bank directly sets the nominal interest rate banks receive on their excess reserves ${}^{\$}i_t^B$. To do so, it follows a monetary policy rule[3]

$$1 + {}^{\$}i_t^B = \left[(1+\bar{i}) \left(\frac{1+\pi_t}{\bar{\Pi}} \right)^{\phi^\pi} \left(\frac{Y_t}{\bar{Y}} \right)^{\phi^y} \right]^{1-\Phi_t} (1+\hat{i})^{\Phi_t}. \tag{48}$$

The central bank's inflation target is $\bar{\pi}$ and its target level for cyclical output is $\bar{Y}$. The first term of the rule specifies deviations from the average gross interest rate $1+\bar{i}$, which is the steady state interest rate at output $\bar{Y}$ and trend inflation $\bar{\Pi}$. Time-varying parameter $\Phi_t \in [0,1]$ governs the degree to which monetary policy may turn temporarily passive. When $\Phi_t = 0$, the central bank fully adheres to its rule. Values of $\Phi_t > 0$ shift weight away from the active rule and towards a passive interest rate peg $\hat{i}$ that could be different from $\bar{i}$.

Fiscal. We assume that all government debt is in the form of short-term debt and reserves held by intermediaries, ${}^{\$}B_t^G$. A fiscal authority raises taxes to pay interest on outstanding bank reserves. Taxes are raised proportionally as a fraction GDP, with the tax share of GDP given by

$$\tau_t = \bar{\tau}_0 \frac{B_t^G}{\bar{B}},$$

[3]During simulations of demand shock driven crises that mimic the Covid shock, we impose a rationally expected zero-lower-bound on the policy rate along the transition path back to steady state. However, the policy rate (almost) never reaches zero in long simulations of the model driven by TFP shocks. Imposing a ZLB outside of crisis periods would have a negligible effect on model dynamics in the stationary equilibrium.

where $\bar{\tau}_0$ is the average tax rate and $\bar{B}$ is the real steady state supply of debt. The tax rule implies that the government responds to higher debt levels through higher taxation. Total tax revenue $\tau_t Y_t$ is raised from borrower labor income and lump-sum taxation of savers. The government also makes regular transfer payments that are fraction ϑ of GDP. Further, the government replaces the labor income of unemployed households at rate ϑ^U, leading to total additional expenditure $Unemp_t$ (given in equation 57). Details on how these taxes and transfers are allocated to borrowers and savers are in equations (60) and (61) below. The government budget constraint in each period is

$$ {}^{\$}B_t^G = (1 + {}^{\$}i_t^B)\, {}^{\$}B_{t-1}^G - (\tau_t - \vartheta) Y_t + Unemp_t. \tag{49} $$

4.10 Equilibrium

In an equilibrium of our economy, borrowers and savers each maximize their lifetime expected utility and all firms maximize the present value of their profits. In addition, all markets need to clear.

Asset Markets. There are five asset markets: borrower and saver housing, deposits, mortgages, and government debt, yielding the following conditions

$$ h_t^B = \bar{H}^B, \qquad h_t^S = \bar{H}^S, \tag{50} $$

$$ {}^{\$}d_t^B + {}^{\$}d_t^S = {}^{\$}D_t^I, \qquad {}^{\$}m_t^B = {}^{\$}m_t^I, \tag{51} $$

$$ {}^{\$}B_t^G = {}^{\$}B_t^I. \tag{52} $$

Labor and Capital Market Clearing. The real wage is subject to a lower bound $\bar{\omega}$ in the spirit of Schmitt-Grohé and Uribe (2016). Labor demand from firms at given real wage ω_t is $N_t^f(w_t)$; we assume that labor market equilibrium is demand-determined such that firms are always on their labor demand curve. Desired labor supply from borrowers and savers are respectively $\ell_t^S(w_t)^B$ and $\ell_t^S(w_t)$, with total desired labor supply given by $N_t^{des}(w_t) = \ell_t^S(w_t) + \ell_t^B(w_t)$. If the market clears at a wage $\geq \bar{w}$, we have $N_t^f(w_t) = N_t^{des}(w_t)$. If wages would have to fall below this bound to clear the labor market, we get rationing where labor demand is strictly less than labor supply. The labor market clearing conditions can be written as

$$N_t^{des}(w_t) \geq N_t^f(w_t), \qquad \omega_t \geq \bar{\omega}, \tag{53}$$

$$(N_t^{des}(w_t) - N_t^f(w_t))(w_t - \bar{\omega}) = 0. \tag{54}$$

If the wage rigidity is binding, involuntary unemployment is $N_t^{des} - N_t^f$. Reflecting the fact the junior employees are more likely to be fired in recessions, unemployment is allocated entirely to borrowers in a recession.[4] Effective labor supplied by borrowers and savers is, respectively,

$$\tilde{\ell}_t^B = \ell_t^B(w_t) - (N_t^{des}(w_t) - N_t^f(w_t)), \tag{55}$$

$$\tilde{\ell}_t^S = \ell_t^S(w_t). \tag{56}$$

Total forgone labor income of unemployed workers is replaced by the government at rate ϑ^U, leading to government expenditure

$$Unemp_t = \vartheta^U w_t(N_t^{des}(w_t) - N_t^f(w_t)). \tag{57}$$

Savers own the complete capital stock $\bar{K}$. Each period, they rent out capital to firms, implying

$$k_t = \bar{K}. \tag{58}$$

Goods Market. In addition, the total supply of consumption Y_t must equal the total use of resources, which consists of consumption C_t by the borrower family, consumption c_t^s by the saver, expenditures on housing maintenance, and depreciation of the fixed capital stock. This yields the following resource constraint

$$Y_t = C_t^B + c_t^S + \delta^h(\bar{H}^B + \bar{H}^S) + \delta^K \bar{K}. \tag{59}$$

Borrower and Saver Incomes. Tax revenue is raised from borrowers and savers in proportions φ_j^τ with $j = B, S$. Transfers are paid out as part of borrower income and lump-sum to

[4] Our results are not sensitive to this assumption. Since savers only supply a small fraction ($\approx$ 10%) of aggregate labor in the calibrated model, unemployment will naturally mostly affect borrowers.

savers in proportions φ_j^ϑ with $j = B, S$. Income of borrower and saver households is then

$$Y_t^B = w_t \tilde{\ell}_t^B - \varphi_B^\tau \tau_t Y_t + \varphi_B^\vartheta \vartheta Y_t = \omega_t \tilde{\ell}_t^B + Y_t \left(\varphi_B^\vartheta \vartheta - \varphi_B^\tau \tau_t \right), \tag{60}$$

$$Y_t^S = Y_t - w_t \tilde{\ell}_t^B - \delta^K \bar{K} - \varphi_S^\tau \tau_t Y_t + \varphi_S^\vartheta \vartheta Y_t = Y_t (1 + \varphi_S^\vartheta \vartheta - \varphi_S^\tau \tau_t) - w_t \tilde{\ell}_t^B - \delta^K \bar{K}. \tag{61}$$

Borrower income consists of labor earnings and transfers net of taxes. Savers receive all other income Y_t^S in (61) including firm profits and capital income, which is GDP adjusted for taxes and transfers, minus labor income paid to borrowers and depreciation of capital.

5 Parameterization and Solution Method

5.1 Parameter Choices

We calibrate the model at quarterly frequency. A subset of parameters is directly set to standard values in the literature or readily available estimates. These parameters are listed in Table 1. The remaining parameter are chosen to match moments from the simulated model to corresponding data targets. Table 2 lists data and model moments with resulting parameter values. All numbers are quarterly for the 1952-2019 sample unless we indicate a different sample. We discuss key parameters below.

Stochastic Environment. We calculate volatility and persistence of the TFP process in equation 21 based on the data provided by Fernald (2012), resulting in a quarterly standard deviation of innovations of 1.5% with an autocorrelation of 0.87. We calibrate the standard deviation of log idiosyncratic income shocks to $\sigma_\epsilon = 0.275$ based on the evidence in Guvenen, Ozkan, and Song (2014).[5] We set the mean of log ϵ such that $\mathrm{E}[\epsilon] = 1$.

Labor Supply, Taxes, and Transfers. We distinguish borrowers and savers in the 2019 Survey of Consumer Finances (SCF) by defining as saver any household who owns a home with a mortgage loan-to-value ratio below 40%. Based on this definition, borrowers receive 53% of

[5] Guvenen et al. (2014) report an average annual income growth standard deviation of 0.55 in Figure 5. We convert this estimate to quarterly frequency assuming serially uncorrelated shocks.

Table 1: Externally Calibrated Parameters

Par	Description	Value	Source
		Stochastic Environment	
σ_Z	TFP volatility	0.015	Vol. Ham. filtered TFP (Fernald (2012))
ρ_z	TFP persistence	0.87	AC(1) Ham. filtered TFP (Fernald (2012))
σ_ϵ	SD of log idios. income	0.275	Guvenen, Ozkan, and Song (2014)
		Housing and Mortgages	
δ^h	Housing maintenance	0.005	BEA residential capital deprec.
$\bar{q}^m$	Mortgage face value	1	Normalization
ι	Mortgage yield	0.0147	Set such that $\bar{q}^m = 1$
δ^m	1-Repayment rate	0.991	30-year mortgage duration
ζ	Foreclosure loss	0.30	Campbell, Giglio, and Pathak (2011)
θ	LTV at origination	0.85	Modal value in data
		Government	
ϑ	Average transfers/GDP	0.034	BEA transfer payments
$\bar{\pi}$	Inflation target	1.005	Annual target 2%
ϕ^π	Mon.pol. rule inflation coefficient	2	Standard value
ϕ^y	Mon.pol. rule output coefficient	0.125	Annual coefficient 0.5
$\bar{e}^R$	Capital requirement reserves	0.03	Supplementary leverage ratio
$\bar{e}$	Capital requirement mortgages	0.08	Basel regulation
		Preferences	
γ	CRRA risk aversion	2	Standard value
χ_1	Inverse Frisch elasticity	2	Chetty, Guren, Manoli, and Weber (2011)
		Population and Income	
φ	Population share borrowers	0.646	2019 SCF (see text)
φ^τ	Borrower share of transfers	0.367	2019 SCF (see text)
χ_0^S	Saver labor disutility	289.2	Normalize $\mathrm{E}[Y_t] = 1$

aggregate income and the vast majority of all labor income. Borrowers account for 65% of households.[6] In the model, we assume that savers receive all capital income and profits. We match the borrower income share of 53% by setting χ_0^B, the labor disutility of borrowers, such that borrowers receive 90% of all labor income in steady state. We further set labor supply disutility of savers, χ_0^S such that steady state labor supply equals 1. We also set $\bar{K} = 1$, implying steady state output of 1. Again using the 2019 SCF, we calculate that borrowers receive 37% of government transfers, consistent with the fact that savers include most retired households, implying $\varphi_B^\vartheta = 0.37$. For taxation, we assume that it is levied in proportion to

[6]We only include homeowners in this calculation. Savers are mainly older (often retired) households, who own the majority of wealth, but receive little labor income.

population shares, implying $\varphi_B^{\tau} = 0.65$. We set the lower bound on wages $\bar{w}$ to 0.97 of steady state wages. When this lower bound becomes binding, unemployment is allocated to borrowers and savers in proportion to their population shares, so $\upsilon^B = 0.65$.[7]

Technology. The share of labor in the production function is $\alpha = 0.7$, implying an effective labor share of 60%. The elasticity of substitution between inputs for final goods producers is $\eta = 7$, a standard value implying a steady state markup of 15%. The Rotemberg menu cost parameter is set to $\xi = 15$, which we choose to match the response of inflation to a 25bp monetary policy surprise in the model to the data response measured in Bauer and Swanson (2023).[8]

Table 2: Jointly Calibrated Parameters

Moment	Par.	Value	M (%)	D (%)	Source
Production and Savers					
Marginal cost/revenue	η	7	85	85	van Vlokhoven (2020)
Inflation response	ξ	15	-0.20	-0.21	Bauer and Swanson (2023)
Labor income/GDP	α	0.7	60	63	BLS labor share
Real Federal Funds rate	β_S	0.99	0.96	0.98	FFR net of CPI inflation 1952-2019
Deposit convenience yield	ψ	0.12	0.34	0.32	FFR-time deposit spread (DSS 2017, 94-14)
Borrowers and Housing					
Borrower income share	χ_0^B	3.16	53	54	2019 SCF (see text)
House value/income	K_h^S	0.35	849	841	2019 SCF (see text)
Borr. house value/income	K_h^B	0.46	676	681	2019 SCF (see text)
Borr. deposits/income	β_B	0.97	34	32	2019 SCF (see text)
Avg. re-optimization rate	μ^h	2.5	4.26	4.20	Gerardi et al. (2023) & 2019 HMDA
Fraction cash-out + purchase	μ^{cr}	0.6	65	64	2019 HMDA
Re-optimization elasticity	σ^h	1.2	0.28	0.23	Gerardi, Willen, and Zhang (2023)
Cash-out elasticity	σ^{cr}	0.7	0.45	0.51	Bhutta and Keys (2016)
Minimum consumption	$\bar{c}$	0.156	33	33	2023 Poverty threshold/income
Intermediaries					
Intermediation cost	ν	0.077	0.45	0.42	Spread prime mortgage over 10y treas.
Government					
Short-term gov. debt/GDP	$\bar{\tau}_0$	0.046	112	115	(Reser.+Tbills)/GDP in Q4 2019 (quarterly)

[7] Since savers on average only supply 10% of all labor, the impact of unemployment on their total income is minor.

[8] We feed an unanticipated 25bp increase in the policy rate into the model, with a persistence of 0.6 per quarter. Inflation declines by 0.2% on impact and mean-reverts quickly. This response matches the percentage decline in the CPI in Figure, column (c) of Bauer and Swanson (2023).

Preferences. The coefficient of relative risk aversion for borrowers and savers is set to $\gamma = 2$, implying an intertemporal elasticity of 0.5 in line with micro estimates. The saver discount factor is $\beta_S = 0.99$ to target a quarterly real interest rate of 0.98%. The borrower discount factor is set to $\beta_B = 0.97$, targeting the ratio of deposits to income for borrowers. Savers' utility from real deposits is $\psi = 0.12$, targeting to a quarterly deposit liquidity premium of 0.32% (Dreschler et al., 2017). Utility from housing targets the housing wealth/income ratio for borrowers, which is matched with $K_h^B = 0.46$. The same parameter for savers targets the total housing wealth/income ratio, yielding $K_h^S = 0.35$. The Frisch elasticity of labor supply of savers is set to 1/2, implying $\chi_1 = 2$, which is consistent with micro estimates (Chetty et al., 2011). We calibrate the subsistence level of consumption $\bar{c}$ such that the ratio of $\bar{c}$ over average borrower income in the model is 1/3. We obtain this ratio by dividing the 2023 Poverty threshold by median household consumption.[9]

Monetary and Fiscal Policy. The central bank targets trend inflation of 2% annually, corresponding to $\bar{\pi} = 1.005$. The response coefficient to inflation deviations in the Taylor rule is $\phi^\pi = 2$ and to output deviations it is $\phi^y = 0.125$, equivalent to an annual coefficient of 0.5. Transfers as share of GDP are set to $\vartheta = 3.4\%$, in line with the data average for the post-war sample. Since we do not model other forms of government spending, we set the average tax rate $\bar{\tau}_0$ such that the ratio of reserves to GDP in the model equals the ratio of short-term government debt to GDP in the data in Q4 of 2019 (reflecting that intermediaries in our model will treat reserves and Tbills as substitutes). Summing reserves and government debt with maturity under 1 year yields a ratio of 1.14 to quarterly GDP. The model generates this ratio with a tax rate that is equivalent to $\bar{\tau}_0 = 4.6\%$ of GDP.

Mortgages. We set $\delta^m = 0.991$. Given the calibrated quarterly mortgage rate of 1.42%, the gometric mortgage perpetuity in the model then has a duration of 11.05 years. A real-world 30-year fixed rate mortgage with this interest rate has the same duration.[10] The coupon payment ι is normalized to achieve a steady state bond price $\bar{q}^m = 1$, implying $\iota = 1.89\%$, which can be interpreted as the mortgage's nominal yield. The two mortgage reoptimization utility cost

[9]We use the poverty threshold provided by the U.S. department for health and human services for a 3-person household: \$24,850. Borrower households in the SCF based on our definition have on average 2.59 members.

[10]Appendix C.2 contains details.

distributions F_h and F_{cr} are log-normal cdfs, and we choose their parameters to match model refi rates and their elasticities to the data. First, the mean cost of entering into the mortgage reoptimization stage $\mu^h = 2.5$ achieves an average rate of reoptimization of 4.25%, close to the data target of 4.20%.[11] Again using 2019 HMDA data, we calculate that cash-out refis and new purchase mortgages account for 64% of new originations. We set $\mu^{cr} = 0.5$ to match this number by the average fraction $F_{cr}(\hat{\eta}^{cr})$ of refinancing borrowers that reset their debt balance to the origination LTV ratio. The origination LTV θ is set to 85%.[12] We set the scale parameters of utility cost distributions F_h and F_{cr} to match elasticities of mortgage refinancing in the data. Gerardi, Willen, and Zhang (2023) estimate that a 1% rise in the total gain from an interest-rate based refi causes a 0.23% increase in the quarterly refi rate. We match this elasticity in regressions of model-generated data by setting $\sigma^h = 1.2$.[13] Similarly, Bhutta and Keys (2016) estimates that a 1% increase in the Zip code house price index increases the likelihood that a refinancing mortgage borrower extracts equity by 0.51%. We match this estimate in regressions of model-generated data by setting $\sigma^{cr} = 0.9$.[14]

Intermediation. The mortgage spread 0.45% is the nominal yield ι net of the nominal reserve rate, in line with the quarterly spread of prime mortgage rates over treasuries with identical duration. We target this spread by setting the intermediation cost $\nu = 0.075$. We set the mortgage equity requirement for intermediaries to $\bar{e} = 0.08$ consistent with Basel regulations, and for reserves we apply the Supplementary Leverage Ratio of 3%, implying $\bar{e}^R = 0.03$.

[11] The data counterpart is the total flow of new originations per quarter as fraction of the stock of outstanding mortgages (including purchase loans). To obtain this number, we compute from the 2019 Home Mortgage Disclosure Act (HMDA) data that refinancings account for 40.7% of new originations. Further, using comprehensive data of the U.S. mortgage market, Gerardi, Willen, and Zhang (2023) estimate that the quarterly prepayment hazard due to refinancing is 1.71%. We obtain our estimate by computing 0.0171/0.407.

[12] This value is also consistent with data used in Gerardi et al. (2023). They calculate an average LTV at origination of 72% for GSE loans, and 94% for FHA loans. We choose an intermediate value closer to the GSE mortgage mean.

[13] The estimate refers to the coefficient on "Call Option V2" in column (5) of Table 3 in Gerardi et al. (2023). See Appendix C.3 for details.

[14] See coefficient on "Zip Code HPI Growth" in column (3) of Table 3 in Bhutta and Keys (2016). See Appendix C.3 for details.

5.2 Solution Method

The economy's state variables are the wealth of borrowers and of savers, and the stocks of outstanding government and mortgage debt. By Walras' law, we only need to track three of these state variables. We choose the stock of borrower deposits, outstanding mortgage debt, and outstanding government debt as our state space. Given these states, we can construct borrower and saver wealth. For our Covid crisis experiments, we hit the economy with a large unanticipated demand shock and impose a ZLB in the monetary policy rule. The shock causes the ZLB and the lower bound on wages to bind simultaneously. To handle these nonlinearities while computing fully stochastic transition paths after the unanticipated Covid shock hits the model, we use a global nonlinear solution method.[15]

6 Results

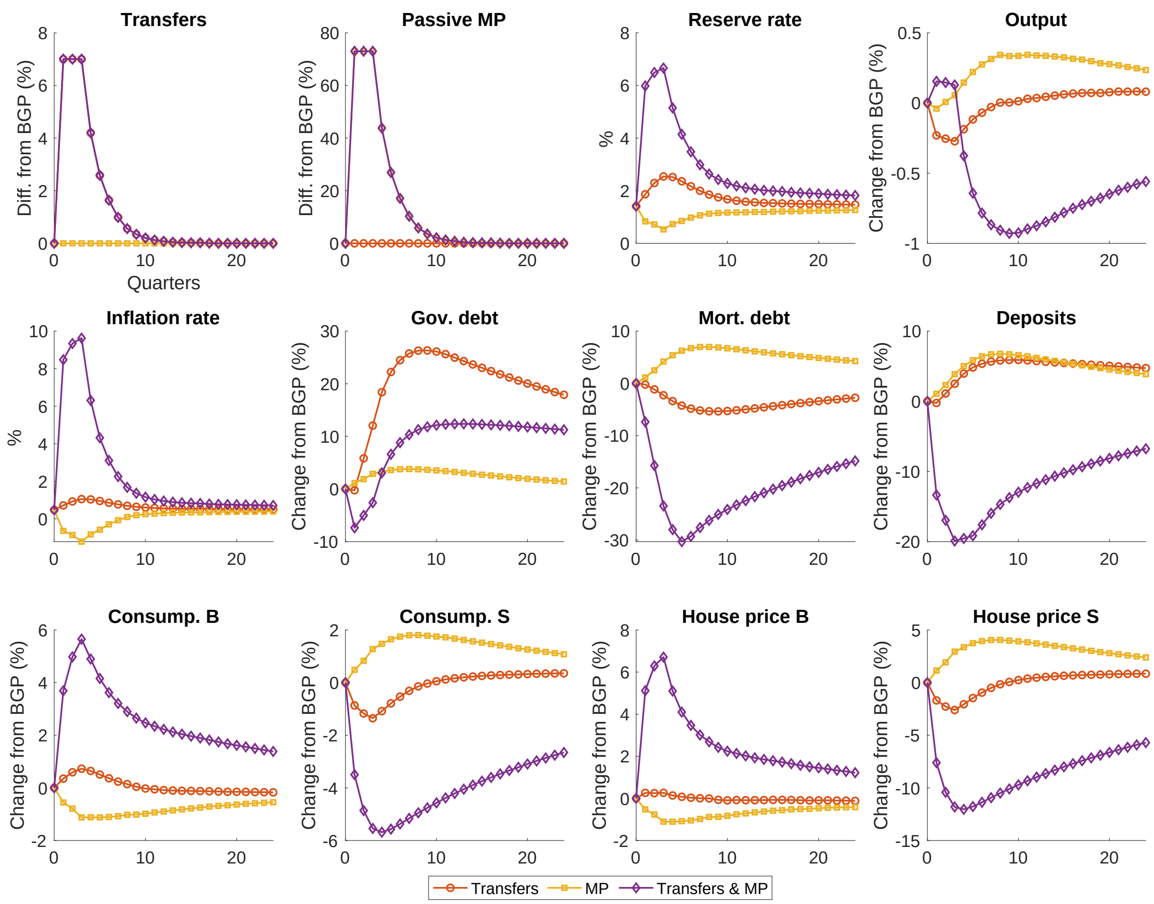
6.1 Monetary Shocks, Fiscal Shocks, and their Interaction

We first examine the interaction between monetary and fiscal stimulus in Figure 3. First, in the line "Transfers," we show a fiscal shock that increases increases aggregate fiscal transfers ϑ by 7% of GDP. Next, in the line "MP," we examine a monetary stimulus where we temporarily change our monetary rule: the weight on the passive interest peg Φ_t jumps from 0 to 0.73. During this time, the central bank puts weight 0.27 on its Taylor rule and weight 0.73 on the steady state interest rate $\bar{i}$. Finally, in the line "Transfers & MP," we present the impact of both policy changes jointly. All policy changes continue for 3 quarters and then revert to the standard monetary and fiscal rules with probability .4 each quarter and otherwise continue. The key result in Figure 3 is that a joint fiscal/monetary stimulus causes a surge in inflation of 10% that is not caused by either policy change alone. Passive monetary policy on its own is slightly deflationary, while increased transfers by themselves cause a reduction in aggregate labor supply and thus a mildly inflationary contraction. The inflationary surge triggered by the combination of both policies results in nearly a 30% reduction in the real value of mortgage

[15] See Elenev, Landvoigt, and Van Nieuwerburgh (2021b) for the general computational approach. We follow the methodology of Elenev, Landvoigt, Shultz, and Van Nieuwerburgh (2021a) in computing nonlinear stochastic transitions.

debt and a 20% reduction in the real value of bank deposits. As can be seen in the bottom row of Figure 3, this joint fiscal/monetary stimulus works largely through redistribution. Borrower consumption increases by nearly 6%, while saver consumption falls by nearly 6%. Similarly, borrower house prices rise by nearly 7% while saver house prices fall by roughly 12%. Because these redistributive effects do not occur in the "Transfers" line with only fiscal stimulus, they are not due to the direct redistribution caused by fiscal policy.

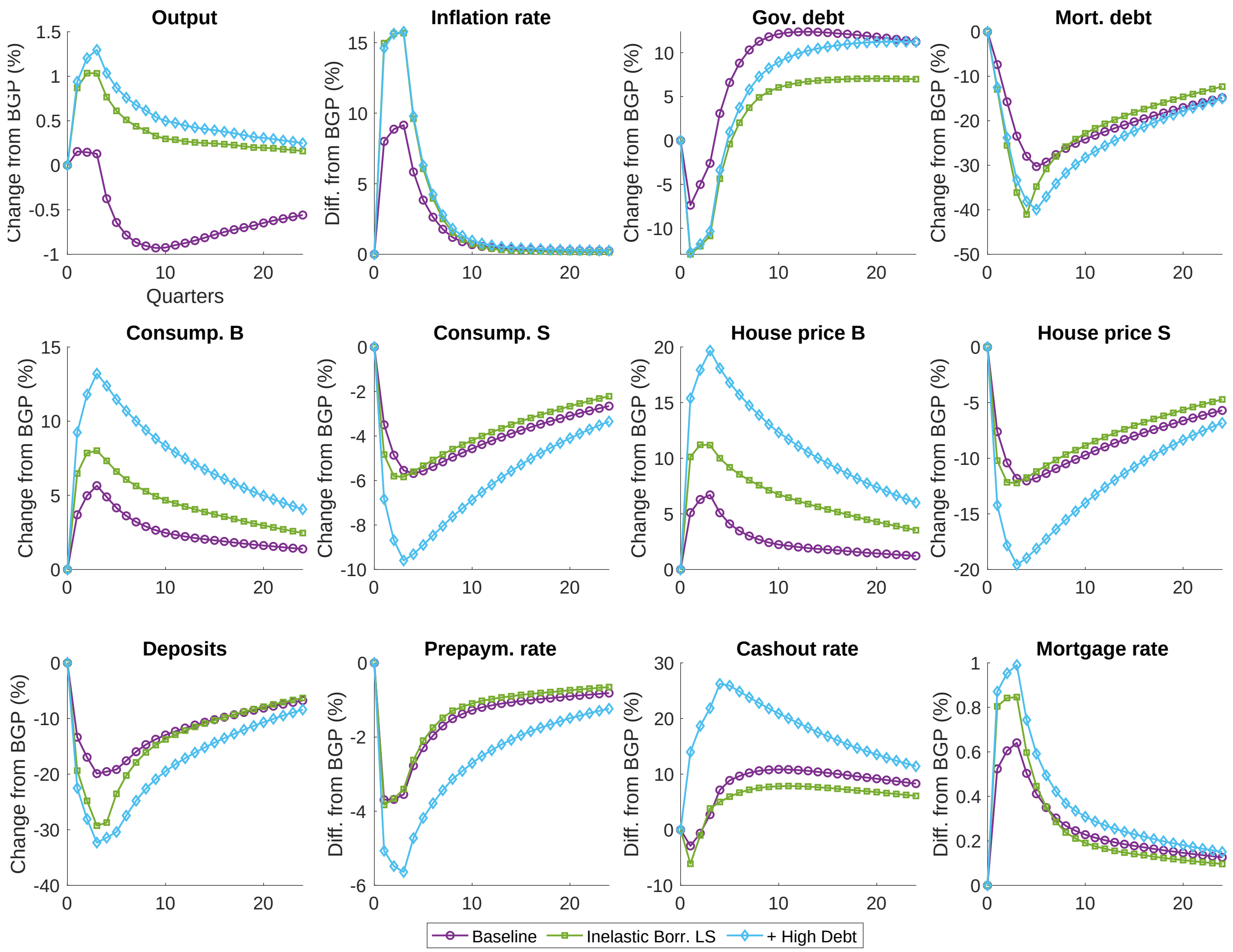
Figure 3: Interaction of Fiscal Stimulus and Passive Monetary Policy



Impulse responses to an increase in fiscal transfers ("Transfers"), a change in the monetary rule reducing its responsiveness to output and inflation ("MP"), and both policies together.

These quantitative results reflect the theoretical result in part 2 of Proposition 3, showing that inflation disproportionately boosts the consumption of borrowers. The inflation caused by stimulus results in "indirect redistribution" between borrowers and savers with different exposures to nominal interest rates. Unlike in the theoretical model above, this redistribution persistently makes borrowers wealthier through the erosion of outstanding mortgage debt and

Figure 4: Transmission of Monetary/Fiscal Policy with Inelastic Borrower Labor Supply



Impulse responses to: 1. "Baseline" combination of fiscal/monetary policy from Figure 3, 2. "Inelastic Borr. LS" same policies but with inelastic borrower labor supply, 3. "High Debt" same as 2 but starting with 30% higher mortgage debt.

therefore reduces their desire to supply labor, resulting in a nearly 1% drop in output 8-10 quarters later. A joint fiscal/monetary stimulus therefore results in a lower medium term level of output despite causing a surge in aggregate demand and inflation in the short run.

6.1.1 Impact of Borrower Leverage and Labor Supply

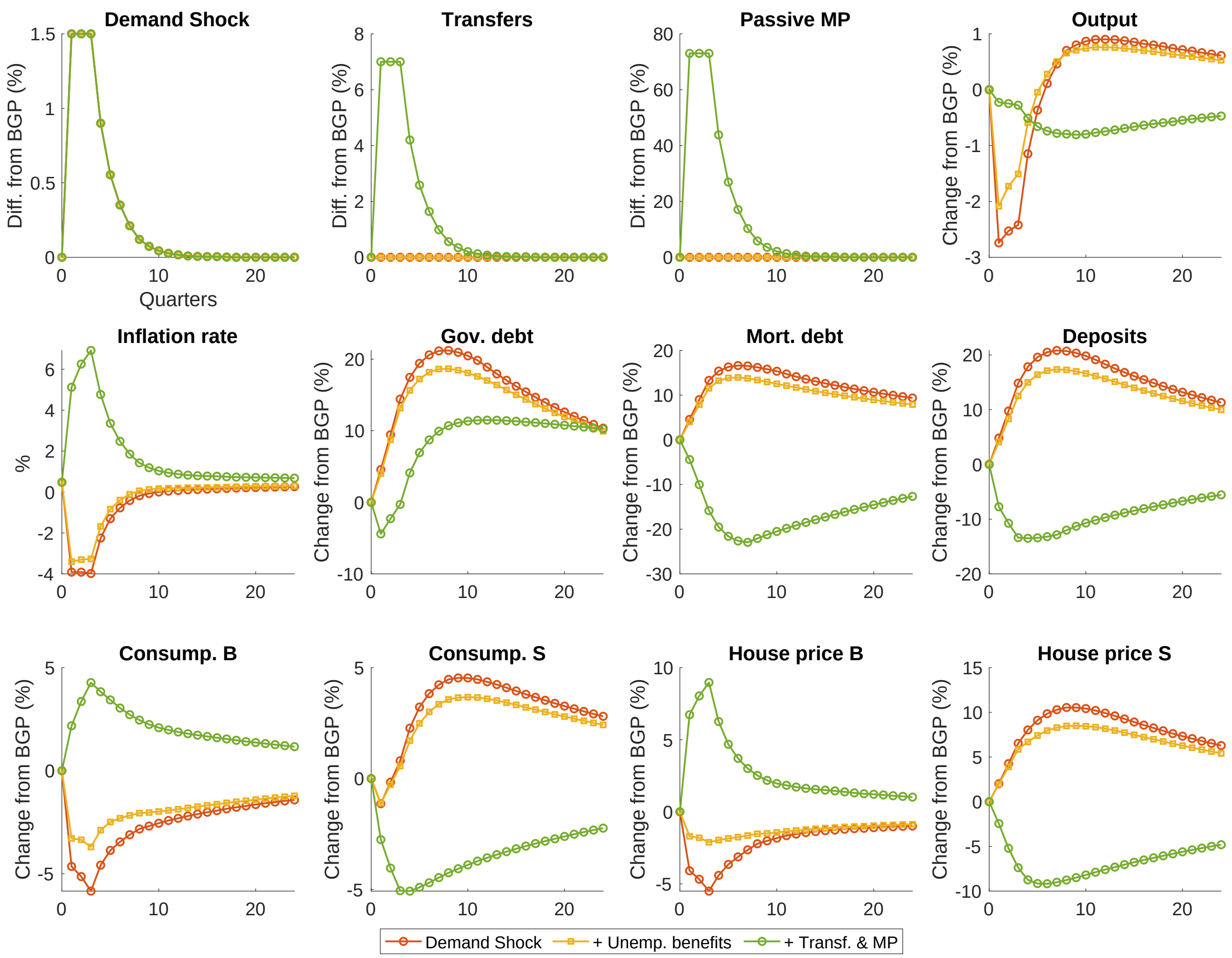
To highlight the importance of borrower labor supply, we examine the same policies we considered in Figure 3, but in a modified economy where borrower labor supply is perfectly inelastic. With inelastic borrower labor supply, we find that our fiscal/monetary easing always increases output, see line "Inelastic Borr. LS" in Figure 4. This demonstrates that a reduction in borrower labor supply was responsible for the longer-term contraction in output we observed in Figure 3. In addition, our fiscal/monetary easing causes more inflation with inelastic labor supply, since borrowers user their increased wealth to consume more instead of working less, amplifying the resulting demand shock. Borrower consumption and house prices grow more, while saver consumption and house prices fall more relative to the results in Figure 3.

Next, we connect these results to the insights developed in the theory model. The line "High Debt" in Figure 4 shows the same policy mix in the economy with inelastic borrower labor supply, but now the staring point of the generalized IRF features borrower mortgage debt that is 30% higher than in steady state. This experiment shows that the mix of easy fiscal and monetary policy stimulates consumption demand more when the economy has a greater stock of mortgage debt. While there is a nearly identical amount of inflation with and without elevated mortgage debt, the stimulative impact of this inflation is greater with more outstanding debt. In the "High Debt" experiment, where inflation causes more redistribution to the borrower, borrower consumption and house prices grow more and saver consumption and house prices fall more than in the baseline. This increased redistribution also results in a greater increase in output. These results mirror our theoretical findings in Proposition 3, part 2. Like in the theory model, elevated mortgage debt does not cause extra inflation, but the amount of demand stimulus due to this inflation grows with the quantity of outstanding mortgage debt.

6.2 Demand Shock and Policy Response

Next, we analyze the ability of policy to respond to a demand-driven recession following an exogenous decrease in consumption demand. This broadly captures the finding in Chetty, Friedman, Hendren, Stepner, and Team (2020) that the mix of Covid itself and lockdowns fighting it, reduced the bundle of consumable goods, making "in person" consumption undesirable. Such a reduction in the bundle causes households to voluntarily reduce their consumption by effectively making them more patient, resulting in a reduction in aggregate demand. In our experiment, we lower consumption demand by increasing households' discount factors by 1.5 percentage points for 3 quarters, after which they have a .4 chance of reverting to their original

Figure 5: Policy Responses to a Recession Driven by Reduced Consumption Demand



Impulse responses to an exogenous decrease in households' discount rates ("Demand Shock"), together with an increase in unemployment insurance ("+ Unemp. benefits"), and then also with the easy fiscal/monetary policies plotted in figure 3 ("+ Transf. & MP").

discount factors each quarter.[16] This demand-driven recession causes a deep contraction in output, during which the policy rate of the central bank hits the zero lower bound at the same time as real wages hit their lower bound, causing high unemployment.

We consider three possible policy responses to this drop in consumption demand in Figures 5-6. First, the line "Demand Shock" shows the impact of the decrease in demand with only the standard policy responses built into our monetary and fiscal rules, which includes replacing

[16]In unreported results, we have included a simultaneous negative supply shock as part of the policy experiment. Subject to recalibration of other shock components, the results regarding the interaction of monetary and fiscal policy are largely unaffected.

the wages of unemployed workers at 50%. Second, "+ Unemp. Benefits" shows the impact of replacing the salary of all unemployed workers at 100% instead. Finally, "+ Trans. & MP" adds a 7% of GDP fiscal stimulus and a deviation from the Taylor rule for monetary policy that puts a .73 weight on a fixed interest rate like in Section 6.1, with the important difference that the fixed interest target is now zero.

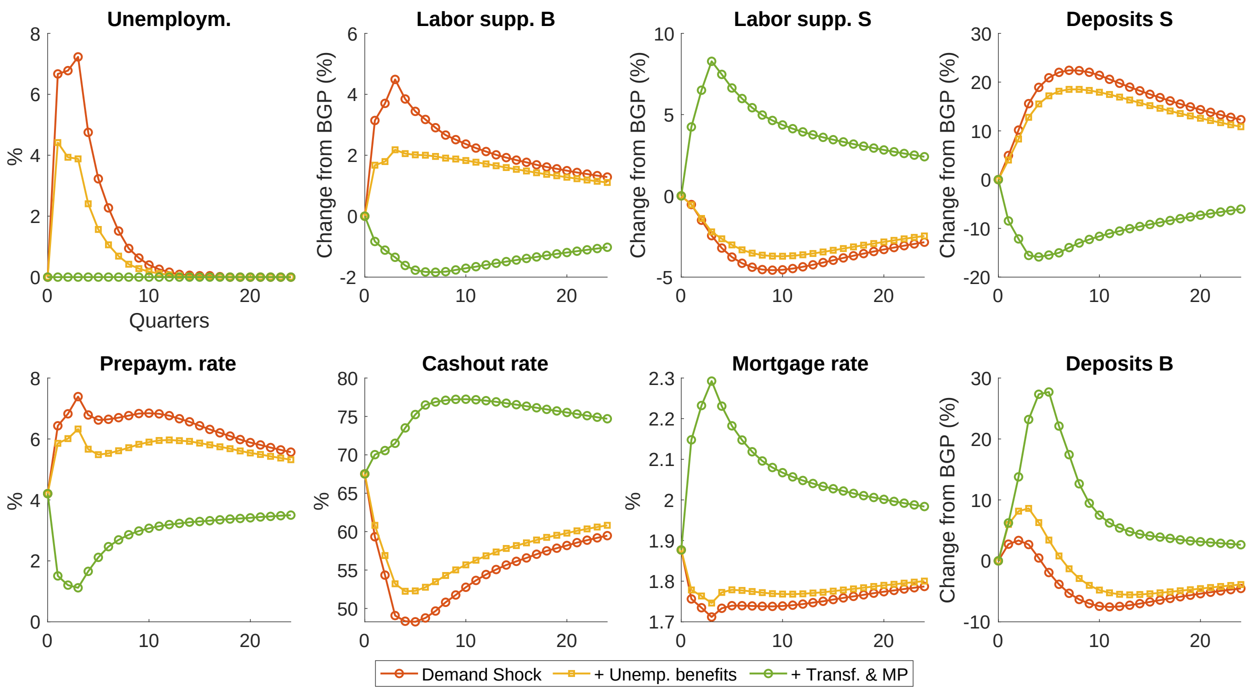
The combination of loose fiscal and monetary policy in the "+ Trans. & MP" response entirely prevents a drop in output and employment. Without a policy response, the economy would have experienced a 2.8% drop in output, which falls to roughly a 2% drop with full unemployment insurance. In addition, the economy would have experienced deflation up to 4%, which the loose fiscal/monetary policy transformed into a surge in inflation up to 8%. This surge in inflation results in redistribution from savers to borrowers, while deflation would have instead resulted in redistribution from borrowers to savers. With inflation, we see a boom in borrower consumption and house prices together with a drop in saver consumption and house prices.

These results show that that the surge in aggregate demand caused by the loose monetary/fiscal combo from Section 6.1 can entirely prevent a recession driven by a large negative demand shock. This can be seen in the zero unemployment rate in Figure 6 with the "+Transf. & MP" policy response. Like in Section 6.1, the surge in inflation leads to large redistribution, with the deposit holdings of savers falling roughly 15% as the deposit holdings of borrowers rise close to 30%. This redistribution lowers borrower labor supply in the long run and reduces output. In addition, we see in the bottom row of Figure 6 that under this policy response mortgage rates rise and mortgage prepayment rates fall, since lenders anticipate the rise in inflation caused by fiscal and monetary policy before the inflation occurs. Put simply, expected inflation along the transition path back to steady state is immediately priced into mortgage rates. We modify our model in the next section to be consistent with the overall increase in house prices and surge in mortgage refinancing observed during the post-Covid boom.

6.2.1 Anchored Inflation Expectations and Housing Preference Shocks

Two features of our analysis in the previous section are inconsistent with the stylized facts in Section 2, which we modify our model to match. First, we find in the model that loose fis-

Figure 6: Policy Responses to a Recession Driven by Reduced Consumption Demand

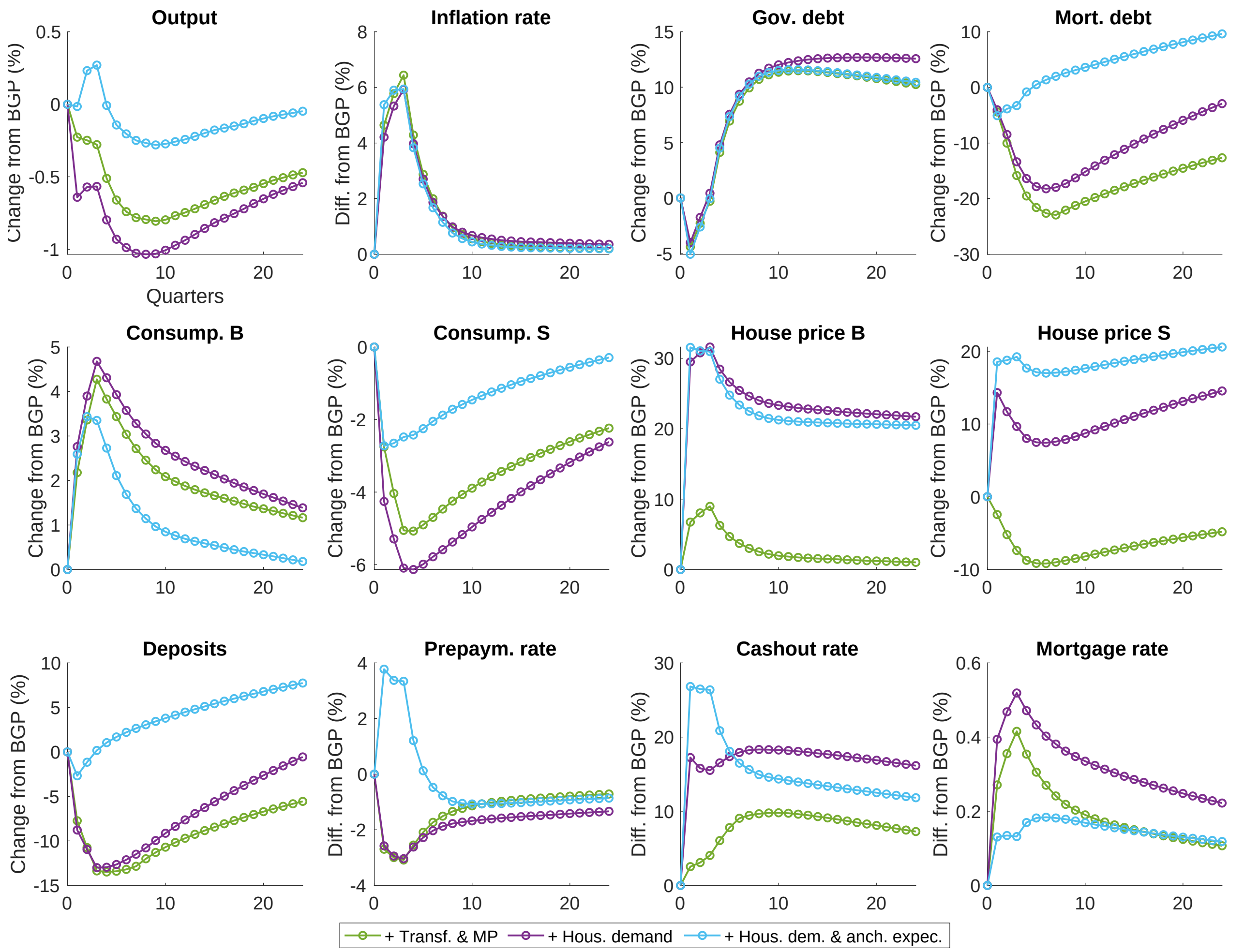


Impulse responses to an exogenous decrease in households' discount rates ("Demand Shock"), together with an increase in unemployment insurance ("+ Unemp. benefits"), and then also with the easy fiscal/monetary policies plotted in figure 3 ("+ Transf. & MP").

cal/monetary policy causes a boom in borrower house prices and a bust in saver house prices. In the data, we see a boom across the housing market that was likely driven by increased demand for living and working space during the pandemic. Consistent with the redistribution channel we emphasize, house prices grew the most in lower-value segments with more constrained homeowners. Second, in our model we find that households anticipate the surge in inflation that follows our economic stimulus, while in the data forward-looking inflation breakeven rates only increase with a lag. The anticipation of future inflation in the model causes a rise in mortgage rates, while in 2021 mortgage rates were at an all time low.

This section extends our model in two ways. First, we considering the impact of an increase in households' preferences (K_h^B, K_h^S) for housing consumption, reflecting pandemic-induced demand for space. Second, we break full-information rational expectations, so that inflation expectations are a weighted average of a rational prediction and the steady state inflation level. We model this anchoring of expectations by setting lenders' inflation expectations to a weighted average of the rational prediction (weight .05) and the long-run inflation target of 2% per year

Figure 7: Increased Housing Demand and Anchored Inflation Expectations



Impulse responses to: 1. The same shocks as "+ Transf. & MP" in figure 5; 2. same as 1, plus an increase in households' preference for housing ("+ Hous. demand"); 3. same as 2, plus anchoring of inflation expectations ("+ Hous. demand & anch. expec.").

(weight .95).

We present the impact of the housing preference shock and anchored inflation expectations in Figure 7. The green line "+ Transf. & MP" is the same as in Figures 5-6. The "+ Hous. demand" line performs the same policy experiment with a permanent increase in utility weights (K_h^B, K_h^S) on housing by 0.1, respectively.[17] Finally, the line "+ Hous. dem. & anch. expec." adds our anchored inflation expectations on top of the increase in housing demand.

The direct result is that borrower house prices rise by 30%, while saver house price increase

[17] K_h^S rises from 0.35 to 0.45, and K_h^B from 0.46 to 0.56.

by 20%. Even though increased housing demand due higher K_h^j is the same for both types of households, borrower house value rise by more due to the additional inflation redistribution channel. This matches our empirical finding in Section 2 that the lower end of the housing market experienced the biggest boom. This housing boom causes a positive wealth effect for borrowers, who increase their consumption and lower their labor supply. Because involuntary unemployment is eliminated in all three experiments in Figure 7, this reduction in labor supply leads to a greater contraction in output than would have occurred without the housing boom.

Witt anchored inflation expectations, our model matches the surge in mortgage refinancing that occurred after 2020 (Fuster et al., 2021). Under rational expectations, mortgage rates quickly increase since forward-looking lenders anticipate the future inflation that is to come. This mortgage rate increase in Figure 7 is smaller with anchored than rational expectations and is far below realized inflation, reducing real mortgage rates. In response, the share of households prepaying their mortgages increases instead of decreases, and these mortgage prepayers have a roughly 25% increase in their likelihood of choosing a cash out refi instead of a rate refi. This increase in borrowing gradually erodes the wealth transfers borrowers received from inflation. As a result, mortgage debt recovers more rapidly, as does output (due to higher borrower labor supply). Finally, anchored expectations cause a faster recovery in the consumption of savers, whose wealth includes the new debt created by the surge in borrowing.

7 Conclusion

This paper theoretically and quantitatively analyzes the impact of fiscal and monetary stimulus in an economy with household debt, where inflation causes redistribution. In our theoretical model, fiscal transfers outside of a recession either must be backed by future tax increases or are immediately inflated away. In a recession, fiscal stimulus causes inflation after a recession if the government commits not to increase future tax revenue. This post-recession inflation redistributes from savers to borrowers, increasing output and house prices in the recession. The power of fiscal stimulus grows with the stock of outstanding household debt.

In our quantitative model, we document a strong interaction between the power of fiscal and monetary policy, where fiscal stimulus only causes a surge in inflation if combined with accommodative monetary policy. This surge of inflation redistributes from savers to borrowers, which can prevent a recession driven by a shortage of demand. The quantitative model reveals potential downsides of aggressive stimulus policies, as the large redistribution to borrowers reduce labor supply and output in the long term. Our model is able to match the post-Covid boom in house prices and surge in mortgage refinancing if we increase households' preferences for housing consumption and give lenders exogenously anchored inflation expectations. Like in our theoretical model, stimulus is more powerful with a greater stock of outstanding mortgage debt. Our work is the first to consider the impact of fiscal inflation in a setting with mortgage debt that can be inflated away. A large literature explores how fiscal and monetary policy interact with nominal government debt, and how this interaction determines the price level and real activity. Our results demonstrate that private nominal debt plays an equally important role when analyzing the fiscal/monetary policy mix.

References

George-Marios Angeletos, Chen Lian, and Christian Wolf. Can deficits finance themselves? *working paper*, 2023.

Adrien Auclert. Monetary Policy and the Redistribution Channel. *American Economic Review*, 109 (6):2333–2367, 2019.

Marco Bassetto and Wei Cui. The Fiscal Theory of the Price level in a World of Low Interest Rates. *Journal of Economic Dynamics and Control*, 89:5–22, April 2018.

Michael D. Bauer and Eric T. Swanson. A reassessment of monetary policy surprises and high-frequency identification. *NBER Macroeconomics Annual*, 37:87–155, 2023. doi: 10.1086/723574.

Saroj Bhattarai, Jae Won Lee, and Choongrul Yang. Redistrubtion and the Monetary-Fixcal Policy Mix. *working paper*, 2021.

Saroj Bhattarai, Jae Won Lee, and Choongryul Yang. Redistribution and the Monetary-Fiscal Policy Mix. *working paper*, 2022.

Neil Bhutta and Benjamin J. Keys. Interest rates and equity extraction during the housing boom. *American Economic Review*, 106(7):1742–74, July 2016. doi: 10.1257/aer.20140040. URL https://www.aeaweb.org/articles?id=10.1257/aer.20140040.

Francesco Bianchi and Cosmin Ilut. Monetary/Fiscal policy mix and agents' beliefs. *Review of Economic Dynamics*, 26:113–139, October 2017.

Francesco Bianchi and Leonardo Melosi. Inflation as a Fiscal Limit. *working paper*, 2022.

Francesco Bianchi, Renato Faccini, and Leonardo Melosi. A Fiscal Theory of Persistent Inflation. *Quarterly Journal of Economics*, 138(4):2127–2179, 2023.

Markus K. Brunnermeier, Sebastian Merkel, and Yuliy Sannikov. The Fiscal Theory of the Price Level with a Bubble. *working paper*, 2022.

John Y. Campbell, Stefano Giglio, and Parag Pathak. Forced sales and house prices. *American Economic Review*, 101:2108–31, 2011.

Susan F. Cherry, Erica Xuewei Jiang, Gregor Matvos, Tomasz Piskorski, and Amit Seru. Government and private household debt relief during covid-19. *working paper*, 2021.

Raj Chetty, Adam Guren, Day Manoli, and Andrea Weber. Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins. *American Economic Review*, 101(3):471–75, May 2011. doi: 10.1257/aer.101.3.471. URL https://www.aeaweb.org/articles?id=10.1257/aer.101.3.471.

Raj Chetty, John N. Friedman, Nathaniel Hendren, Michael Stepner, and The Opportunity Insights Team. The economic impacts of covid-19: Evidence from a new public database built using private sector data. *Working Paper*, 2020.

Johh Cochrane. Long-Term Debt and Optimal Policy in the Fiscal Theory of the Price Level. *Econometrica*, 69(1):69–16, 2001.

Natalie Cox, Peter Ganong, Pascal Noel, Arlene Wong, Diana Farrell, and Fiona Greig. Initial impacts of the pandemic on consumer behavior: Evidence from linked income, spending, and savings data. *Brookings Papers on Economic Activity*, 2020.

Morris A. Davis, Andra Ghent, and Jesse Gregory. The Work-from-Home Technology Boon and its Consequences. *Review of Economic Studies, forthcoming*, 2023.

Marco Di Maggio, Amir Kermani, Benjamin Keys, Tomasz Piskorski, Rodney Ramcharan, Amit Seru, and Vincent Yao. Interest Rate Pass-Through: Mortgage Rates, Household Consumption and Voluntary Deleveraging. *American Economic Review*, 107(11):3550–3588, 2017.

Matthias Doepke and Martin Schneider. Inflation and the Redistribution of Nominal Wealth. *Journal of Political Economy*, 114(6):1069–97, 2006.

Itamar Dreschler, Alexi Savov, and Philipp Schnabl. The Deposits Channel of Monetary Policy. *Quarterly Journal of Economics*, 132(4):1819–1876, 2017.

Vadim Elenev, Tim Landvoigt, Patrick J Shultz, and Stijn Van Nieuwerburgh. Can monetary policy create fiscal capacity? Working Paper 29129, National Bureau of Economic Research, August 2021a. URL http://www.nber.org/papers/w29129.

Vadim Elenev, Tim Landvoigt, and Stijn Van Nieuwerburgh. A macroeconomic model with financially constrained producers and intermediaries. *Econometrica*, 89(3):1361–1418, 2021b. doi: https://doi.org/10.3982/ECTA16438. URL https://onlinelibrary.wiley.com/doi/abs/10.3982/ECTA16438.

Miguel Faria-e-Castro. Fiscal policy during a pandemic. *Working Paper*, 2021.

John G. Fernald. A Quarterly, Utilization-Adjusted Series on Total Factor Productivity. 2012.

Andreas Fuster, Aurel Hizmo, Lauren Lambie-Hanson, James Vickery, and Paul S. Willen. How resilient is mortgage credit supply? evidence from the covid-19 pandemic. *Working Paper*, 2021.

William Gamber, James Graham, and Anirudh Yadav. Stuck at home: Housing demand during the COVID-19 pandemic. *Journal of Housing Economics*, 2022.

Peter Ganong and Pascal Noel. Why do borrowers default on mortgages? a new method for causal attribution. *Working Paper*, 2021.

Peter Ganong, Fiona Greig, Max Liebeskind, Pascal Noel, Daniel Sullivan, and Joseph Vavra. Spending and job search impacts of expanded unemployment benefits: Evidence from administrative micro data. *working paper*, 2021a.

Peter Ganong, Pascal Noel, and Joseph Vavra. Us unemployment insurance replacement rates during the pandemic. *Working Paper*, 2021b.

Kristopher Gerardi, Paul S. Willen, and David Hao Zhang. Mortgage prepayment, race, and monetary policy. *Journal of Financial Economics*, 147(3):498–524, 2023. ISSN 0304-405X. doi: https://doi.org/10.1016/j.jfineco.2022.12.001. URL https://www.sciencedirect.com/science/article/pii/S0304405X22002458.

Veronica Guerrieri, Guido Lorenzoni, Ludwig Straub, and Iván Werning. Monetary policy in times of structural reallocation. *Proceedings of the 2021 Jackson Hole Symposium*, 2021a.

Veronica Guerrieri, Guido Lorenzoni, Ludwig Straub, and Iván Werning. Macroeconomic implications of covid-19: Can negative supply shocks cause demand shortages? *American Economic Review, forthcoming*, 2021b.

Arpit Gupta, Vrinda Mittal, Jonas Peeters, and Stijn Van Nieuwerburgh. Flattening the curve: Pandemic-Induced revaluation of urban real estate. *Journal of Finacial Economics*, 146(2), 2022.

Fatih Guvenen, Serdar Ozkan, and Jae Song. The nature of countercyclical income risk. *Journal of Political Economy*, 122(3):621–660, 2014. doi: 10.1086/675535.

Greg Howard, Jack Liebersohn, and Adam Ozimek. The short-and long-run effects of remote work on US housing markets. *Journal of Finacial Economics*, 150(1), 2023.

Greg Kaplan, Benjamin Moll, and Giovanni L. Violante. Monetary policy according to hank. *American Economic Review*, 108(3):697–743, March 2018. doi: 10.1257/aer.20160042. URL http://www.aeaweb.org/articles?id=10.1257/aer.20160042.

Greg Kaplan, Georgios Nikolakoudis, and Giovanni L. Violante. Price level and inflation dynamics in heterogeneous agent economies. *working paper*, 2023.

Eric Leeper. Equilibria Under 'Active' and 'Passive' Monetary and Fiscal Policies. *Journal of Monetary Economics*, 27(1):129–147, 1991.

Ross Levine, Chen Lin, Mingzhu Tai, and Wensi Xie. How did depositors respond to covid-19? *Review of Financial Studies*, 34(11):5438–5473, 2021.

John A. Mondragon and Johannes Wieland. Housing Demand and Remote Work. *working paper*, 2022.

Julio J. Rotemberg. Sticky Prices in the United States. *Journal of Political Economy*, 90(6):1187–1211, 1982.

Stephanie Schmitt-Grohé and Martín Uribe. Downward nominal wage rigidity, currency pegs, and involuntary unemployment. *American Economic Review*, 124(5):1466–1514, 2016.

Christopher Sims. Stepping on a Rake: The Role of Fiscal Policy in the Inflation of the 1970s. *European Economic Review*, 55(1):48–56, January 2011.

Has van Vlokhoven. Estimating the Cost of Capital and the Profit Share. 2020.

Michael Woodford. Fiscal Requirements for Price Stability. *Journal of Money, Credit, and Banking*, 33(3):669–728, 2001.

A Model Appendix

Derivation of bank budget constraint in equation 7

If we sum the budget constraints of all households (equation (2)) we get $\sum_s d^s_{t+1} = (1 + r_t)\sum_s[d^s_t - p_t(qc^s_t + (1-q)c^{s,liq}_t) + w_t l^s_t - (m^s_t + t^s_t)]$. Imposing the resource constraint in equation 6 and that $p_t = w_t$ then yields the bank budget constraint

$$\sum_s D^s_{t+1} = R_t \left[\sum_s D^s_t - \sum_s \left(\lambda^s h^s P^{h,s}_t - \frac{\lambda^s h^s P^{h,s}_{t+1}}{R_t} + T^s_t\right)\right]. \tag{62}$$

where $T^s_t = \frac{t^s_t}{p_t}$ is the real tax/transfer at time t. This yields the recursion

$$\frac{\sum_s D^s_{t+1}}{R_t} + \sum_s \left(\lambda^s h^s P^{h,s}_t - \frac{\lambda^s h^s P^{h,s}_{t+1}}{R_t} + T^s_t\right) = \sum_s D^s_t. \tag{63}$$

Iterating this recursion forward (noting that all the terms $\frac{\lambda^s h^s P^{h,s}_{t+1}}{R_t}$ cancel out) gives

$$\sum_s D^s_t = \sum_s \lambda^s h^s P^{h,s}_t + \sum_{\tau=0}^{\infty} \frac{\sum_s T^s_{t+\tau}}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}} + \lim_{\tau\to\infty} \frac{\sum_s D^s_{t+\tau} - \lambda^s h^s P^{h,s}_{t+\tau}}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}}, \tag{64}$$

which is equation (7) in the main text.

Steady State Deposit Demand (equation (8))

Given the real rate R_{ss}, the steady state real deposit holdings D^s_{ss} demanded by group s satisfy (by equation (4))

$$u'(c^s_{ss}) = \beta_s R_{ss}\left[qu'(c^s_{ss}) + (1-q)min(u'(D^s_{ss}), u'(c^s_{ss}))\right]. \tag{65}$$

Because we have from the firm's problem that $p_t = w_t$, equation (3) implies that $u'(c^s_{ss}) = k$, so equation (65) becomes

$$k = \beta_s R_{ss}\left[qk + (1-q)min(u'(D^s_{ss}), k)\right]. \tag{66}$$

This yields a total real deposit demand (if $\beta_s R_{ss} < 1$ for all households s) of

$$\sum_s (u')^{-1}\left(k\frac{1-q\beta_s R_{ss}}{(1-q)\beta_s R_{ss}}\right) = \sum_s D^s_{ss}, \tag{67}$$

which is equation (8) in the main text.

Steady State Deposit Supply (equation (9))

With no tax revenue ($\sum_s T^s_{ss} = 0$), the budget constraint in equation (7) at steady state reduces to $R_{ss} = 1$. For a constant real rate $R_{ss} > 1$, equation (7) gives the steady state supply of deposits

$$\sum_s D^s_{ss} = \sum_s \lambda^s h_s P^{h,s}_{ss} + \frac{R_{ss}}{R_{ss} - 1} \sum_s T^s_{ss}. \tag{68}$$

This supply depends on both government tax revenue and house values. Steady state house prices are given by, using equation (5), and that fact that $u'(c^s_t) = k$ from equation 3,

$$kP^{s,h}_{ss}(1 - \frac{\lambda^s}{R_{ss}} - \beta(1 - \lambda^s)) = v'(h^s). \tag{69}$$

Plugging this house price expression into equation (68) yields

$$\sum_s D^s_{ss} = \sum_s \lambda^s h_s \frac{v'(h^s)}{(1 - \frac{\lambda^s}{R_{ss}} - \beta(1 - \lambda^s))k} + \frac{R_{ss}}{R_{ss} - 1} \sum_s T^s_{ss}. \tag{70}$$

This is equation (9) in the main text.

Steady State Equilibria We now charecterize all steady state equilibria with nonnegative tax levels. First, if there is no tax revenue, we have as noted above that $R_{ss} = 1$. The equilibrium quantity of deposits then follows from plugging $R_{ss} = 1$ into equation (67).

For strictly positive quantities of tax revenue for which we have $\beta_s R_{ss} < 1$ for all s, equations (67) and (70). The joint solution to these two equations uniquely determines equilibrium real rates and deposit quantities. Finally, once we reach a real rate such that $\beta_s R_{ss} = 1$ for the most patient household, that household's deposit demand becomes perfectly elastic. As a result, it will hold arbitrarily large deposit quantities, so additional deposit injections can no longer raise the steady state real rate.

A.1 Nominal Rigidites, Involuntary Unemployment, and Fiscal Stimulus

Equilibrium after time T We first solve for the market equilibrium after time T, when wage rigidites no longer bind. The tax authorities raise real tax revenue $\sum_s T^s_{ss} > 0$ from time T+2 and on, and a potentially different quantity $\sum_s T^s_{T+1}$ at time T+1. Because nominal rigidites never bind, we have that $u'(c_t^s) = k$ for all agents s and all $t \geq T+1$. Equilibrium is given for $t \geq T+1$ by

$$\sum_s D_{t+1}^s = R_t \left[\sum_s D_t^s - \sum_s \left(\lambda^s h^s P_t^{h,s} - \frac{\lambda^s h^s P_{t+1}^{h,s}}{R_t} \right) - \sum_s T_t^s \right] \tag{71}$$

$$k = \beta_s R_t [qk + (1-q)u'(D_{t+1}^s)] \tag{72}$$

$$k \left[P_t^{s,h} - \frac{\lambda^s P_{t+1}^{s,h}}{R_t} \right] = v'(h^s) + \beta_s k (1-\lambda^s) P_{t+1}^{s,h}. \tag{73}$$

This system of equations is solved when the economy is in the steady state described in section 3 for $t \geq T+2$ since $\sum_s T_t^s$ stays at its steady state value. Because D_{T+2}^s equals its steady state value, equation (72) implies that R_{T+1} must also equal its steady state value. It then follows from equation (73) that $P_{T+1}^{s,h}$ equals its steady state value as well. Finally, equation (71) implies that since $\sum_s D_{T+2}^s, R_{T+1}, P_{T+2}^{h,s}, P_{T+1}^{h,s}$ are all at their steady state values, $\sum_s D_{T+1}^s - \sum_s T_{T+1}^s$ must also be at its steady state value.

Fiscal Stimulus in Partial Equilibrium An individual house at time T has the deposit Euler equation and budget constraint

$$u'(c_T^s) = \beta_s R_T \left[qk + (1-q)u'(D_{T+1}^s) \right] \tag{74}$$

$$D_{T+1}^s = R_T [D_T^s - qc_T^s - (1-q)D_T^s + l_T^s - \left(M_T^s - \frac{\lambda^s h^s P_{ss}^{h,s}}{R_T} \right) - T_T^s]. \tag{75}$$

Here, we write M_T for the real mortgage debt owed at time T, since this is a parameter which does not respond to a time T change in policy. The household's consumption choices depend on its "total wealth" $W_T = [qD_T^s + l_t - \left(M_T^s - \frac{\lambda^s h^s P_{ss}^{h,s}}{R_T} \right) - T_T^s]$ and the real interest rate R_T.

If we provide the agent with additional wealth W_T and the agent consumes a fraction $\frac{\partial c_T^s}{W_T} MPC_T^s$, the budget constraint implies that $R_T[1 - qMPC_T^s] = \frac{\partial D_{T+1}^s}{\partial W_T}$. Plugging this expression into the Euler equation yields

$$u''(c_T^s) MPC_T^s = \beta_s R_T^2 (1 - qMPC_T^s)(1-q)u''(D_{T+1}^s). \tag{76}$$

This explicitly charecterizes the marginal propensity to consume out of wealth for each household s.

Next, we charecterize the consumption response $\frac{\partial c_T^s}{\partial R_T}$ of household s responds to a change in real rates holding wealth fixed. By the budget constraint in equation (75), we have $[W_T - qc_T^s] - qR_T \frac{\partial c_T^s}{\partial R_T} = \frac{\partial D_{T+1}^s}{\partial R_T}$. Plugging this into the equation 74 yields

$$u''(c_T^s)\frac{\partial c_T^s}{\partial R_T} = \beta_s[qk + (1-q)u'(D_{T+1}^s)] + \beta_s R_T[[W_T - qc_T^s] - qR_T\frac{\partial c_T^s}{\partial R_T}](1-q)u''(D_{T+1}^s). \quad (77)$$

Government Budget Constraint We begin with the bank budget constraint, in the case where real rates are strictly above 1 at steady state starting at time T+1. Equation (78) becomes

$$\sum_s D_t^s = \sum_s \lambda^s h^s P_t^{h,s} + \sum_{\tau=0}^{\infty} \frac{\sum_s T_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}}. \quad (78)$$

If we define $G_T = \sum_{\tau=1}^{\infty} \frac{\sum_s T_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1} R_{t+\theta}}$, then we have that $G_T = \frac{G_{T+1}+\sum_s T_{T+1}^s}{R_T}$. Because G_{T+1} returns to its steady state value G_{ss}, we have that

$$G_{ss} = G_{T+1} = R_T G_T - \sum_s T_{T+1}^s, \quad (79)$$

which is equation (13) in the main text.

B Quantitative Model Appendix

B.1 Solution to the Borrower Problem

Recall the borrower solves the program given in (35) subject to cash in advance constraints (equations (27), (28)), the default threshold $\hat{\epsilon}_t$ given in equation (29), the transition law for mortgage debt in (32), and the law of motion for real deposits (36) with d_t^+ given in equation (31).

First, we define the marginal continuation values

$$\begin{aligned}
V_{d,t}^+ &= \frac{\partial V_t}{\partial d_t^+} = \beta_B \mathrm{E}_t\left[\frac{1+{}^{\$}i_t}{1+\pi_{t+1}} V_{d,t+1}\right] \\
V_{h,t}^+ &= \beta_B \mathrm{E}_t\left[V_{h,t+1}\right] \\
V_{m,t}^+ &= \beta_B \mathrm{E}_t\left[\frac{V_{m,t+1}}{1+\pi_{t+1}}\right].
\end{aligned}$$

Using these continuation values, we can use the envelope condition the compute the derivatives of our value function.

Next, let $\nu_t^k(\epsilon)$ be the Lagrange multiplier for $k = d, nd$ on the borrower's cash in advance constraints. We can write our Lagrangian as

$$
\begin{aligned}
&V(h_t^B, m_t, d_t^B) = \int_0^{\hat{\epsilon}_t} u(c^d(\epsilon))dF(\epsilon) + \int_{\hat{\epsilon}_t}^{\infty} u(c^{nd}(\epsilon))d\epsilon + K_h^B u(h_t^B) - \chi_0^B v(\ell_t^B) + \\
&\int_0^{\hat{\epsilon}_t} \nu_t^d(\epsilon)[w_t\tilde{\ell}_t^B\epsilon + d_t^B - c_t^d(\epsilon)]dF(\epsilon) + \int_{\hat{\epsilon}_t}^{\infty} \nu_t^{nd}(\epsilon))[w_t\tilde{\ell}_t^B\epsilon + d_t^B - Q^m m_t - c_t^{nd}(\epsilon)]dF(\epsilon) \\
&-(1 - F(\hat{\epsilon}_t))F_h(\hat{\eta}_t^h)\mathrm{E}[\eta^h \mid \eta^h < \hat{\eta}_t^h] - (1 - F_d(\hat{\epsilon}_t))F_h(\hat{\eta}_t^h)F_{cr}(\hat{\eta}_t^{cr})\mathrm{E}[\eta^{cr} \mid \eta^{cr} < \hat{\eta}_t^{cr}] \\
&+ \beta_B \mathrm{E}_t\left[V(h_{t+1}^B, m_{t+1}, d_{t+1}^B)\right].
\end{aligned}
$$

For borrowers with sufficiently high liquidity, the CIA constraints are slack. They choose a level of consumption c_t^* at which consumption and saving have the same marginal value:

$$u'(c_t^*) = V_{d,t}^+.$$

For a borrower which which the cash in advance constraint binds, the Lagrange multiplier $\nu_t^k(\epsilon)$ is given by

$$\nu_t^k(\epsilon) = f(\epsilon)[u'(c_t^k(\epsilon)) - u'(c_t^*)] = f(\epsilon)[u'(c_t^k(\epsilon)) - V_{d,t}^+],$$

where $f()$ is the density function associated with distribution $F()$. Because the default threshold $\hat{\epsilon}_t$ is exogenously imposed to model liquidity-driven default, we cannot use the envelope theorem to hold it fixed when taking first-order conditions. The marginal value of increasing the threshold at time t is

$$
\begin{aligned}
\frac{\partial V_t}{\partial \hat{\epsilon}_t} &= f(\hat{\epsilon}_t)(u(c_t^d(\hat{\epsilon}_t)) - u(c_t^{nd}(\hat{\epsilon}_t))) \\
&\quad - V_{d,t}^+ f(\hat{\epsilon}_t)\Big[c_t^d(\hat{\epsilon}_t) - c_t^{nd}(\hat{\epsilon}_t) + \left(p_t^{h,B} - \delta^h + F_h(\hat{\eta}^h)F_{cr}(\hat{\eta}^{cr})\theta p_t^{h,B}\right)h_t^B \\
&\quad - \left(Q^m + \delta^m F_h(\hat{\eta}^h)F_{cr}(\hat{\eta}^{cr})\kappa\right)m_t\Big] \\
&\quad - V_{m,t}^+ f(\hat{\epsilon}_t)\left[\delta^m m_t\left(1 - F_h(\hat{\eta}_t^h) + F_h(\hat{\eta}_t^h)(1 - F_{cr}(\hat{\eta}_t^{cr}))\frac{\kappa}{q_t^m}\right)\right. \\
&\qquad \left. + F_h(\hat{\eta}_t^h)F_{cr}(\hat{\eta}_t^{cr})\frac{\theta p_t^{h,B}h_t^B}{q_t^m}\right]m_t \equiv V_{\hat{\epsilon},t}.
\end{aligned}
$$

Using the cash-in-advance Lagrange multipliers $\nu_t^k(\epsilon)$ and expression for $\frac{\partial V_t}{\partial \hat{\epsilon}_t}$, we can now compute the marginal value changing the borrower's state variables at time t. The expressions are given by:

$$
\begin{aligned}
V_{d,t} = \frac{\partial V_t}{\partial d_t^B} =& \int_0^\infty (\nu_t^d(\epsilon) + \nu_t^{nd}(\epsilon)) d\epsilon + V_{d,t}^+ + V_{\hat{\epsilon},t} \frac{\partial \hat{\epsilon}_t}{\partial d_t^B} \\
V_{h,t} = \frac{\partial V_t}{\partial h_t^B} =& K_h^B u'(h_t^B) + (1 - F(\hat{\epsilon}_t)) \left[\left(p_t^{h,B} - \delta^h + F_h(\hat{\eta}^h) F_{cr}(\hat{\eta}^{cr}) \theta p_t^{h,B} \right) V_{d,t}^+ \right. \\
& \left. + F_h(\hat{\eta}_t^h) F_{cr}(\hat{\eta}_t^{cr}) \frac{\theta p_t^{h,B}}{q_t^m} V_{m,t}^+ \right] \\
V_{m,t} = \frac{\partial V_t}{\partial m_t} =& - Q^m \int_0^\infty \nu_t^{nd}(\epsilon) d\epsilon - (1 - F(\hat{\epsilon}_t)) \left(Q^m + \delta^m F_h(\hat{\eta}^h) F_{cr}(\hat{\eta}^{cr}) \kappa \right) V_{d,t}^+ \\
& + \delta^m (1 - F(\hat{\epsilon}_t)) \left(1 - F_h(\hat{\eta}^h) + F_h(\hat{\eta}^h)(1 - F_{cr}(\hat{\eta}^{cr})) \frac{\kappa}{q_t^m} \right) V_{m,t}^+ + V_{\hat{\epsilon},t} \frac{\partial \hat{\epsilon}_t}{\partial m_t}
\end{aligned}
$$

With these marginal values, we now derive the borrower's first-order conditions for consumption $\{c_t^d(\epsilon), c_t^{nd}(\epsilon)\}$, labor supply ℓ_t^B, new housing h_{t+1}^B, and the optimal refinancing thresholds $\hat{\eta}_t^h$ and $\hat{\eta}_t^{cr}$.

FOC for consumption

$$
f(\epsilon)(u'(c_t^d(\epsilon)) - V_{d,t}^+) = \nu_t^d(\epsilon) \tag{80}
$$

$$
f(\epsilon)(u'(c_t^{nd}(\epsilon)) - V_{d,t}^+) = \nu_t^{nd}(\epsilon) \tag{81}
$$

Labor Supply FOC

$$
\chi_0^B v'(\ell_t^B) = V_{d,t}^+ w_t + w_t \int_0^\infty \epsilon (\nu_t^d(\epsilon) + \nu_t^{nd}(\epsilon)) dF(\epsilon)
$$

FOC for new housing

$$
V_{d,t}^+ p_t^{h,B} = V_{h,t}^+.
$$

FOCs for mortgage stage and cash-out refi thresholds.

$$
\begin{aligned}
& - f_h(\hat{\eta}_t^h)(\hat{\eta}_t^h + F_{cr}(\hat{\eta}_t^{cr}) \bar{\eta}_t^{cr})(1 - F(\hat{\epsilon}_t)) \\
& + V_{d,t}^+ f_h(\hat{\eta}_t^h) F_{cr}(\hat{\eta}_t^{cr})(1 - F(\hat{\epsilon}_t)) \left(\theta p_t^{h,B} h_t^B - \kappa \delta^m m_t \right) \\
& + V_{m,t}^+ f_h(\hat{\eta}_t^h)(1 - F(\hat{\epsilon}_t)) \left[\delta^m m_t \left((1 - F_{cr}(\hat{\eta}_t^{cr})) \frac{\kappa}{q_t^m} - 1 \right) + F_{cr}(\hat{\eta}^{cr}) \frac{\theta p_t^{h,B} h_t^B}{q_t^m} \right] = 0.
\end{aligned}
$$

Simplifying this expression yields

$$\begin{aligned}\hat{\eta}_t^h =& V_{d,t}^+ F_{cr}(\hat{\eta}_t^{cr}) \left(\theta p_t^{h,B} h_t^B - \kappa \delta^m m_t\right) \\ &+ V_{m,t}^+ \left[\delta^m m_t \left((1 - F_{cr}(\hat{\eta}_t^{cr})) \frac{\kappa}{q_t^m} - 1\right) + F_{cr}(\hat{\eta}^{cr}) \frac{\theta p_t^{h,B} h_t^B}{q_t^m}\right] \\ &- F_{cr}(\hat{\eta}_t^{cr}) \bar{\eta}_t^{cr},\end{aligned} \tag{82}$$

where $\bar{\eta}_t^{cr} = \mathrm{E}[\eta^{cr} \mid \eta^{cr} < \hat{\eta}^{cr}]$.

Once in the mortgage stage, the borrower then chooses a threshold $\hat{\eta}_t^{cr}$ at which they are indifferent between choosing a cash out refi or a rate refi. The first-order condition is

$$\begin{aligned}&- f_{cr}(\hat{\eta}_t^{cr}) \hat{\eta}_t^{cr} F_h(\hat{\eta}_t^h)(1 - F(\hat{\epsilon}_t)) \\ &+ V_{d,t}^+ f_{cr}(\hat{\eta}_t^{cr}) F_h(\hat{\eta}_t^h)(1 - F(\hat{\epsilon}_t)) \left(\theta p_t^{h,B} h_t^B - \kappa \delta^m m_t\right) \\ &+ V_{m,t}^+ f_{cr}(\hat{\eta}_t^{cr}) F_h(\hat{\eta}_t^h)(1 - F(\hat{\epsilon}_t)) \left[\frac{\theta p_t^{h,B} h_t^B}{q_t^m} - \delta^m m_t \frac{\kappa}{q_t^m}\right] = 0.\end{aligned}$$

Simplifying this expression yields

$$\hat{\eta}_t^{cr} = \left(\theta p_t^{h,B} h_t^B - \kappa \delta^m m_t\right) \left(V_{d,t}^+ + \frac{V_{m,t}^+}{q_t^m}\right). \tag{83}$$

B.2 How to handle CIA constraints

We can compute income shock thresholds corresponding to both CIA constraints

$$\begin{aligned}\epsilon_t^{*,nd} &= \frac{c_t^* + Q^m m_t - d_t^B}{w_t \tilde{\ell}_t^B}, \\ \epsilon_t^{*,d} &= \frac{c_t^* - d_t^B}{w_t \tilde{\ell}_t^B}.\end{aligned}$$

For households with income shocks $\epsilon \geq \epsilon_t^{*,nd}$, the no-default CIA constraint is not binding and we thus have $c_t^{nd}(\epsilon) = c_t^*$ for $\epsilon \geq \epsilon_t^{*,nd}$.

For reasonable parameter values, we have $\epsilon_t^{*,nd} > \hat{\epsilon}_t$, and the households on this interval do not default, but have a binding no-default CIA constraint.

For defaulters, there are two possible cases, depending on whether $\epsilon_t^{*,d} < \hat{\epsilon}_t$. This case occurs when

$$Q^m m_t > c_t^* - \bar{c},$$

i.e. if households have a lot of debt and the subsistence level is relatively low. In that case there is a set of unconstrained defaulters $[\epsilon_t^{*,d}, \hat{\epsilon}_t]$. Otherwise, if $\epsilon_t^{*,d} \geq \hat{\epsilon}_t$, all defaulters are on their default CIA constraint. In our numerical solution algorithm, we distinguish these cases and use Gaussian quadrature where appropriate to calculate expected values on intervals between the different thresholds.

B.3 Solution to the Saver Problem

Given the saver's preferences

$$U^S(c_t^S, h_t^S, d_{t+1}^S, \ell_t^S) = \frac{(c_t^S)^{1-\gamma}}{1-\gamma} + K_h^S \frac{(h_t^S)^{1-\gamma}}{1-\gamma} + K_d \frac{(d_{t+1}^S)^{1-\gamma}}{1-\gamma} - \chi_0^S \frac{(\ell_t^S)^{1+\chi_1}}{1+\chi_1} \tag{84}$$

its marginal utility of non-durable consumption is

$$\frac{\partial U^s}{\partial c_t^S} = (c_t^S)^{-\gamma} \tag{85}$$

The saver therefore has the stochastic discount factor

$$\mathcal{M}_{t,t+1}^S = \beta_S \left(\frac{c_t^S}{c_{t+1}^S} \right)^{\gamma}. \tag{86}$$

The saver's marginal utility of housing consumption and holding bank deposits are

$$\frac{\partial U^s}{\partial h_t^S} = K_h^S (h_t^S)^{-\gamma}$$
$$\frac{\partial U^s}{\partial d_{t+1}^S} = K_d (d_{t+1}^S)^{-\gamma}.$$

The saver's first-order conditions for housing and investing in bank deposits are therefore

$$p_t^h = \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^S \left(p_{t+1}^h - \delta^h \right) \right] + \frac{\partial U^s / \partial h_t^S}{\partial U^s / \partial c_t^S}, \tag{87}$$

$$1 = \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^S \frac{1 + {}^{\$}i_t}{\pi_{t+1}} \right] + \frac{\partial U^S / \partial d_{t+1}^S}{\partial U^s / \partial c_t^S}. \tag{88}$$

The saver's labor supply is given by

$$\chi_0 (\ell_t^S)^{\chi_1} = \frac{\partial U^s}{\partial c_t^S} w_t.$$

B.4 Rebates of Mortgage Default Costs

Lump-sum rebates are the intermediation cost and foreclosure losses

$$Reb_t = \nu \left(\mathcal{P}_t m_t^I - \frac{D_t^I}{1 + \pi_t} \right) + F(\hat{\epsilon}_t) \zeta p_t^{h,B} h_t^B. \tag{89}$$

B.5 Price Index Derivation

The final good is produced with the usual NK setup of retailers and monopolistically competitive intermediate goods producers. This implies that total output is given by

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}, \tag{90}$$

with the price index

$$P_t = \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{1}{1-\eta}}.$$

B.5.1 Pricing Final Consumption Goods

Profit maximization and zero profits implies that the final goods producer is willing to pay a price for an intermediate good equal to its marginal revenue product, so we have

$$\begin{aligned} \frac{P_t(i)}{P_t} = \frac{\partial Y_t}{\partial Y_t(i)} &= \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}-1} Y_t(i)^{\frac{\eta-1}{\eta}-1} \\ &= (Y_t)^{\frac{1}{\eta}} Y_t(i)^{\frac{-1}{\eta}} \\ Y_t(i) &= Y_t \left(\frac{P_t(i)}{P_t} \right)^{-\eta}. \end{aligned} \tag{91}$$

Plugging the final good's firms demand curve for intermediates (equation 91) into the firm's feasibility constraint in equation (90) yields

$$\begin{aligned} Y_t &= \left(\int_0^1 (Y_t(\frac{P_t(i)}{P_t})^{-\eta})^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}} \\ 1 &= (P_t)^{\eta} \left(\int_0^1 P_t(i)^{-\eta}) \frac{\eta-1}{\eta} di \right)^{\frac{\eta}{\eta-1}} \\ (P_t)^{-\eta} &= \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{\eta}{\eta-1}} \\ P_t &= \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{1}{1-\eta}}. \end{aligned} \tag{92}$$

Each intermediate firm therefore faces the demand curve given by equation (91) where the final goods price P_t is given by equation (92) .

B.5.2 New Keynesian Philips Curve Derivation

We solve the Bellman equation by first determining how the firm minimizes its cost of production taking its output $y(p_t)$ as given. We then solve for the firm's optimal pricing choices, which yield the New Keynesian Phillips Curve.

The firm's cost minimization problen can be written as

$$\min_{n_t,k_t} w_t n_t + r_t^K k_t \tag{93}$$

subject to the production feasibility constraint

$$(Z_t n_t)^\alpha (k_t)^{1-\alpha} \geq \bar{y}. \tag{94}$$

We denote the multiplier on the feasibility constraint in equation (94) as mc_t. The first order conditions are

$$w_t = mc_t (Z_t)^\alpha \alpha (n_t)^{\alpha-1} (k_t)^{1-\alpha}, \tag{95}$$

$$r_t^K = mc_t (Z_t)^\alpha (1-\alpha)(n_t)^\alpha (k_t)^{-\alpha}, \tag{96}$$

which implies

$$\frac{w_t}{r_t^K} = \frac{\alpha (n_t)^{\alpha-1}(k_t)^{1-\alpha}}{(1-\alpha)(n_t)^\alpha (k_t)^{-\alpha}} = \frac{k_t \alpha}{n_t(1-\alpha)} \tag{97}$$

$$(1-\alpha) w_t n_t = \alpha r_t^K k_t. \tag{98}$$

We plug equation (98) back into the production function (equation (94)) to solve for labor and capital demand

$$\begin{aligned} \bar{y} = (Z_t n_t)^\alpha (k_t)^{1-\alpha} &= (Z_t n_t)^\alpha \left(\frac{(1-\alpha) w_t n_t}{\alpha r_t^K} \right)^{1-\alpha} \\ \frac{\bar{y}}{(Z_t)^\alpha} &= n_t \left(\frac{(1-\alpha) w_t}{\alpha r_t^K} \right)^{1-\alpha} \\ n_t &= \frac{\bar{y}}{(Z_t)^\alpha} \left(\frac{1-\alpha}{\alpha} \right)^{\alpha-1} \left(\frac{w_t}{r_t^K} \right)^{\alpha-1} \end{aligned}$$

and

$$k_t = n_t \frac{(1-\alpha) w_t}{\alpha r_t^K} = \frac{\bar{y}}{(Z_t)^\alpha} \left(\frac{(1-\alpha)}{\alpha} \right)^\alpha \left(\frac{w_t}{r_t^K} \right)^\alpha .$$

Differentiating 94 with respect to $\bar{y}$ and substituting these expressions for n_t and k_t gives the marginal cost of production

$$\begin{aligned} mc_t &= w_t \frac{\bar{y}}{(Z_t)^\alpha} \left(\frac{1-\alpha}{\alpha} \right)^{\alpha-1} \left(\frac{w_t}{r_t^K} \right)^{\alpha-1} + r_t^K \frac{\bar{y}}{(Z_t)^\alpha} \left(\frac{(1-\alpha)}{\alpha} \right)^\alpha \left(\frac{w_t}{r_t^K} \right)^\alpha \\ &= \frac{1}{(Z_t)^\alpha} \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^\alpha (w_t)^\alpha (r_t^K)^{1-\alpha}. \end{aligned}$$

With this solution in hand, the Bellman equation can be simplified. Because the production is constant returns to scale we can write the cost as $w_t n_t + r_t^K k_t = y(p_t) mc_t$, which yields

$$V^W(p_{t-1}, \mathcal{S}_t) = \max_{p_t} y(p_t)\left(\frac{p_t}{P_t} - mc_t\right) - \frac{\xi}{2}\left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1\right)^2 + \mathrm{E}_t\left[\mathcal{M}_{t,t+1} V^W(p_t, \mathcal{S}_{t+1})\right].$$

The FOC for choosing the price p_t is

$$0 = y'(p_t)\left(\frac{p_t}{P_t} - mc_t\right) + \frac{y(p_t)}{P_t} - \xi\left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1\right)\frac{1}{\bar{\Pi} p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right]. \quad (99)$$

The demand curve has derivative

$$y'(p_t) = -\frac{\eta}{P_t} Y_t \left(\frac{p_t}{P_t}\right)^{-\eta-1} \quad (100)$$

In equilibrium all firms in the sector choose the same price so this becomes

$$y'(p_t) = -\frac{\eta}{P_t} Y_t \quad (101)$$

Plugging equation (101) into the pricing FOC (and using $p_t = P_t$ and $\Pi_t = \frac{p_t}{p_{t-1}}$) yields

$$\begin{aligned}
0 &= -\frac{\eta}{P_t} Y_t \left(\frac{p_t}{P_t} - mc_t\right) + \frac{Y_t}{P_t} - \xi\left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1\right)\frac{1}{\bar{\Pi} p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right] \\
0 &= Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1\right)\frac{1}{\bar{\Pi} p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right] \\
0 &= Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{\Pi_t}{\bar{\Pi}} - 1\right)\frac{\Pi_t}{\bar{\Pi} P_t} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right].
\end{aligned}$$

The marginal value of being able to change today's price is given by the envelope theorem

$$\frac{\partial V^W(p_{t-1}, \mathcal{S}_t)}{\partial p_{t-1}} = \xi\left(\frac{p_t}{\bar{\Pi} p_{t-1}} - 1\right)\frac{p_t}{\bar{\Pi}(p_{t-1})^2}.$$

So,

$$\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t} = \xi\left(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1\right)\frac{\Pi_{t+1}}{\bar{\Pi}(P_t)}.$$

The pricing FOC can then be written as

$$0 = Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{\Pi_t}{\bar{\Pi}} - 1\right)\frac{\Pi_t}{\bar{\Pi} P_t} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\xi\left(\frac{\Pi_{t+1}}{\bar{\Pi}} - 1\right)\frac{\Pi_{t+1}}{\bar{\Pi} P_t}\right].$$

After multiplying through by P_t, this finally yields

$$\xi\left(\frac{1+\pi_t}{\bar{\Pi}} - 1\right)\frac{1+\pi_t}{\bar{\Pi}} = Y_t(1 - \eta + \eta mc_t) + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\xi\left(\frac{1+\pi_{t+1}}{\bar{\Pi}} - 1\right)\frac{1+\pi_{t+1}}{\bar{\Pi}}\right]. \quad (102)$$

which is the New Keynesian Phillips Curve for this sector.

C Data and Calibration

C.1 Repeat Sales Index with Two Tiers

This appendix explains how we constructed our repeat sales house price indices in figure 1a. We use the Corelogic housing database and consider only transactions that occur in or after after the year 2010. For each house, we first compute its median price across all transactions in the dataset. Then, for each county, we compute the median transaction price since 2010 in that county. We then separate our houses into "high value" and "low value" homes by comparing their median price to the median price in their county.

We then use these "high" and "low" value segments of the housing market to construct two repeat sales house prices indices. Next, for each of our two segments of the housing market, we find all pairs of transactions for which a house i transacts at time t at a price P_{it}. Let δ_t be our house price index at time t. We estimate δ_t using the repeat sales regression

$$log(P_{it}) = \delta_t + \alpha_i + e_{it} \tag{103}$$

where e_{it} is the error of our regression, and α_i is a house fixed effect, so that only pairs of trades on a house impact the δ_t. We choose the values of each δ_t to minimize the median absolute deviations from our regression equation, and use $exp(\frac{\delta_t}{\delta_{t'}})$ as our measure of price growth from time t to time t'. We bucket all transactions within each quarter and run our regression at a quarterly frequency. Finally, to plot our results, we normalize the house price index to be 100 at the start of 2019.

C.2 Computing Mortgage Duration

This appendix explains how we match the duration of the mortgage contracts in our model to that of a 30-year fixed rate mortgage. We first compute the duration of a 30-year fixed rate mortgage, and then show how we compute the duration of the mortgages in our model.

A 30-year fixed rate mortgage makes a sequence of monthly payments that pay off a given face value f at an annual mortgage rate r_f. If the monthly payment is i, then we must have that

$$f = \sum_{t=1}^{12*30} \frac{i}{(1+r_f)^{t/12}} \tag{104}$$

The duration of the mortgage is therefore

$$\frac{\sum_{t=1}^{12*30} \frac{t*i/12}{(1+r_f)^{t/12}}}{\sum_{t=1}^{12*30} \frac{i}{(1+r_f)^{t/12}}} = \frac{\sum_{t=1}^{12*30} \frac{t/12}{(1+r_f)^{t/12}}}{\sum_{t=1}^{12*30} \frac{1}{(1+r_f)^{t/12}}}. \tag{105}$$

The mortgages in our model are geometrically declining perpetuities with quarterly payments. If $r_q = (1+r_f)^{.25} - 1$ is the per-quarter discount rate, the present value of our declining geometric perpetuity with a next payoff of 1 is

$$\frac{1}{r_q + 1 - \delta} \tag{106}$$

Their duration is given by

$$DUR = (1/4)\frac{1/(1+r_q)}{\frac{1}{r_q+1-\delta}} + (\frac{1}{\frac{1}{r_q+1-\delta}})\sum_{t=2}^{\infty} \frac{\delta^{t-1}t/4}{(1+r_q)^t} \tag{107}$$

$$= (1/4)\frac{1+r_q-\delta}{1+r_q} + (1 - \frac{1+r_q-\delta}{1+r_q})(DUR + 1/4) \tag{108}$$

so

$$DUR = 1/4\frac{1+r_q}{1+r_q-\delta} \tag{109}$$

$$\delta = \frac{(1+r_q)(DUR - 1/4)}{DUR}. \tag{110}$$

We apply these expressions at the quarterly mortgage yield $r_q = .014$ (coming from a 98 basis point real risk-free rate and 42 basis point mortgage spread) to compute the value $\delta = .991$, matching the 11.05 year duration of a 30-year fixed rate mortgage.

C.3 Refinancing Elasticities in Model and Data

This appendix explains how we calibrate the refinancing cost parameters of our model. To do so, we use two data moments on how refinancing decisions vary with interest rates and house prices. Bhutta and Keys (2016) estimate that a 1% increase in the Zip code house price index increases the likelihood that a refinancing mortgage borrower extracts equity by 0.51%.

Gerardi, Willen, and Zhang (2023) estimate that a 1% rise in the total gain from an interest-rate based refi causes a 0.23% increase in the quarterly refi rate. We choose our model parameters so that regressions run on model-generated data replicate these findings.

To match these empirical findings in our model, we first construct a measure of the benefit of refinancing a mortgage. When a new mortgage is issued, q_t^m is the present value of future mortgage payments for one unit of face value discounted at the mortgage interest rate. To prepay a mortgage costs κ per unit of face value. The ratio $\frac{\kappa - q_t^m}{\kappa}$ is a measure of the benefits of refinancing a mortgage.

We run the following regression on data from the model's ergodic distribution:

$$Pr(corefi)_t = \alpha_{corefi} + \beta^q_{corefi}(log(\kappa - q_t^m) - log(\kappa)) + \beta^p_{corefi}(log(p_t^{h,B}) - log(E(p_t^{h,B}))) + e_{corefi,t} \tag{111}$$

$$Pr(prepay)_t = \alpha_{prepay} + \beta^q_{prepay}(log(\kappa - q_t^m) - log(\kappa)) + \beta^p_{prepay}(log(p_t^{h,B}) - log(E(p_t^{h,B}))) + e_{prepay,t} \tag{112}$$

Here, $Pr(refi)_t$ is the probability that a borrower who prepays its mortgage chooses to take a cash out refi at time t, and $Pr(prepay)_t$ is the probability a borrower prepays their mortgage. We target regression parameters of $\beta^p_{corefi} = .51$ and β^q_{prepay}=.23.