Printing Away the Mortgages: Fiscal Inflation and the Post-Covid Housing Boom *

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Abstract

We theoretically and quantitatively analyze the impact of fiscal and monetary stimulus during and after the 2020 Covid recession on output, inflation, and house prices. Our theoretical analysis clarifies that fiscal stimulus increases consumption demand in a recession by providing liquidity, by redistributing from savers to borrowers, and by lowering the return on saving if it causes future inflation. Future inflation only occurs if taxes after the recession do not increase to pay for the stimulus. In our quantitative analysis, we study a temporary shift to passive monetary policy with low responsiveness to inflation. Fiscally-driven inflation enabled by this passive monetary policy reduces the real value of both mortgages and government debt, so it increases the spending capacity and housing demand of credit-constrained homeowners. Together with transfer payments and large fiscal deficits during the Covid recession, this policy greatly reduces the recession's severity and causes high house prices and inflation similar to the data.

Keywords: fiscal policy, Covid-19, consumption demand, housing markets, financial intermediation

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1 Introduction

The US government responded to the 2020 Covid crisis with its largest fiscal and monetary stimulus in history. As the economy locked down in March 2020 and consumption fell by roughly 35% (Cox et al., 2020; Chetty et al., 2020), the government responded with expanded unemployment insurance, checks sent to individuals, moritoria on home foreclosures and evictions, and loans to firms. This resulted in deficits in 2020 and 2021 of \$3.1 trillion and \$2.7 trillion. At the same time, the Federal Reserve increased its holdings of government debt from \$2.6 trillion at end of 2019 to \$6.2 trillion at the start of 2022, paying for these purchases with \$2.4 trillion in new bank reserves, a form of interest-bearing money held within the banking system. 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% (Gamber et al., 2022), and inflation grew from 1.5% to 7.5%. This paper theoretically and quantitatively examines how post-Covid fiscal and monetary stimulus contributed to the economy's rapid recovery and the boom in goods and house prices.

We first analyze the impact of fiscal stimulus in a simple theoretical model where holding government debt allows banks to provide liquidity to households. Because of rigid wages, households face involuntary unemployment when there is a shortage of consumption demand during a recession. The model isolates three distinct channels by which fiscal stimulus can reduce unemployment in a recession, only one of which causes inflation. First, an increase in government debt allows households to hold more liquid assets, who therefore consume more when they face a liquidity shock. 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.

We then simulate the impact of post-Covid fiscal and monetary stimulus in a richer quantitative model. Our model features two distinct groups of "saver" and "borrower" households, a financial intermediary that provides mortgages, and a non-financial sector with sticky prices and sticky wages. Our savers are more patient than borrowers, so in equilibrium savers hold most financial assets while borrowers have a sizable mortgage. These mortgages are provided by a financial intermediary that finances its mortgages with riskless deposits and risky equity, where there is a cost of raising equity capital. Borrowers have to fund their consumption and pay their mortgage out of their holding of riskless deposits and choose to default on their mortgage if paying it would result in an extremely low level of consumption. Our approach to modeling mortgage default is new and 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. A central bank sets nominal interest rates, and a fiscal authority sets the magnitude of taxes and transfers, both as a function of the state of the economy. The interaction between fiscal and monetary policy plays a crucial role in explaining how our economy responds to shocks.

In our calibrated model, we simulate the policy response to a recession caused by a drop in consumption demand similar to that during the early Covid pandemic. In the absence of government intervention, the recession would have been more severe and would have caused a severe rise in mortgages defaults and a drop in house prices. This is because homeowners would have lost their jobs and become unable to pay their mortgages. Unemployment insurance that replaces the income of those unable to work considerably reduces the depths of the recession, regardless of how it is funded. However, if the monetary authority decides not to raise real interest rates in response to inflation and the fiscal authority is slow to raise taxes to reduce debt after the recession, a large burst of inflation occurs as the recession ends. Only after the monetary authority raises interest rates sufficiently aggressively does inflation return to normal levels. This post-recession inflation reduces the return on savings during the recession and helps to stimulate the economy as well.

One unique feature of our model is that when the government inflates away its debt after the Covid recession, a boom in house prices occurs too. This is because private sector mortgage debt is inflated away as well, transferring resources from savers to borrowers. Because borrowers' demand for housing is constrained by the supply of credit, this inflation reduces their indebtedness and allows them to afford even more housing. Like the post-recession inflation in our model, this house price boom is transitory and reverts when the central bank raises rates enough to control inflation. A large literature following Leeper (1991) has analyzed how the interaction between fiscal and monetary policy impacts inflation. We believe our paper is the first to connect inflation caused by lax fiscal policy to the redistributive effects of inflation on asset and house prices (Leombroni et al., 2020; Doepke and Schneider, 2006). This allows us to parsimoniously match a range of otherwise seemingly unrelated stylized facts from the Covid recession.

Our quantitative model also allows us to decompose the channels by which fiscal and monetary stimulus were most effective after the Covid recession. We show that the less responsive monetary policy is to inflation after the Covid recession, the greater the burst of inflation and house prices. In addition, the recovery from the recession is strongest when monetary policy is the least responsive to inflation. However, as monetary policy returns to its standard Taylor rule that reacts strongly to inflation, both inflation and house prices revert back to normal levels. The magnitude of this boom is increasing in the size of deficits during the recession, since a greater amount of debt can then be inflated away. Consistent with our simpler theoretical model, the only quantitatively important way that fiscal stimulus causes post-recession inflation is when a loose policy after a recession forces government debt to be inflated away. Although our model allows for other potential channels, it suggests quantitatively that this interaction between fiscal and monetary policy plays the most important role in explaining the inflation and house price boom that occured after the Covid recession.

Related Literature Our work relates to theoretical work modeling the Covid crisis as a drop in consumption demand (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. (Cox et al., 2020; Chetty et al., 2020) document a particularly large drop in consumption in the recession. Cherry, Jiang, Matvos, Piskorski, and Seru (2021) shows that large-scale debt forbearance during the crisis lead to an unprecedented drop in delinquencies during a recession. (Ganong et al., 2021a,b) show that despite the large wave of unemployment in the Covid crisis, generous unemployment insurance stabilized incomes during the period. Like our work, these theoretical papers that are motivated by stylized facts from the Covid recession find that generous social insurance and redistribution played a crucial role in dampening the severity of the Covid recession.

Our paper is among the first to study the impact of stimulus during the Covid recession on the boom in inflation and house prices that occurred in 2021-2022. Of the above papers, only Bhattarai, Lee, and Yang (2021) shows that redistribution that is not combined with future tax increases can cause inflation. In addition Bianchi and Melosi (2022) show that inflation occurs if post-Covid stimulus caused households to believe that the government pay not tax away all the newly-issued debt. This relates to a broader literature on the "fiscal theory of the price level" (Leeper, 1991; Woodford, 2001; Sims, 2011; 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. Our theoretical model decomposes the impact of fiscal stimulus into several channels, one of which involves causing future inflation by committing not to raise taxes. Quantitatively, we find that this channel has only a moderate impact on consumption demand and that much of the stimulus provided during the Covid recession could have been acheived without inflation if fiscal and monetary policy tightened appropriately afterwards.

Relative to existing work on the internation between fiscal and monetary policy, ours is the first to include a realistic financial sector that provides deposits and mortgages. We therefore can confront empirical evidence from Levine, Lin, Tai, and Xie (2021); Fuster, Hizmo, Lambie-Hanson, Vickery, and Willen (2021) of an unprecedented boom in bank deposit quantities and in mortgage refinancing during the post-Covid recovery. In addition, our model has a novel channel by which fiscally-driven inflation causes redistribution between agents in the private sector due to privately issued nominal debt. Redistribution between borrowers and savers plays an important role in the transmission of conventional monetary policy (Auclert, 2019), though we believe we are the first to emphasize this channel in the context of fiscally-driven inflation. As a result, our model is able to match the large housing boom that occured post-Covid, primarily because inflation caused redistribution to credit-constrained homeowners who could then buy even more housing.

2 Motivating Facts

Figure 1 presents four key dimensions in which the US economy behaved unusually during and after the 2020 Covid recession. First, unemployment spiked dramatically in 2020 to 14 percent and then rapidly reverted to a 6 percent unemployment rate in 2021 and then continued to decline. Second, inflation was moderately low during 2020 after which it surged in 2021 and 2022 to a peak of 9 percent. During this inflation boom, house prices, which had grown at a trend rate in 2020, also began an usually rapid boom as well. A final dimension in which the economy behaved unusually is that the M2 money supply (which includes cash as well as various forms of bank deposits) surge from roughly \$ 15 trillion at the start of 2020 to over \$21 trillion in 2022.

Figure 2 illustrates several dimensions in which aggressive fiscal and monetary stimulus may have contributed to the behave of the post-Covid economy. While the unemployment spike in 2020 was likely due to the impact of the pandemic itself, the rapid recovery of unemployment may have been due to aggressive stimulus. The U.S. ran its largest primary deficits (before interest payments) 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. However, most of the debt created by these deficits was purchased by the Federal Reserve, who increased their debt holdings from \$ 2.6 trillion \$ 6.2 trillion. To finance these purchases, the central bank paid for them by increasing the supply of bank reserves, a form of money-like asset held within the banking system from \$1.7 trillion to \$4.2 trillion. 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.

3 Model

3.1 Flexible Price Steady State

The goal of this paper is to understand and decompose the various channels by which fiscal and monetary stimulus impacted the post-Covid economy. Figure 2 shows us that large-scale deficit spending, a massive increase in the supply of liquid assets, and loose conventional monetary

Figure 1: US Economy During and After 2020 Covid Recession

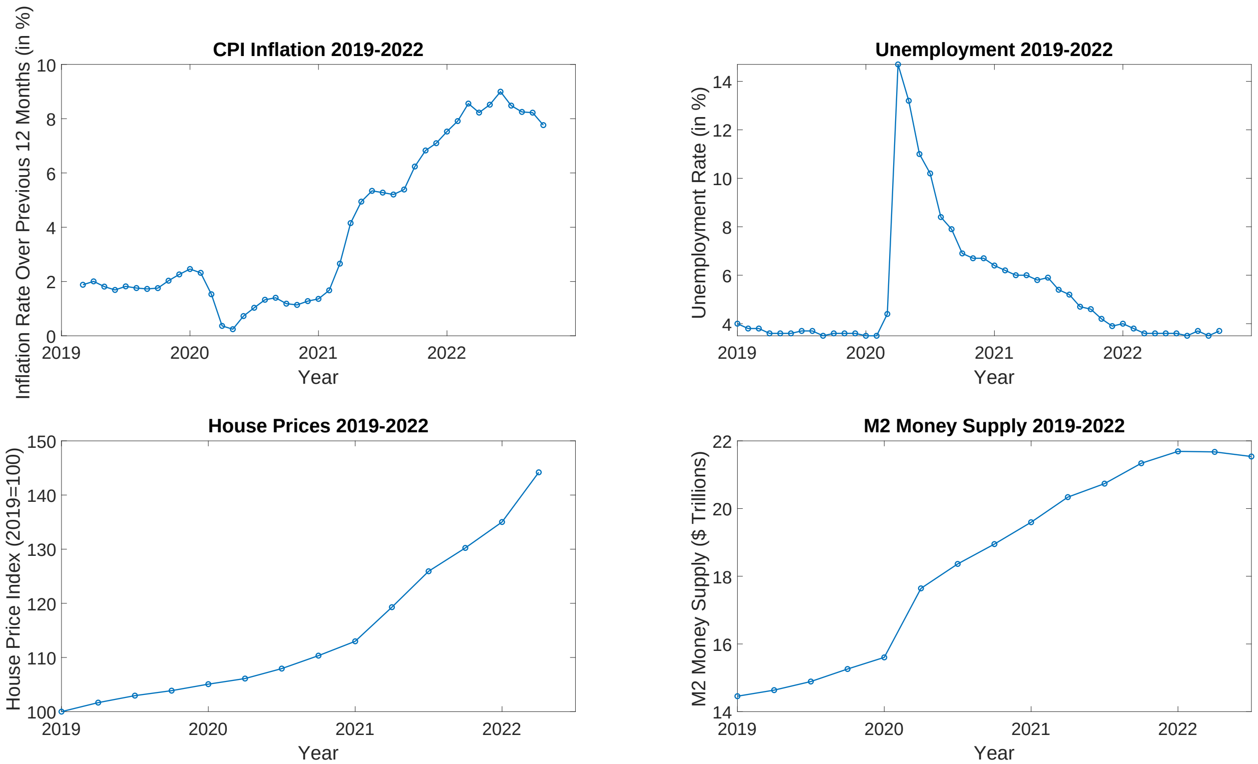
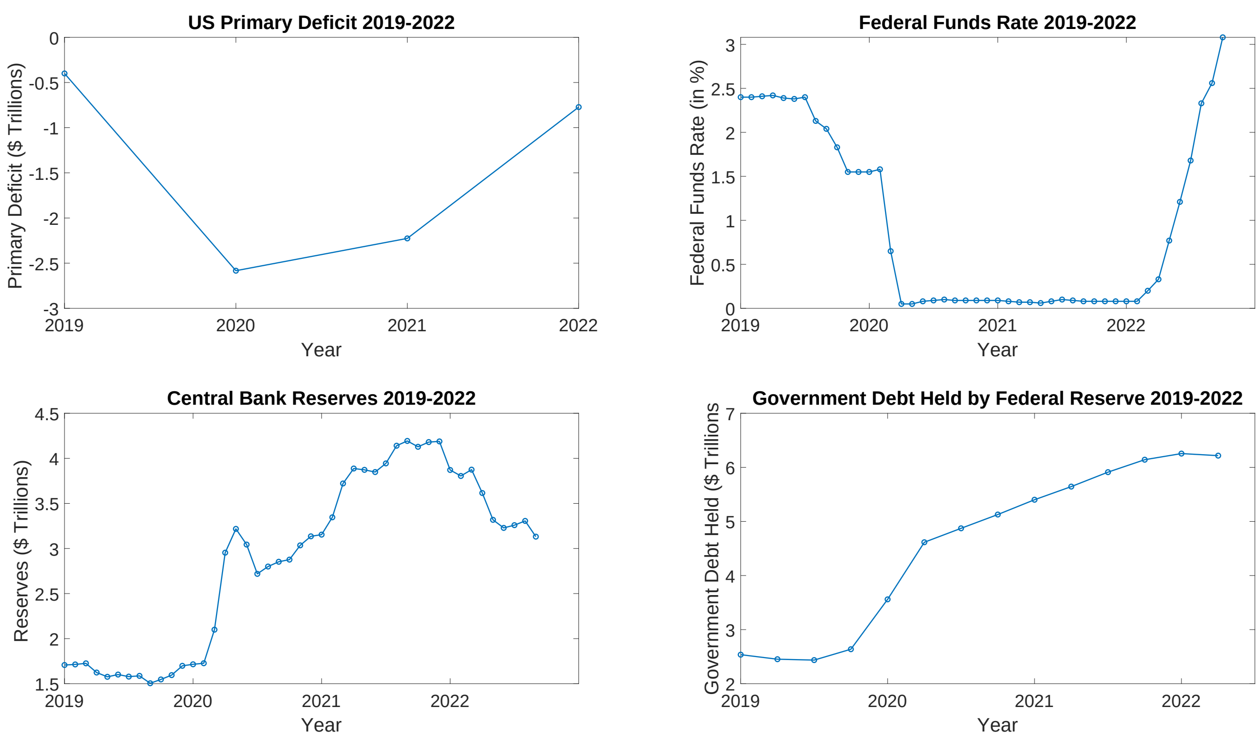


Figure 2: Policy Response to 2020 Covid Recession



policy are three key aspects of post-Covid stimulus. This motivates us to begin with a tractable theoretical model in which government taxes and spending can both redistribute resources between agents as well as provide a supply of liquid assets that households demand. We first analyze this model's steady state behavior outside of an economic crisis. We then consider the impact of fiscal policy in a temporary recession with sticky wages, where unemployment occurs because of a lack of consumption demand before the economy returns to steady state.

The model features households who consume, own houses with mortgages, provide labor, and face idiosyncratic liquidity shocks. After a liquidity shock, a household member can only consume out of bank deposits holdings and mortgage borrowing but not out of its labor income. These deposits are backed by risk-free government debt and risk-free mortgages. The model has a family of different steady states indexed by the amount of taxes the government raises. In steady states with higher taxes, the government can back a larger real quantity of outstanding debt, which provides more liquidity insurance to households. Holding real tax revenue fixed, any increase in nominal deposit/government debt holdings is inflated away by a proportional increase in the price level.

Households' Liquidity Management Problem. The representative household of type s maximizes its expected utility over labor, housing, and consumption. The household begins period t holding a nominal quantity of bank deposits/liquid assets d_t^s. In addition, it earns nominal labor income $w_t l_t^s$ from its labor supply l_t^s, faces a transfer t_t^s from the government, and owns housing h_{t-1}^s at nominal price $p_t^{h,s}$. In each period t, each member of the household has a probability $1-q$ of learning that it faces a "liquidity shock." When a household member faces a liquidity shock, it can only consume out of its per capita deposit holdings and mortgage borrowing in that period, not out of labor income. Households can buy consumption goods at the nominal price p_t and new housing at price $p_t^{h,s}$. They invest in deposits at the nominal interest rate r_t. They take on a mortgage with face value f_t^s using their housing assets as collateral, subject to the constraint $f_t^s \leq \lambda^s p_{t+1}^{s,h} h_t^s$. Mortgages are nominal, short-term and frictionless with the same rate as deposits, and it is always optimal for households to exhaust their borrowing constraint.

The household has a utilitarian objective function over the welfare of all its members

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

where $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. In this expression, c_t^s is the per capita consumption of those not facing a liquidity shock and $c_t^{s,liq}$ the per capita consumption of those that do. The household faces the 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

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

The household also faces a liquidity constraint $p_t c_t^{s,liq} \leq d_t^s$. If this liquidity constraint does not bind, the optimal consumption level is the same whether or not a liquidity shock. If it does, 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

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

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

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

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 $p_t C_t - w_t L_t$ subject to $C_t \leq L_t$. Their first-order condition yields $p_t = w_t$. This implies that the household's labor supply decision can be written as

$$u'(c_t^s) = k. \tag{6}$$

The total output of the economy is $\sum_s l_t^s$, so the economy therefore has the resource constraint

$$\sum_s l_t^s = \sum_s \left[qc_t^s + (1-q)c_t^{s,liq} \right]. \tag{7}$$

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. If we sum the budget constraints of all households we get $\sum_s d_{t+1}^s = (1+r_t)\sum_s [d_t^s - p_t(qc_t^s + (1-q)c_t^{s,liq}) + w_t l_t^s - (m_t^s + t_t^s)]$. Imposing the resource constraint and that $p_t = w_t$ then yields the nominal bank budget constraint

$$\sum_s d_{t+1}^s = (1+r_t)\left[\sum_s d_t^s - \sum_s \left(f_{t-1}^s - \frac{f_t^s}{1+r_t} + t_t^s \right) \right]. \tag{8}$$

which can be solved forward to get the present value form of the bank's budget constraint

$$\sum_s d_t^s = \sum_s f_{t-1}^s + \sum_{\tau=0}^{\infty} \frac{\sum_s t_{t+\tau}^s}{\Pi_{\theta=0}^{\tau}(1+r_{t+\theta})} + \lim_{\tau\to\infty} \frac{\sum_s d_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1}(1+r_{t+\theta})}. \tag{9}$$

The assets held by the bank are first mortgages of value $\sum_s f_{t-1}^s$ and second government debt of present value $g_t = \sum_{\tau=0}^{\infty} \frac{\sum_s t_{t+\tau}^s}{\Pi_{\theta=0}^{\tau-1}(1+r_{t+\theta})} + \lim_{\tau\to\infty} \frac{\sum_s d_{t+\tau}^s}{\Pi_{\theta=0}^{\tau}(1+r_{t+\theta})}$, potentially with a rational bubble. 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.

Real Allocations. We can write these nominal first order conditions, budget constraints, and resource constraints as the associated real expressions

$$u'(c_t^s) = \beta_s R_t \left[q u'(c_{t+1}^s) + (1-q) u'(D_{t+1}^s) \right] \tag{10}$$

$$u'(c_t^s) = k \tag{11}$$

$$\sum_s l_{s,t} = \sum_s q c_t^s + (1-q) D_t^s \tag{12}$$

$$u'(c_t^s) \left[P_t^{s,h} - \frac{\lambda^s P_{t+1}^{s,h}}{R_t} \right] = v'(h_t^s) + \beta_s u'(c_{t+1}^s)(1-\lambda^s) P_{t+1}^{s,h} \tag{13}$$

$$D_{t+1}^s = R_t \left[D_t^s - (q c_t^s + (1-q) D_t^s) + l_t^s - \left(F_{t-1}^s - \frac{F_t^s}{R_{t+1}} \right) - T_t^s \right] \tag{14}$$

In these expressions, $R_t = (1+r_t)\frac{p_t}{p_{t+1}}$ is the real interest rate, $D_t^s = \frac{d_t^s}{p_t}$ is real deposit holdings, $P_t^{s,h} = \frac{p_t^{s,h}}{p_t}$ is the real house price for group s, and $T_t^s = \frac{t_t^s}{p_t}$ is real taxes/transfers. Given this system, the real allocation in an equilibrium is determined by the real tax/transfer policies T_t^s of the government.

Steady State Equilibria. We first analyize steady state equilibria in the special case without mortgage borrowing, $\lambda^s = 0$, which sets the total supply of deposits equal to the stock of outstanding government debt. The model has a continuum of steady state equilbria determined by the supply of real assets. When the government raises a large quantity of tax revenue relative to the outstanding stock of deposits, it can pay a high real interest rate on deposits. As a result, the demand for deposits is high, and the market clears with a large supply of liquidity and a small convenience yield for liquid deposits. Conversely, when tax revenue is low, the equilibrium quantity of real liquid assets is low and the convenience yield for liquid assets is high. These equilibria are indexed by a parameter κ we call the taxation ratio given by the ratio between total real tax revenue and total real government debt supply in steady state

$$\kappa = \frac{\sum_s T_{ss}^s}{D_{ss}}. \tag{15}$$

The real government budget constraint in steady state is

$$\sum_s T_{ss}^s = (R_{ss} - 1) \sum_s D_{ss}^s. \tag{16}$$

$$D_{ss}^s = \sum_t \frac{T_{ss}^s}{(R_{ss})^t} + lim_{t \to \infty} \frac{D_{ss}^s}{(R_{ss})^t}, \tag{17}$$

which implies the real interest rate must be

$$R_{ss} = 1 + \kappa. \tag{18}$$

Given the real rate R_{ss}, the steady state real deposit holdings D_{ss}^s demanded by group s satisfy

$$k = \beta_s R_{ss} \left[qk + (1-q) \max(u'(D_{ss}^s), k) \right]. \tag{19}$$

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

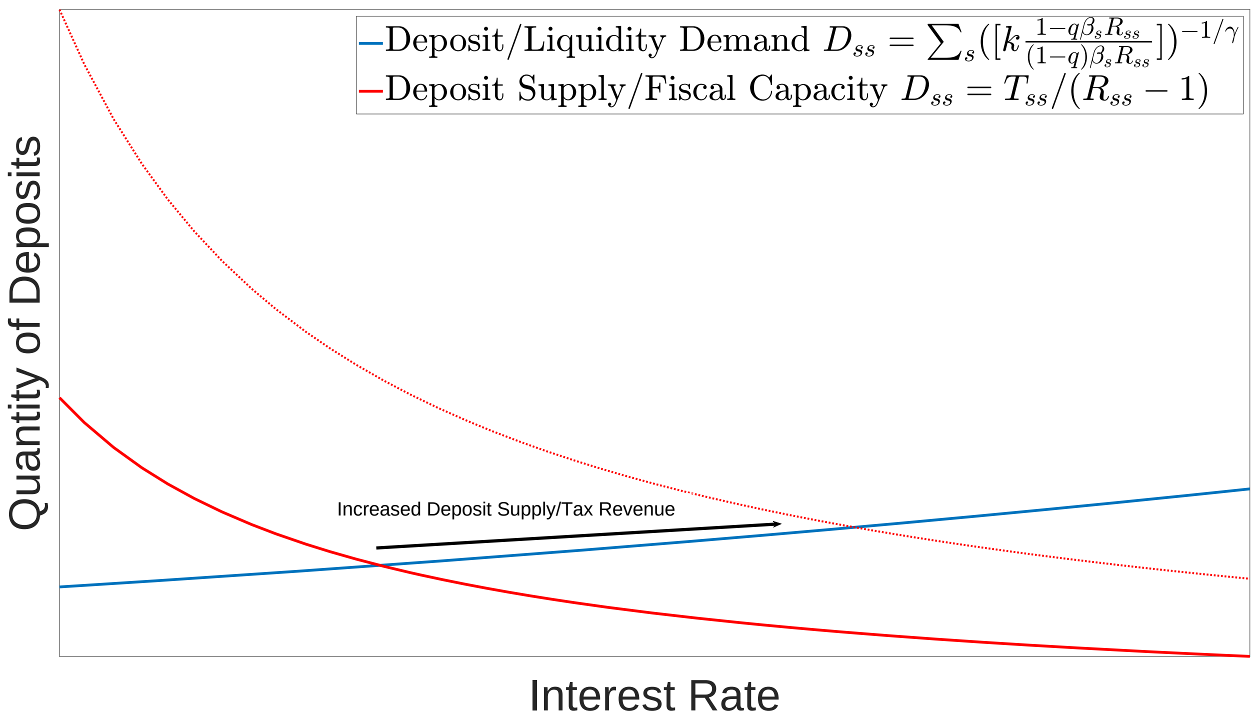
$$\sum_s (u')^{-1} \left(k \frac{1 - q\beta_s R_{ss}}{(1-q)\beta_s R_{ss}} \right) = \sum_s D_{ss}^s \tag{20}$$

that is increasing in the real return R_{ss}.

Figure 3 illustrates how equilibrium is determined in the model. Given the amount of real tax revenue $\sum_s T_{ss}^s$ raised, the government budget constraint (equation 16) acts as a supply curve for deposits. The lower the interest rate, the greater the quantity of deposits that can be backed by a given amount of tax revenue. In addition, equation 20 yields a demand curve for deposits that is increasing in the real interest rate. In this model, an asset whose cash flows cannot be consumed after a liquidity shock has a real rate of return R_{nc} equal to $1 = \max_s \beta_s R_{nc}$ determined by the time preference of the most patient group. As a result, an increase in the real return on deposits reflects a reduction in its convenience yield, the return forgone to hold a deposit instead of a less liquid asset. Equating supply and demand determines both the equilibrium real rate and quantity of deposits.

An increase in tax revenue shifts out the deposit supply curve, resulting in a higher quantity of deposits and higher equilibrium real rate. More deposits allows households to be better

Figure 3: Fiscal capacity and the market for liquid assets



insured against liquidity shocks.[1]

Proposition 1. *1. The model has a family of steady state equilibria indexed by the ratio $\kappa = \frac{\sum_s T^s_{ss}}{\sum_s D^s_{ss}}$ between total real tax revenue and total supply of real deposits. As the taxation ratio κ increases, real deposit rates and quantites both increase to satisfy equations 16 and 20.*

2. Given the ratio κ which determines real quantities, the model is neutral to any nominal changes. 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 nominal interest rates results in a higher inflation rate to hold real rates fixed.

The model integrates two theories of what determines the level of goods prices. First, the model has a "monetarist" flavor in which the price level is determined by the supply and demand for money-like assets. Holding fixed real interest rates and the nominal supply of liquid assets,

[1]There is even an equilibrium with no tax revenue $T^s_{ss} = 0$ where $R_{ss} = 1$. However, such an equilibrium is supported by a high marginal utility of consumption for agents facing a liquidity shock and thus an inefficiently low level of social insurance. All Pareto optimal allocations have in common that deposits earn a real rate of return satisfying $1 = \max_s \beta_s R_{ss}$, providing the maximum of liquidity insurance possible to households.

the price level must adjust to a level in which real liquid balances satisfy the demand for liquidity (equation 20). Second, the model must also satisfy the government budget constraint (equation 17), where says the price level must equate the real value of outstanding government debt and the present value of future primary surpluses the government pays to debtholders. Because the real interest rate in this present value endogenously responds to changes in the convenience yield of safe assets, monetarism and the fiscal theory of the price level are reflected by two markets that must jointly clear at the equilibrium quantities and yields of government debt.

3.2 Nominal Rigidites, Involuntary Unemployment, and Fiscal Stimulus

With rigid wages that result in involuntary/Keynesian unemployment added to the model, fiscal policy becomes an attractive tool for stimulating the economy. This section extends the above model by adding a simple version of rigid wages that can result in unemployment. If the nominal wage level is w_t at time t, wages cannot be lowered but can be costlessly increased in periods after t. We assume that after some time T, the economy is in flexible price equilibrium with a nonnegative inflation rate. In the finite period before this, a shortage of aggregate demand pushes output below the level acheived with flexible prices. In this enviornment, we analyize the impact of a government sending transfers to consumers. The same set of real equations (equations 10,12, and 14) still follow, except that labor supply may be strictly below that desired by the consumer.

Output is no longer pinned down by $u'(c_t^s) = k$, which sets the marginal utility of consumption equal to the marginal disutility of labor but can potentially be below this level. Given the nominal deposit holdings d_t^s of each agent s, the real deposit holdings D_t^s are the only state variables we have to explicitly track and are determined by the wage level w_t. The labor market no longer clears at an equilibrium wage, with an excess of household labor supply resulting in involuntary unemployment. When there is unemployment, we impose the rationing rule that all households face an equal amount of unemployment. That is, if household s wants to supply labor $l_{s,t}^*$ at the prevailing wage, the realized labor $l_{s,t}$ is chosen so that $l_{s,t}^* - l_{s,t}$ is constant across all households s.

We first charecterize the economy's behaviour starting after time T. For $t \geq T+1$ where we have the labor market clearing condition $u'(c_t^s) = k$, we have that if the government implements a real rate R_{ss} with real tax revenue T_{ss}

$$\sum_s D_{t+1}^s = R_{ss}\left[\sum_s D_t^s - \sum_s \left(\lambda^s h^s P_t^{h,s} - \frac{\lambda^s h^s P_{t+1}^{h,s}}{R_{ss}}\right) - \sum_s T_{ss}^s\right] \tag{21}$$

$$k = \beta_s R_{ss}[qk + (1-q)u'(D_{t+1}^s)]. \tag{22}$$

$$k\left[P_t^{s,h} - \frac{\lambda^s P_{t+1}^{s,h}}{R_t}\right] = v'(h^s) + \beta_s k(1-\lambda^s)P_{t+1}^{s,h} \tag{23}$$

Equation 22 is the steady state Euler equation which implies that D_{t+1}^s takes on its steady state value D_{ss}^s. Equation 23 implies that $P_t^{s,h} = P_{t+1}^{s,h}$ equals the steady state value $P_{ss}^{s,h}$. Because we have $\sum_s D_{t+1}^s = \sum_s D_{ss}^s$, the bank budget constraint (equation 21) implies that $\sum_s D_t^s = \sum_s D_{ss}^s$. It is therefore possible for the distribution of deposits at time T to differ from the steady state value but not the total quantity. In addition, because house prices and real interest rates are at their steady state levels from $t = T+1$ and on, this also implies that real government debt G_t also must equal its steady state level G_{ss} from time $T+1$ and on.

Next, we determine how fiscal policy impacts consumption at time T. The fiscal policies we examine combine an exogenous trasnfer of deposits D_T^s at time t and potentially an increase in taxes T_{T+1}^s at time $T+1$. The consumption Euler equation for household s (equation 10) shows how it responds to our change τ in fiscal policy. For any marginal change τ of government taxes/transfers, the consumption response must satisfy

$$u''(c_T^s)\frac{dc_T^s}{d\tau} = \beta_s \frac{\partial R_T}{\partial \tau}[qk + (1-q)u'(D_{T+1}^s)] + \beta_s R_T (1-q) u''(D_{T+1}^s)\frac{dD_{T+1}^s}{d\tau}. \tag{24}$$

Dividing through by $u'(c_s^T) = \beta_s[qk + (1-q)u'(D_{T+1}^s)]$ and noting that $\frac{u''(c_T^s)}{u'(c_T^s)} = \frac{-\gamma}{c_s^T}$ for our CRRA utility function, this becomes

$$-\frac{\gamma}{c_s^T}\frac{dc_T^s}{d\tau} = \frac{\frac{\partial R_T}{\partial \tau}}{R_T} + \frac{(1-q)u''(D_{T+1}^s)\frac{dD_{T+1}^s}{d\tau}}{qk + (1-q)u'(D_{T+1}^s)} \tag{25}$$

This expression decomposes the impact of stimulus at time T into a term representing a reduction in real interest rates and a term representing redistribution between agents. Consumption c_T^s at time T can be increased either by 1. a reduction in real rates that causes the same consumption growth in all households or 2. redistribution of deposits towards consumers with a higher marginal propensity to consume, since the total quantity of deposits D_{T+1}^s stays fixed. To completely charecterize the impact of fiscal transfers on consumption c_t^s, we therefore need to know how the real interst rate responds ($\frac{\partial R_T}{\partial \tau}$) and how deposit holdings next period respond ($\frac{dD_{T+1}^s}{d\tau}$). In addition, the supply of liquid assets at time T increases household consumption in the liquidity shock state, since households facing a liquidity shock consume all their deposits

$$\frac{dc_T^{s,liq}}{d\tau} = \frac{dD_T^s}{d\tau}. \tag{26}$$

To determine how fiscal policy impacts the real rate at time, T note that the government's budget constraint $G_{ss} = R_T G_T - T_{T+1}$ implies

$$0 = \frac{\partial R_T}{\partial \tau} G_T + R_T \frac{\partial G_T}{\partial \tau} - \frac{\partial T_{T+1}}{\partial \tau} \tag{27}$$

$$\frac{\partial R_T}{\partial \tau} = \frac{\frac{\partial T_{T+1}}{\partial \tau} - R_T \frac{\partial G_T}{\partial \tau}}{G_T} \tag{28}$$

This decreases the real interest rate if and only if $R_T \frac{dG_T}{d\tau} < \frac{dT_{t+1}}{d\tau}$. That is, the real rate falls if and only if the amount of tax revenue raised at time T+1 decreases relative to the amount of tax revenue $R_T D_T$ that must be paid to depositors at the existing real interest rate. Holding fixed nominal interest rates, this implies that inflation is caused if and only if the government does not raise enough tax revenue to finance the debt it issues, which is sometimes referred to as the "fiscal theory of the price level."

We summarize our results so far decomposing the transmission channels of fiscal policy in the following proposition.

Proposition 2. *Suppose that at time T the economy experiences unemployment but that it reverts to full employment at time T+1. If the government provides transfers τ to agents at time T and potentially raises taxes at time T+1, the impact of fiscal policy can be decomposed into three channels.*

1. *Any transfer that increases real deposit holdings $\sum_s D_T^s$ increases the consumption $\sum_s c_T^{s,liq} =$*

$\sum_s D_T^s$ *of households in a liquidity shock, regardless of what happens with future taxes. This has no impact on future inflation.*

2. Any increase in government debt G_T *that is not matched with an increase in future taxes* $\sum_s T_{T+1}^s$ *reduces the real interest rate* $\frac{dR_T}{d\tau} = \frac{\frac{dT_{t+1}}{d\tau} - R_T \frac{dG_T}{d\tau}}{G_T}$ *by causing inflation at time T+1 if nominal rates are held fixed. This increases the consumption* c_t^s *of all households at the same rate.*

3. Holding fixed total deposit and tax quantities, redistribution of deposits towards households s for whom $\beta_s \frac{u''(D_{T+1}^s)}{u''(c_T^s)}$ *is the highest increases total consumption and has no impact on future inflation.*

3.3 The Role of Housing

While channels 1 and 2 in proposition 2 are respectively pinned down by the direct impact of government taxes and transfers, the third redistributive channel crucially depends on the role of housing in the model. We can write the wealth W_t^s that group s has to finance its saving and its consumption outside of the liquidity shock state as

$$W_t^s = qD_t^s + l_T^s - \left(\lambda^s h^s P_T^{h,s} - \frac{\lambda^s h^s P_{T+1}^{h,s}}{R_T} \right) - T_T^s \tag{29}$$

which implies

$$\frac{\partial W_t}{\partial \tau} = (1-q)\frac{\partial D_t^s}{\partial \tau} - \frac{\lambda^s h^s P_{T+1}^{h,s}}{(R_T)^2}\frac{\partial R_T}{\partial \tau} + \frac{\partial l_T^s}{\partial \tau}. \tag{30}$$

Equation 30 shows that on top of the "direct" transfers that households receive in the form of deposits D_t^s, they also receive an additional "indirect transfer" $-\frac{\lambda^s h^s P_{T+1}^{h,s}}{(R_T)^2}\frac{\partial R_T}{\partial \tau}$ due to their increased borrowing capacity when interest rates fall. This indirect transfer is largest for groups s that have pledged the most mortgage debt $\lambda^s h^s P_{T+1}^{h,s}$, so it is received disproportionately by those who are highly levered (with a large λ^s). The final term $\frac{\partial l_T^s}{\partial \tau}$, reflecting general equilibrium effects of increased consumption demand on the labor market, is indirectly determined by the first two. We summarize this in the proposition below.

Proposition 3. *Suppose the government provides additional deposits* D_T^s *to households at time T and potentially changes taxes* T_{T+1}^s *at time T+1 to finance the transfers. The impact of this* *fiscal intervention in a model with housing is equivalent to that in a model without housing combined with an additional transfer equal to the added borrowing capacity* $-\frac{\lambda^s h^s P^{h,s}_{T+1}}{(R_T)^2}\frac{\partial R_T}{\partial \tau}$ *households get from lowered rates, where this additional transfer cannot be consumed in the liquidity shock state.*

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 $T+1$, we have that house prices satisfy at time T

$$u'(c^s_T)\left[P^{s,h}_T - \frac{\lambda^s P^{s,h}_{SS}}{R_T}\right] = v'(h^s) + \beta_s u'(c^s_{ss})(1-\lambda^s)P^{s,h}_{ss} \tag{31}$$

$$u''(c^s_T)\frac{\partial c^s_T}{\partial \tau}\left[P^{s,h}_t - \frac{\lambda^s P^{s,h}_{t+1}}{R_t}\right] + u'(c^s_t)\left[\frac{\partial P^{s,h}_t}{\partial \tau} + \frac{\lambda^s P^{s,h}_{t+1}}{(R_t)^2}\frac{\partial R_t}{\partial \tau}\right] = 0 \tag{32}$$

$$\frac{\partial P^{s,h}_t}{\partial \tau} = \frac{\gamma}{c^T_s}\frac{\partial c^s_T}{\partial \tau}\left[P^{s,h}_t - \frac{\lambda^s P^{s,h}_{t+1}}{R_t}\right] - \frac{\lambda^s P^{s,h}_{t+1}}{(R_t)^2}\frac{\partial R_t}{\partial \tau}. \tag{33}$$

The house price of group s increases through two channels. First, an increase in consumption c^s_t decreases the marginal disutility of funding the down payment $[P^{s,h}_t - \frac{\lambda^s P^{s,h}_{t+1}}{R_t}]$ needed for another unit of housing. Second, a reduction in the real interest rate R_T increases the quantity $\frac{\lambda^s P^{s,h}_{t+1}}{(R_t)}$ households can borrow against a unit of housing. In the special case of "no redistributive effects" where D^s_{T+1} is not changed by fiscal policy, equation 25 implies that $\frac{\gamma}{c^T_s}\frac{\partial c^s_T}{\partial \tau} = \frac{\partial R_T}{\partial \tau}\frac{1}{R_T}$. Equation 33 then simplifies to $\frac{\partial P^{s,h}_T}{\partial \tau}\frac{1}{P^{s,h}_T} = \frac{\partial R_T}{\partial \tau}\frac{1}{R_T}$, so every group's house price grows at the same rate. If instead, $\beta_s \frac{\partial D^s_{T+1}}{\partial \tau}\frac{u''(D^s_{T+1})}{u''(c^s_T)}$ is larger for borrowers than savers, borrower house prices grow more than saver house prices, resulting in the following proposition.

Proposition 4. *Fiscal stimulus that increases households' consumption* c^S_T *at time* T *and lowers the real interest rate* R_T *boosts time* T *house prices. If this stimulus results in redistribution towards borrowers instead of savers, so that* $\beta_s \frac{\partial D^s_{T+1}}{\partial \tau}\frac{u''(D^s_{T+1})}{u''(c^s_T)}$ *is greatest for borrowers, borrower house prices grow at a greater rate than saver house prices.*

3.4 Numerical Illustration

The theoretical analysis above shows that there are three channels by which fiscal stimulus can increase consumption. First, supplying liquid assets D^s_t to agents allows them to increase their consumption $c_t^{s,liq}$ after a liquidity shock. Second, consumption c_s^T is increased for all agents if the real interest rate R_T falls. This fall in R_T only occurs when not enough tax revenue is raised after time T to pay the interest on outstanding debt D_T^s at prevailing future interest rates. As a result, inflation must reduce the real value of government debt, causing real interest rates to fall. Third, redistribution of resources towards agents for whom $\beta_s \frac{u''(D^s_{T+1})}{u''(c^s_T)}$ is largest, increases overall consumption demand. The redistributive impact of fiscal policy is strengthened in the presence of mortgage debt, since falling interest rates allow particularly the most highly levered consumers to borrow and finance their consumption demand.

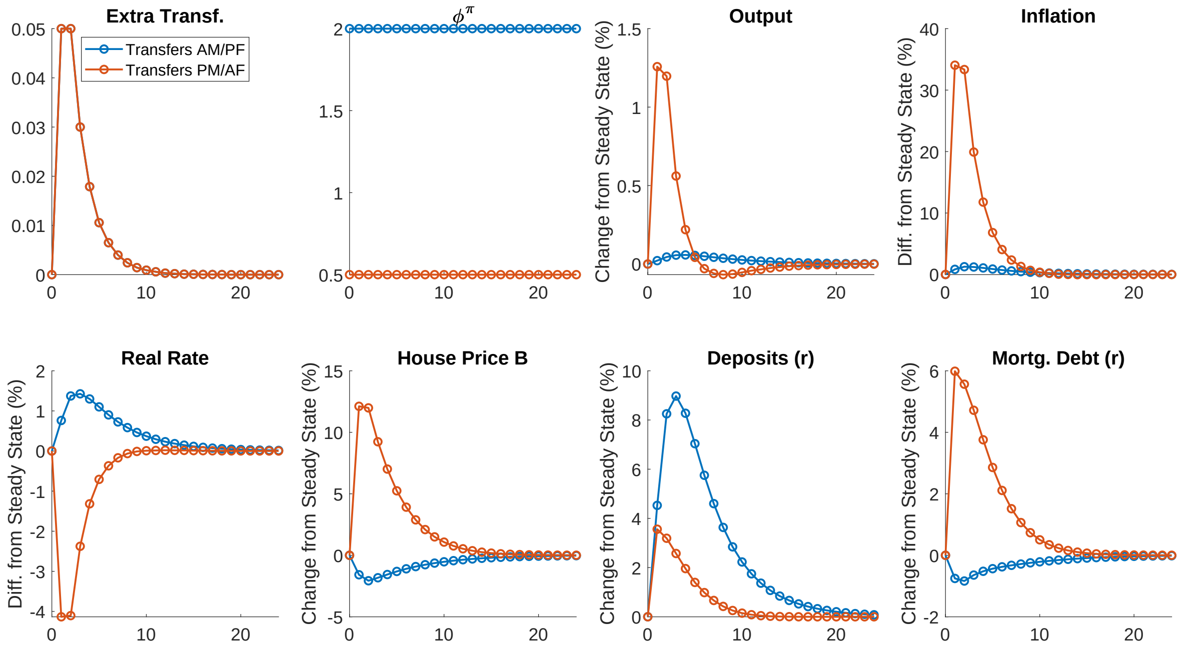
For analytical tractability, we assumed so far that prices are flexible except for one period of disequilibrium. Perfectly elastic labor supply and fiscal and monetary authorities that follow simply pegs of tax and nominal interest rates, respectively, are also necessary to obtain closed-form solutions. In this section, we relax these assumptions to move the analysis closer to a quantitative model of the post-Covid housing boom. First, we focus on two groups of households of equal population, borrowers and savers with a difference in patience $\beta_B < \beta_S$. Borrowers take on mortgage debt, $\lambda^B > 0$, while savers do not ($\lambda^S = 0$). Both types of households have a standard separable disutility from working. On the production side, we foreshadow the quantitative model by adopting a canonical New Keynesian setup with sticky prices a la Rotemberg (1982).

We compute the model equilibrium under these assumptions for standard parameter values, without attaching any significance to magnitudes. In particular, we consider transition paths back to steady state after the economy experiences an unexpected fiscal stimulus of increased transfer payments. To abstract away from direct redistribution, borrowers and savers receive the same per-capita transfer payments. For fiscal and monetary policies, we assume

$$\tau_t = \bar{\tau}_0 \left(\frac{g_t}{\bar{g}} \right)^{\bar{\tau}_1}, \quad 1 + r_t = (1 + \bar{r}) \left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi^\pi}.$$

The tax rule on the left specifies a tax rule with base rate $\bar{\tau}_0$ and sensitivity $\bar{\tau}_1$ to the deviation of real debt g_t from its steady state level $\bar{g}$. The interest rule on the right is standard and changes the nominal rate in response to deviations of inflation from its targets. We compute transitions after the fiscal shock for two different model regimes. First, the active fiscal/passive

Figure 4: Fiscal Shock and Regimes

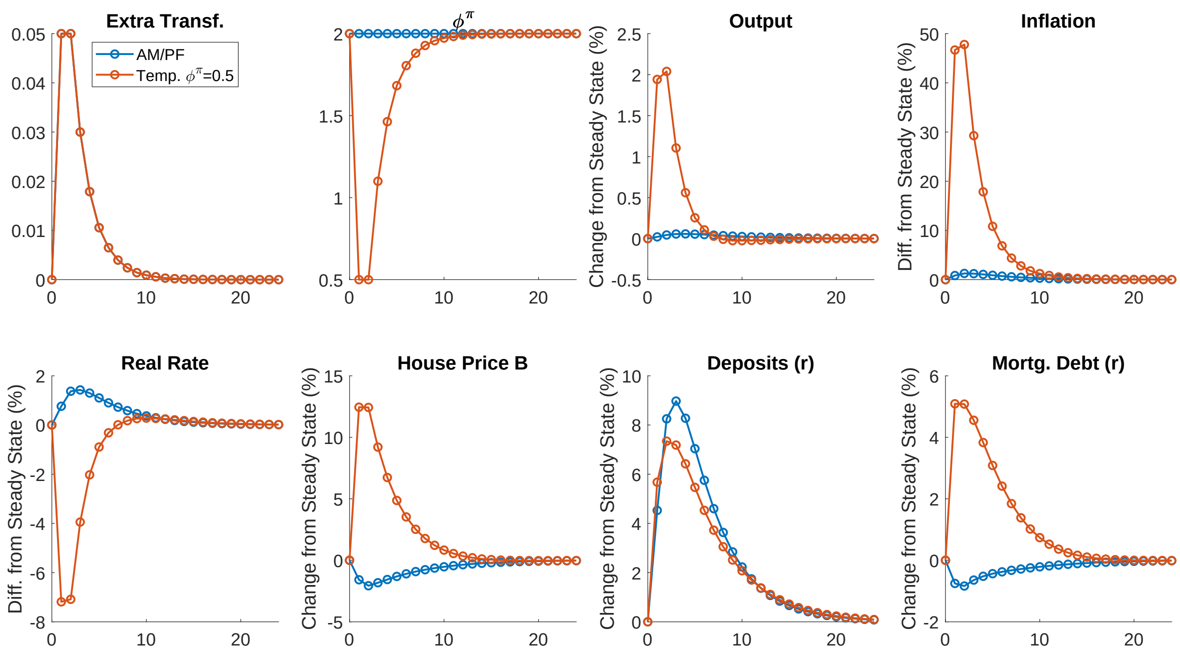


monetary regime (AF/PM) of the theoretical model, setting $\bar{\tau}_1 = 0$ and $\phi^{\pi} = 0.5$.[2] In this regime, the tax rate is constant and nominal rates respond weakly to inflation. Second, the passive fiscal/active monetary regime (PF/AM) that is the "standard" equilibrium considered in the New Keynesian literature, with $\bar{\tau}_1 = \phi^{\pi} = 2$. In the PF/AM regime, the fiscal authority adjusts tax rates to stabilize debt/GDP, and the monetary authority aggressively responds to inflation.

Figure 4 plots rational-expectation transition paths back to steady state for both regimes, with all other parameters the same. The transfer shock hits unexpectedly and then mean-reverts each period with probability 0.4. In the standard PF/AM economy (blue line), the shock has small effects on output, inflation, and house prices. It mainly increases deposit balances as the quantity of government debt rises. The economy's response looks "Ricardian," which is not surprising: transfers do not redistribute wealth and households expect higher taxes along the transition back to steady state. The AF/PM economy (red line), however, looks fundamentally different. Tax rates are known to remain constant, and the central bank only partially stabilizes inflation. Households gain additional nominal wealth from buying government debt that is not

[2] Qualitatively, results are the same with $\phi^{\pi} = 0$, but magnitudes are easier to plot under this slightly response rule.

Figure 5: Temporary Passive Monetary Policy

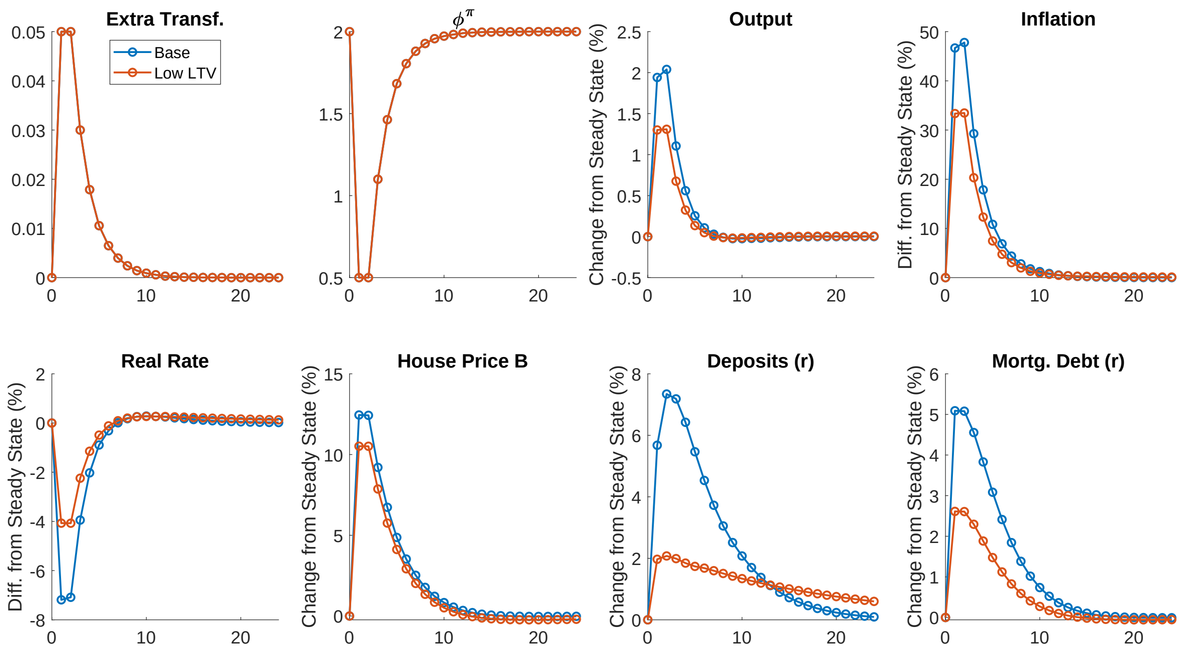


backed by future taxes. This increases aggregate demand and inflation, which in turn causes real wealth to shrink until demand is compatible with supply in the goods market. The same fiscal shock that is almost neutral in the PF/AM economy has substantial stimulative effects in the PF/AM economy and causes high inflation. By redistributing from savers to borrowers through inflation, it boosts borrower house prices consistent with proposition 4.

The fiscal shock in the latter regime functions through the fiscal theory of the price level. A common critique of this theory is that it is unrealistic to assume that the government is always completely unresponsive to the level of debt. A model purely based on the fiscal theory implies inflation that is too volatile and monetary responses inconsistent with the data. However, even temporarily passive monetary policy in an economy that is usually in the active-monetary regime can induce model dynamics that closely resemble those of the AF/PM economy. Figure 5 plots transitions to the same fiscal shock in the standard PF/AM economy (blue line), and considers how the impact changes when the central bank drops its inflation response from 2 to 0.5 *only for the duration of the fiscal shock.* The tax coefficient is $\bar{\tau}_1 = 2$ throughout. Households therefore rationally expect higher taxes, if the quantity of real debt rises substantially.

Furthermore, households know that the central is only temporarily passive. Nonetheless, the

Figure 6: Temporary Passive Monetary Policy and Mortgage Leverage



response of the economy under this brief deviation from active monetary policy that coincides with a fiscal expansion closely resembles the economy that is permanently in the AF/PM regime in Figure 4 above. We can further confirm that the amplitude of the inflationary impact depends on the amount of mortgage debt in the system. We conduct the same experiment as in Figure 5 above, but set a tighter LTV parameter λ^B for borrowers. The result is in Figure 6: a tighter LTV limit reduces the magnitude of the effect.

These numerical exercises demonstrate that the mechanisms derived in the theoretical model survive in an environment with sticky prices, inelastic labor supply, and more conventional monetary and fiscal rules. In the following section, we calibrate an extended model with a more realistic mortgage sector to investigate if the mechanism has quantitative relevance.

4 Quantitative Model

We next analyze the impact of fiscal and monetary stimulus after a Covid recession in a richer quantitative model. The model has seperate borrower and saver households, where borrower households finance their consumption with mortgage debt. A financial intemediary 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 suffciently low. The central bank sets both a monetary policy Taylor rule, reacting to both inflation and output in its interest rate choices. Finally, a fiscal authority raises taxes from labor income and gradually increases these tax rates as the debt level grows.

We use this model to simulate a Covid-motivated 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 a wave of mortgage defaults without any government intervention. We then show that with "unemployment insuranace" that replaces the income of all unemployed households, the drop in consumption caused by this recession falls by roughly half. Finally, we show that when this fiscal stimulus is combined with a temporary change in the monetary policy rule to respond less to inflation, consumption recovered 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 12 % 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 varities $Y_t(i)$, as is standard in a New Keynesian model. Total output is given by

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}, \tag{34}$$

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

$$Y_t(i) = Z_t n_t(i)^{1-\alpha} k_t(i)^{\alpha} \tag{35}$$

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:

$$z_{t+1} = (1-\rho_z)\bar{z} + \rho_z z_t + \varepsilon_{t+1}. \tag{36}$$

4.3 Households

Borrowers get utility $u^B(c_t^B, h_{t-1}^B)$ at time t from consuming non-durables c_t^B and housing h_{t-1}^B where

$$u^B(c_t^B, h_{t-1}^B) = \frac{\left((c_t^B)^{1-\theta}(h_{t-1}^B)^{\theta}\right)^{1-\gamma}}{1-\gamma}.$$

Their housing consumption at time t is based on the amount of housing h_{t-1}^B they chose at time $t-1$. Borrowers aim to maximize their lifetime expected utility

$$\mathrm{E}_0 \sum_t \beta_B^t u^B(c_t^B, h_{t-1}^B). \tag{37}$$

Borrowers are endowed with $\bar{N}^B$ units of labor that they supply inelastically.

Savers obtain utility $u^S(c_t^S, h_{t-1}^S, d_{t-1}^S, n_t^S)$ from non-durables c_t^S, housing h_{t-1}^S, and their holdings d_{t-1}^S of bank deposits. They also dislike supplying labor to firms. Their utility function is

$$u^S(c_t^S, h_{t-1}^S, d_{t-1}^S, n_t^S) = \frac{\left((c_t^S)^{1-\theta-\psi}(h_{t-1}^S)^{\theta}(d_{t-1}^S)^{\psi}\right)^{1-\gamma}}{1-\gamma} - \chi_0 \frac{(n_t^S)^{1+\frac{1}{\chi_1}}}{1+\frac{1}{\chi_1}}. \tag{38}$$

Savers aim to maximize their lifetime expected utility

$$\mathrm{E}_0 \sum_t \beta_S^t \left[u^S(c_t^S, h_{t-1}^S, d_{t-1}^S, n_t^S)\right]. \tag{39}$$

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 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.

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 ${}^{\$}i_t$, and there is a market accessible only to borrowers where they can trade shares of their labor endowment at price p_t^B. Following Diamond and Landvoigt (2021), this assumption implies that we can derive the stochastic discount factor of a representative borrower, even though individual borrowers face uninsurable idiosyncratic shocks, which is crucial for tractability.

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 ${}^{\$}m_t = (1 - \delta^m){}^{\$}m_{t-1}$. 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 $(\iota + \delta^m \bar{q}^m){}^{\$}m_{t-1}^B$ at time t. The variable ι can be seen as the interest payment of the mortgage and $\delta^m \bar{q}^m$ 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.

4.5 Borrower's Problem

In each time period t, an individual borrower's choices can be broken into two sub-periods[3] – a "consumption stage" followed by a "trading stage." In the consumption stage, the borrower chooses whether or not to default on its mortgage as well as on how many non-durables to consume. In the trading stage, the borrower can buy and sell housing and financial assets as well as refinance its mortgage. At the start of the trading stage at time t, the borrower has

[3]For readability, we omit i subscripts on individual borrower variables.

wealth w_t^B and a value function $V(w_t^B, \mathcal{Z}_t)$ that depends on its wealth w_t^B as well as on the vector $\mathcal{Z}_t$ of aggregate state variables.

Default stage. At this stage, aggregate and idiosyncratic income shocks are realized. Borrowers choose whether to default on their mortgage, and their consumption in period t. At the end of period $t-1$ borrowers hold (in real terms):

1. Housing h_{t-1}^B. The borrower has housing of value $h_{t-1}^B p_t^h$, where p_t^h is the real house price,
2. Deposits ${}^{\$}d_{t-1}^B$,
3. Mortgage debt with face value ${}^{\$}m_{t-1}^B$,
4. Labor shares n_{t-1}^B. The total payment to borrower labor is y_t^B. Each borrower faces an idiosyncratic shock ϵ_t to its income. Income shocks have mean one and two possible realizations, $\epsilon_t \in \{\epsilon_\ell, \epsilon_h\}$.

The borrower is able to consume out of its deposit holdings ${}^{\$}d_{t-1}^B$ and the payment $(y_t^B + \epsilon_t)n_{t-1}^B$ it receives for its labor income. It must pay the maintenance $\delta^h h_{t-1}^B$ required for its housing and can choose whether to make the mortgage payment $(\iota + \delta^m \bar{q}^m)\,{}^{\$}m_{t-1}^B$ that it owes. If the borrower does not make its mortgage payment, it loses its housing and a fraction λ of the value of its labor supply. If the borrower consumes less than the maximum amount available to it, the remainder is saved as within-period deposits ${}^{\$}d_t^{*,nd} \geq 0$ and carried forward to the trading stage. In addition to the income shock, each borrower faces a continuous idiosyncratic shock $\eta_{B,t}$ to its post-default value function. The idiosyncratic shocks ϵ_t and $\eta_{B,t}$ lead some borrowers to default and others not to, even if ex ante before the shock realizations all borrowers were identical.

If the borrower chooses not to default, its consumption satisfies

$$P_t c_t^{B,nd} = {}^{\$}d_{t-1}^B + P_t\left(y_t^B(1+\epsilon_t)n_{t-1}^B - \delta^h h_{t-1}^B\right) - (\iota + \delta^m \bar{q}^m)\,{}^{\$}m_{t-1}^B - {}^{\$}d_t^{*,nd}. \tag{40}$$

If the household does default, it can consume

$$P_t c_t^{B,d} = {}^{\$}d_{t-1}^B + P_t(y_t^B + \epsilon_t)n_{t-1}^B. \tag{41}$$

If the borrower does not default, it enters the next trading stage with wealth

$$P_t w_t^{B,nd} = {}^{\$}d_t^{*,nd} - (1-\delta^m)^{\$}m_{t-1}^B q_t^m + P_t(p_t^B n_{t-1}^B + p_t^{h,B} h_{t-1}). \tag{42}$$

If the borrower does default, it enters the next trading stage with wealth

$$P_t w_t^{B,d} = P_t(1-\lambda)p_t^B n_{t-1}^B. \tag{43}$$

Denote vector of last period's asset choices in the trading stage as $a_{t-1}^B = [{}^{\$}d_{t-1}^B, h_{t-1}^B, n_{t-1}^B, {}^{\$}m_{t-1}^B]$. Taking as given the form of the value function $V(w_t^B, \mathcal{Z}_t)$ the borrower will face in the following trading stage, the borrower's value function in the default stage conditional on not defaulting is

$$V^{nd}(a_{t-1}^B, \epsilon_t, \mathcal{Z}_t) = \max_{{}^{\$}d_t^{*,nd} \geq 0} \; u(c_t^{B,nd}, h_{t-1}^B) + V(w_t^{B,nd}, \mathcal{Z}_t). \tag{44}$$

subject to equations (40) and (42) that determine the household's consumption and wealth, respectively, conditional on its choice of savings ${}^{\$}d_t^{*,nd}$.

The borrower's value function (before its idiosyncratic shock $\eta_{B,t}$) conditional on defaulting is

$$V^d(a_{t-1}^B, \epsilon_t, \mathcal{Z}_t) = u(c_t^{B,d}, h_{t-1}^B) + V(w_t^{B,d}, \mathcal{Z}_t). \tag{45}$$

subject to equations (41) and (43) that determine its consumption and wealth, respectively. The borrower chooses to default if and only if $\eta_{B,t} V^d(a_{t-1}^B, \mathcal{Z}_t) > V^{nd}(a_{t-1}^B, \epsilon_t, \mathcal{Z}_t)$, which occurs only when ϵ_t is sufficiently low and $\eta_{B,t}$ sufficiently high.

Trading Stage. At the trading stage, the borrower has wealth w_t^B depending on its decisions in the default stage. It can use this wealth to invest in bank deposits at nominal interest rate ${}^{\$}i_t$, trade shares of labor endowment at price p_t^B, and buy and sell housing at price $p_t^{h,B}$. In addition, if the household takes out a mortgage of nominal face value ${}^{\$}m_t^B$, it receives a loan today of $q_t^m {}^{\$}m_t^B$. These choices yield the state vector $a_t^B = [{}^{\$}d_t^B, h_t^B, n_t^B, {}^{\$}m_t^B]$ with which the borrower enters the next default stage. Given wealth w_t^B, the value function at the trading stage is

$$V(w_t^B, \mathcal{Z}_t) = \max_{^{\$}d_t^B, n_t^B, h_t^B, {}^{\$}m_t^B} \beta_B \mathrm{E}_t \left[\max \left\{ V^{nd}(a_t, \epsilon_{t+1}, \mathcal{Z}_{t+1}), \eta_{B,t+1} V^d(a_t, \epsilon_{t+1}, \mathcal{Z}_{t+1}) \right\} \right] \tag{46}$$

subject to the budget constraint

$$P_t w_t^B = \frac{^{\$}d_t^B}{1 + {}^{\$}i_t} - q_t^m {}^{\$}m_t^B + P_t(p_t^B n_t^B + p_t^{h,B} h_t^B). \tag{47}$$

The borrower's entire value function can be written as

$$V(w_{t-1}^B, \mathcal{Z}_{t-1}) = \max_{^{\$}d_{t-1}^B, n_{t-1}^B, h_{t-1}^B, {}^{\$}m_{t-1}^B}$$
$$\beta_B \mathrm{E}_{t-1} \left[\max \left\{ \max_{^{\$}d_t^{*,nd} \geq 0} u(c_t^{B,nd}, h_{t-1}^B) + V(w_t^{B,nd}, \mathcal{Z}_t), \eta_{B,t}[u(c_t^{B,d}, h_{t-1}^B) + V(w_t^{B,d}, \mathcal{Z}_t)] \right\} \right] \tag{48}$$

subject to the budget constraint in equation (47) and the definitions of next period's consumption and wealth given by equations (40)-(43).

4.6 Saver's Problem

The representative saver maximizes its lifetime expected utility given in equation (38) depending on consumption c_t^S, housing h_{t-1}^S, saver's labor supply n_t^S, and the real value of bank deposits held $d_t^S = \frac{^{\$}d_t^S}{P_{t+1}}$, where $^{\$}d_t^S$ are the saver's nominal deposit holdings. To align borrower and saver problems, we can think of savers as beginning each period with a "consumption stage" where they are able to finance their consumption out of deposit holdings and labor income. After the consumption stage, savers enter a "trading stage" where they receive capital income and can invest in housing, the capital stock of non-financial firms, bank deposits, and bank equity. Unlike borrowers, savers neither hold a mortgage nor face any idiosyncratic shocks. As a result, savers immediately aggregate to a single representative agent. We can therefore write the optimization problem in the standard form.

Let Y_t^S denote the total labor and 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 in equation (53) and equ_t^I be the value of intermediary equity 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, housing h_t^S, labor n_t^S, and deposits d_t^S. Finally, let Reb_t be a payoff to the saver equal to all the 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 (123) in the Appendix.

The saver's Bellman equation can be written as

$$V^S(w_t^S, \mathcal{Z}_t) = \max_{c_t^S, h_t^S, d_t^S, n_t^S} u^S(c_t^S, h_t^S, d_t^S, n_t^S) + \beta_S \mathrm{E}_t V^S(w_{t+1}^S, \mathcal{Z}_{t+1}) \tag{49}$$

subject to the budget constraint

$$P_t w_t^S = P_t(c_t^S + p_t^{h,S} h_t^S + equ_t^I) + \frac{{}^{\$}d_t^S}{1 + {}^{\$}i_t}, \tag{50}$$

and the definition of next period's wealth

$$P_{t+1} w_{t+1}^S = P_{t+1}(Y_{t+1}^S + (p_{t+1}^{h,S} - \delta^h) h_t^S + div_{t+1}^I + Reb_{t+1}) + {}^{\$}d_t^S, \tag{51}$$

with the utility function given by (38).

4.7 Financial Intermediary

The financial intermediary is a profit maximizing firm whose equity is owned by savers. The intermediary provides mortgages to borrowers and is financed by issuing a mix of riskless deposits and loss-bearing equity. For simplicity, the intermediary has to pay out all remaining cash flows generated by its mortgage portfolio every period in the trading stage and then raise new deposits and equity to fund more loans. With q_t^m being the equilibrium price of a mortgage, the intermediary lends a nominal payment $q_t^m {}^{\$}m_t$ when it issues mortgages of nominal face value ${}^{\$}m_t$. These funds are a combination of equity equ_t^I raised and promising a riskless nominal payment of ${}^{\$}D_t^I$ to depositors at time $t+1$. Intermediaries also hold central bank reserves ${}^{\$}B_t$, which pay the nominal interest rate ${}^{\$}i_t$, 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 ${}^{\$}D_t^I$ to depositors at time $t+1$. The nominal deposit rate is ${}^{\$}i_t^D$, and the intermediary raises funding $\frac{{}^{\$}D_t^I}{1+{}^{\$}i_t}$ from issuing deposits. Thus, the intermediary faces the budget constraint

$$P_t equ_t^I + \frac{{}^{\$}D_t^I}{1+{}^{\$}i_t} = q_t^m {}^{\$}m_t^I + \frac{{}^{\$}B_t}{1+{}^{\$}i_t}. \tag{52}$$

Suppose the intermediary holds mortgages of total nominal face value ${}^{\$}m_{t-1}^I$ at time $t-1$ which generate a nominal repayment $\mathcal{P}_t$ per dollar of face value. The intermediary first owes the nominal payment ${}^{\$}D_{t-1}^I$ 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^I given by

$$P_t div_t^I = (1-\nu)\left(\mathcal{P}_t {}^{\$}m_{t-1}^I - {}^{\$}D_{t-1}^I\right). \tag{53}$$

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

$${}^{\$}D_t^I \leq (1-\bar{e}^R){}^{\$}B_t + (1-\bar{e}) \min_{z_{t+1}|\mathcal{Z}_t} \mathcal{P}_{t+1} {}^{\$}m_t^I \tag{54}$$

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 (given in equation (96)), so at time t it maximizes

$$\max_{m_t^I, equ_t^I, div_t^I} - equ_t^I + \mathrm{E}_t M_{t,t+1}^S div_t^I \tag{55}$$

subject to equations (52), (53) and inequality (54). Because the saver gets utility directly from holding deposits, the deposit rate will always be strictly below the risk-free rate implied by $M_{t,t+1}^S$. The intermediary therefore always issues the maximum quantity of deposits and its leverage constraint in (54) is always binding.

Let $F_{\eta,t}$ be the probability at time t that a borrower defaults. The nominal value $\mathcal{P}_t$ of the intermediary's mortgage portfolio per dollar of face value is given by

$$\mathcal{P}_t = (1 - F_{\eta,t})[\iota + \delta^m \bar{q}^m + (1-\delta^m) q_t^m] + P_t F_{\eta,t} \frac{h_{t-1}^B}{{}^{\$}m_{t-1}^B} \left((1-\zeta) p_t^{h,B} - \delta^h \right). \quad (56)$$

If a borrower does not default, the intermediary receives a cash payment of $\iota + \delta^m \bar{q}^m$ per dollar of face value and the remaining mortgage has a fraction $(1-\delta^m)$ of its previous face value. The nominal market value of this remaining mortgage is $(1-\delta^m)q_t^m$. If the borrower does default, the intermediary seizes $\frac{h_{t-1}^B}{m_{t-1}^B}$ units of housing collateral per dollar of mortgage face value which are then hit by the ϵ shock. The intermediary has to make a real payment of $\delta^h \frac{h_{t-1}^B}{m_{t-1}^B}$ 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

$$\max_{Y_t, Y_t(i)} P_t Y_t - \left(\int_0^1 Y_t(i) P_t(i) di \right). \quad (57)$$

subject to equation (34) 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 A.3.1) imply that a profit maximizing final goods producer has demand for intermediate goods given by

$$Y_t(i) = Y_t \left(\frac{P_t(i)}{P_t} \right)^{-\eta}, \tag{58}$$

where

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

Equation (58) 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 wages and 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 the level today of their prices $P_t^j(i)$ which we now denote as p_t^j as well as all aggregate states. The firm faces a demand curve $y_j(p_t^j)$ for its intermediate good given by equation (58). The intermediate good firm's Bellman equation can be written as

$$\begin{aligned} V^W(p_{t-1}, \mathcal{Z}_t) = \max_{p_t, n_t, k_t} \frac{p_t}{P_t} y(p_t) - (\omega_t n_t + r_t^K k_t) - \frac{\xi}{2} \left(\frac{p_t}{\bar{\pi} p_{t-1}} - 1 \right)^2 \\ + \mathrm{E}_t \left[\mathcal{M}_{t,t+1}^S V^W(p_t, \mathcal{Z}_{t+1}) \right], \end{aligned} \tag{59}$$

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, ω_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. $\mathcal{M}_{t,t+1}^S$ is the stochastic discount factor of the firm's shareholders (who in equilibrium are the savers).

Because all intermediate goods producers in a sector are identical, they choose the same price $p_t = P_t$. In appendix A.3.2, 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 ${}^{\$}i_t$. To do so, it follows a standard monetary policy rule subject to a zero lower bound

$$ {}^{\$}i_t = \max\left\{i_t^*, 0\right\}, \tag{60} $$

where

$$ 1 + i_t^* = (1 + \bar{i}) \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi^\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi^y}, \tag{61} $$

where we denote gross inflation as $\pi_t = P_t/P_{t-1}$. The central bank's inflation target is $\bar{\pi}$ and its target level for cyclical output is $\bar{Y}$. 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 $\bar{\pi}$.

Fiscal. We assume that all government debt is held 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

$$ \tau_t = \bar{\tau}_0 \left(\frac{B_t}{\bar{B}}\right)^{\bar{\tau}_1}, $$

where $\bar{\tau}_0$ is the average tax rate, $\bar{B}$ is the steady state supply of debt, and $\bar{\tau}_1$ is the elasticity of the tax rate with respect to deviations from steady-state debt. Total tax revenue $\tau_t Y_t$ is raised from borrower labor income and lump-sum taxation of savers, with details in equations (74) and (75) below. The government also makes regular transfer payments that are fraction ϑ of GDP. The government budget constraint in each period is

$$ \frac{{}^{\$}B_t^G}{1 + {}^{\$}i_t} = {}^{\$}B_{t-1}^G - (\tau_t - \vartheta)Y_t. \tag{62} $$

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 six asset markets: borrower and saver housing, deposits, mortgages, government reserves, borrowers trading the housing endowment assets, yielding the following conditions

$$H_t^B = \bar{H}^B, \tag{63}$$

$$H_t^S = \bar{H}^S, \tag{64}$$

$$^{\$}d_t^B + {}^{\$}d_t^S = {}^{\$}D_t^I \tag{65}$$

$$^{\$}m_t^B = {}^{\$}m_t^I, \tag{66}$$

$$^{\$}B_t^G = {}^{\$}B_t, \tag{67}$$

$$N_t^B = \bar{N}^B. \tag{68}$$

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 wage ω_t is $N_t^f(\omega_t)$; we assume that labor market equilibrium is demand-determined such that firms are always on their labor demand curve. Desired labor supply from borrowers is inelastic and always $\bar{N}^B$, and desired supply from savers is $N_t^S(\omega_t)$. If the market can clear at a wage above $\bar{\omega}$, we have $N_t^f(\omega_t) = \bar{N}^B + N_t^S(\omega_t)$. 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. Denoting total desired supply by $N_t^{des} = \bar{N}^B + N_t^S$, the labor market clearing conditions can then be written as

$$N_t^{des} \geq N_t^f, \tag{69}$$

$$\omega_t \geq \bar{\omega}, \tag{70}$$

$$(N_t^{sup} - N_t^f)(\omega_t - \bar{\omega}) = 0. \tag{71}$$

If the wage rigidity is binding, involuntary unemployment is $N_t^{des} - N_t^f$. Unemployment is allocated to borrowers and savers according to proportions υ^j, with $j = B, S$. Thus effective labor supplied by borrowers and savers is, respectively,

$$\tilde{N}_t^B = \bar{N}^B - \upsilon^B (N_t^{des} - N_t^f), \tag{72}$$

$$\tilde{N}_t^S = N_t^S - \upsilon^S (N_t^{des} - N_t^f). \tag{73}$$

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

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

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

$$y_t^B = \omega_t - \frac{\varphi_B^\tau \tau_t Y_t}{\tilde{N}_t^B} + \frac{\varphi_B^\vartheta \vartheta Y_t}{\tilde{N}_t^B} = \omega_t + \frac{Y_t}{\tilde{N}_t^B} \left(\varphi_B^\vartheta \vartheta - \varphi_B^\tau \tau_t \right), \tag{74}$$

$$Y_t^S = Y_t - \omega_t \tilde{N}_t^B - \delta^K \bar{K} - \varphi_S^\tau \tau_t Y_t + \varphi_S^\vartheta \vartheta Y_t = Y_t (1 + \varphi_S^\vartheta \vartheta - \varphi_S^\tau \tau_t) - \omega_t \tilde{N}_t^B - \delta^K \bar{K}. \tag{75}$$

Note that borrower income in (74) is per unit of labor supplied, i.e. total income of all borrowers is $Y_t^B = y_t^B \tilde{N}_t^B$. Individual borrowers decide on how many units of human capital to acquire n_t^B, and take as given that each unit will yield payoff y_{t+1}^B at $t+1$. Savers receive all other income Y_t^S in (75) including firm profits and capital income, which is GDP adjusted for taxes and transfers, minus labor income paid to borrowers and depreciation of capital.

Goods Market. In addition, the total supply of consumption Y_t must equal the total use of resources, which consists of consumption by both types of households, expenditures on housing maintenance, and depreciation of the fixed capital stock. This yields the following resource constraint

$$Y_t = C_t^B + C_t^S + \delta^h (\bar{H}^B + \bar{H}^S) + \delta^K \bar{K}. \tag{76}$$

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 1953-2019 sample unless we indicate a different sample. We discuss key parameters below.

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))
Π_ℓ	Prob. of low income	0.058	BLS unemployment rate
ϵ_ℓ	Income drop in low state	-0.75	Ganong and Noel (2019)
ϵ_h	Income jump in high state	0.046	Normalization $\mathrm{E}[\epsilon_t] = 0$
	Housing and Mortgages		
$\bar{\delta}^h$	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	Repayment fraction	0.06	Average mortg. duration 7 years
μ_{η_B}	Mean borrower default penalty	1	Normalization
	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	1.5	Standard value
	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)

Stochastic Environment. We calculate volatility and persistence of the TFP process 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. To calibrate the idiosyncratic income shocks ϵ_t, we need to choose the probability and size of the low realization. Since the low income state is meant to capture unemployment, we set its probability to the average unemployment rate at $\Pi_\ell = 5.8\%$. The probability of the high income state is therefore 94.2%. Ganong and Noel (2019) document that the average drop in market income during unemployment is around 75%, implying $\epsilon_\ell = -0.75$ and, given the probabilities and the restriction that $\mathrm{E}[\epsilon_t] = 0$, $\epsilon_h = 0.046$.

Labor Supply, Taxes, and Transfers. We normalize aggregate labor supply in steady state to 1 and also set $\bar{K} = 1$, implying steady state output of 1. We distinguish borrowers and savers in the 2019 Survey of Consumer Finances (SCF) by defining as saver any household with a mortgage loan-to-value ratio below 30%. Based on this definition, borrowers receive 53% of aggregate income and the vast majority of all labor income. Borrowers account for 65% of households.[4] In the model, we assume that savers receive all capital income and profits. We match the borrower income share of 53% by setting $\bar{N}^B = 0.9$, such that borrowers receive 90% of all labor income in the model. We calibrate χ_0, the disutility of labor supply for savers, such that savers receive the remaining 10% of labor income in steady state. 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 population shares, implying $\varphi_B^\tau = 0.65$. We set the lower bound on wages in the a sector $\bar{w}^a$ to 0.98 times the steady state wage in that sector. When this lower bound becomes binding, unemployment is allocated to borrowers and savers in proportion to their population shares, so $\upsilon^B = 0.65$.[5]

Technology. The elasticity of labor in the production function $\alpha = 0.7$, implying an effective labor share of 67%. 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

[4] In the data, savers are mainly older (often retired) households, who own the majority of wealth, but receive little labor income.

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

parameter is set to $\xi = 30$, which we choose to match the volatility of inflation in the model to the volatility of deviations from the inflation target in the data. We follow Elenev, Landvoigt, Shultz, and Van Nieuwerburgh (2021) in computing this data target.[6]

Table 2: Jointly Calibrated Parameters

Moment	**Par.**	**Value**	**M (%)**	**D (%)**	**Source**
			Production and Savers		
Marginal cost/revenue	η	7	85	85	van Vlokhoven (2020)
Vol(inflation)	ξ	30	0.30	0.34	Vol. of deviations from infl. target (core PCE)
Labor income/GDP	α	0.7	67	67	BLS labor share
Vol(Labor income/GDP)	χ_1	5	0.65	0.87	BLS labor share (Hamilton filt.)
Avg. saver income share	χ_0	1.28e4	47	46	2019 SCF (see text)
Real Federal Funds rate	β_S	0.994	0.52	0.54	FFR net of CPI inflation 1959-2019
Deposit convenience yield	ψ	0.016	0.34	0.32	FFR-time deposit spread (DSS 2017, 94-14)
			Borrowers and Housing		
Avg. borrower income share	$\bar{N}^B$	0.90	53	54	2019 SCF (see text)
Avg. house value/income	θ	0.115	8.37	8.41	2019 SCF (see text)
Avg. mortgage debt/income	β_B	0.985	2.44	2.36	2019 SCF (see text)
Avg. borrower deposits/income	λ	0.08	101	106	2019 SCF (see text)
Avg. LTV	$\bar{L}$	0.7	67	65	2019 SCF (see text)
			Intermediaries		
Mortgage delinquency rate	σ_{η_B}	0.023	0.73	0.76	Mortgage delinquencies (see text)
Mortgage charge-off rate	ζ	0.35	0.06	0.06	Mortgage charge-offs (see text)
Intermediation cost	ν	0.075	0.45	0.42	Spread prime mortgage of 10y treas.
			Government		
Short-term gov. debt/GDP	$\bar{\tau}_0$	0.04	104	115	(Reserves+Tbills)/GDP in Q4 2019 (quarterly)
Vol(Short-term gov. debt/GDP)	$\bar{\tau}_1$	0.6	16.2	14.7	(Reserves+Tbills)/GDP 2001-2019 (Ham. filt.)

Mortgage Defaults. The idiosyncratic default penalty is drawn from a log-normal distribution with mean μ_{η_B} normalized to 1. We choose the standard deviation to match the delinquency rate on mortgages in the model to that in the data. Aggregate delinquency data are available from 1991. Targeting the average delinquency rate between then and 2019, while excluding the crisis period 2008-2012, leads to a quarterly rate of 0.76% and a parameter value of $\sigma_{\eta_B} = 0.023$. The magnitude of losses for banks resulting from delinquencies is governed by the foreclosure loss ζ, which we set to 35% to target the charge-off rate of residential mortgages of 0.06% (calculated for the same sample period as delinquencies). We set the pecuniary default penalty λ

[6]The model does not contain many sources of inflation volatility in the data, such as changes in the fundamental monetary policy stance that change the target. Thus, it is more appropriate to match deviations from the target in the data to deviations in the target.

to match the ratio of deposits to income in the model to the ratio of liquid assets to income for borrowers in the 2019 SCF, resulting in $\lambda = 0.08$. This parameter governs borrowers' motive to hold deposits in order to insure against the low income realization, since it makes defaulting more costly.

Preferences. The coefficient of relative risk aversion for borrowers and savers is set to $\gamma = 1.5$, implying an intertemporal elasticity of 0.67 in line with micro estimates. The saver discount factor is $\beta_S = 0.994$ to target a quarterly real interest rate of 0.54%. The borrower discount factor is set to $\beta_B = 0.985$, targeting the ratio of mortgage debt to income from the 2019 SCF by governing borrower's valuation of housing. Savers' utility from real deposits is $\psi = 0.016$, targeting to a quarterly deposit liquidity premium of 0.32% (Dreschler et al., 2017). Utility from housing for both households is $\theta = 0.115$, matching a value of housing to quarterly income of 8.41. The Frisch elasticity of labor supply of savers is set to 1/5, implying $\chi_1 = 5$. With this value of χ_1, the model matches the volatility of labor income to GDP ratio.

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 $\bar{\tau}_0 = 4\%$ of GDP. The sensitivity of tax rates to deviations of debt from steady state is set to $\bar{\tau}_1 = 0.5$, which we choose to match the volatility of the (Hamilton-filtered) ratio, equal to 16.2% in the data.

Mortgages and Intermediation. Mortgage amortization is $\delta^m = 0.05$, implying an average duration of 7 years for mortgage debt at the steady state nominal yield of 1.5%. The coupon payment ι is normalized to achieve a steady state bond price $\bar{q}^m = 1$, implying $\iota = 1.47\%$, which can be interpreted as the mortgage's nominal yield. The mortgage spread is ι net of the reserve rate, $1.47\% - 1.02\% = 0.45\%$, 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 $\bar{e} = 0.08$, and for reserves we apply the Supplementary Leverage Ratio of 3%, implying $\bar{e}^R = 0.03$.

5.2 Solution Method

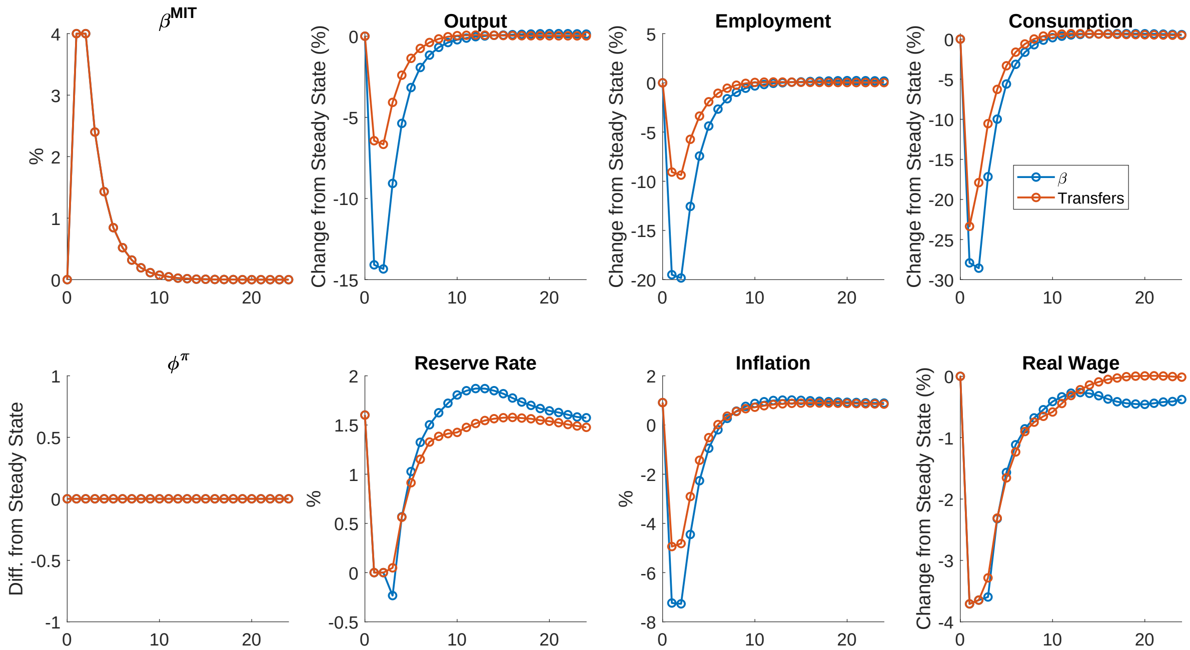
The model features nonlinearities due to the ZLB in the monetary policy rule, the non-negativity of deposit holdings at the liquidity stage, and the wage rigidity. To handle these nonlinearities while computing fully stochastic transition paths after the unanticipated Covid shock hits the model, we use a global nonlinear solution method (Elenev, Landvoigt, and Van Nieuwerburgh (2020)).

The economy's state variables are the wealth distribution between borrowers and savers, aggregate borrower consumption, and the stock of government debt (reserves). Borrower consumption is a state variable at the trading stage when borrowers decide on their portfolio for next period, and savers solve their consumption-savings problem. This is because the wealth distribution does not fully encode the remaining available resources for consumption at the trading stage after borrowers have already decided how much to consume and save at the default stage.[7]

To handle the two-stage nature of the borrower decision problem, we compute optimal borrower deposit savings at the default stage d^*_{t+1} for all relevant combinations of the borrower portfolio chosen at t. We then interpolate this function on a fine grid and evaluate it as part of the expectations formed over next-period marginal values in Euler equations. Including this type of "liquidity-in-advance" constraint motivated by mortgage default frictions in a general equilibrium model with borrowers, savers, and financial intermediaries is a technical contribution of this paper.

[7]An alternative would be to include the full vector of borrower portfolio choices from $t-1$ in the state vector for period t, since the borrower default and deposit decision generally depends on all components of this portfolio. However, this is unnecessary since borrower consumption and value functions aggregate given our assumptions on borrowers' ability to trade labor endowment claims.

Figure 7: Covid Shock and Fiscal Policy: Macro Variables



6 Results

6.1 Covid Shock and Fiscal Response

We model the Covid pandemic as an unexpected shock to labor supply and aggregate demand. The labor supply shock reflects lock downs and other restrictions on businesses due to Covid-19. It is implemented as a 10% reduction in labor supply of both households. The demand shock captures consumers cutting back dramatically on any in-person consumption expenditures. It is implemented as a temporary increase in the discount factor of both households.

Figure 7 shows the responses of macro-economic aggregates to this shock (blue lines). At time 0, the economy is in steady state. In period 1, β_j, for $j = B, S$ jumps by 0.06. The shock is unanticipated and persists with a probability of 0.6 per year. This probability is known to all agents. The transition paths in all figures show equilibrium dynamics for a sample path with fixed realizations of the shock state for periods 1 and 2, after which the economy stochastically reverts to the pre-pandemic state with annual probability of 0.4.

The shock without any government policy interventions sends the economy into a deep demand-driven recession, with output falling by 15%. As monetary policy becomes stuck at the zero lower bound, the economy experiences deflation of 7%. The lower bound on real wages becomes binding, and unemployment reaches 20%.

The shock captures the deep negative impact on aggregate demand. However, the dynamics of shock-only blue lines in Figure 7 are counterfactual since they do not contain any of the extraordinary economic policy responses enacted in 2020.

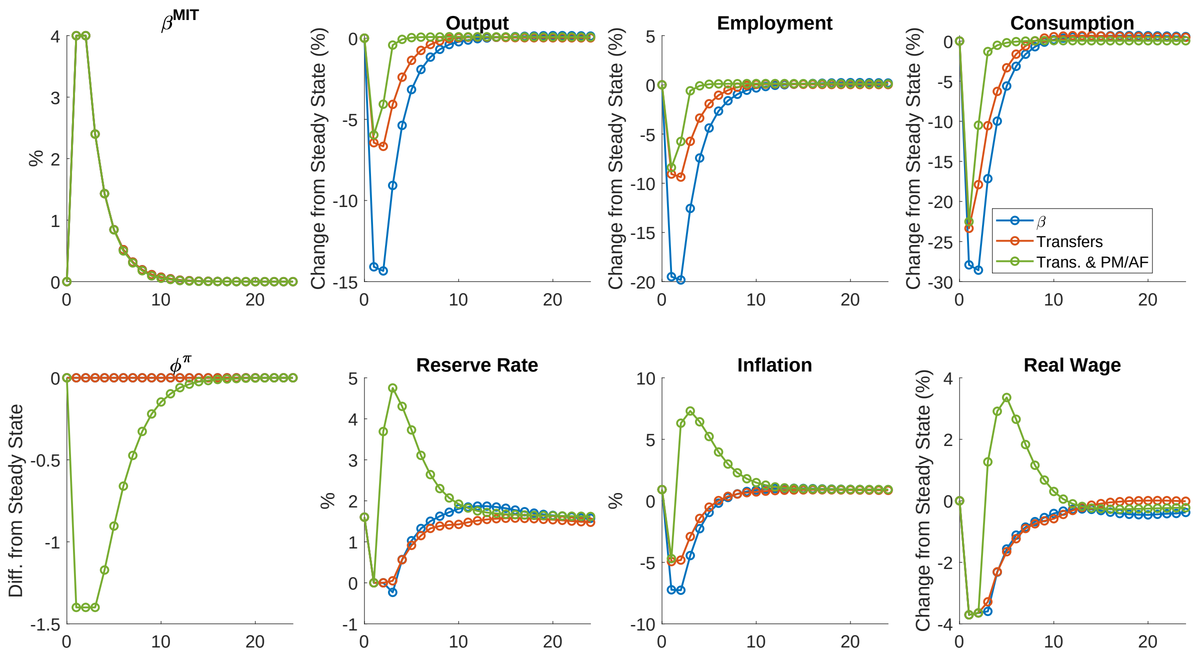
The red lines show dynamics with additional government transfers that fully replace the labor income of unemployed households. The shortfall in labor income is the difference between desired labor supply and equilibrium employment, times the wage: $\omega_t(N_t^{des} - N_t^f)$. The government pays these transfers to borrowers and savers in the same proportions that unemployment is allocated to the two groups of households, i.e. using the proportionality coefficients υ^j. The transfers are financed through greater deficit borrowing that adds more reserves to the banking system. The fiscal intervention is only partially effective in curbing the demand shortfall. With transfers, output only declines by 7% instead of 15%. Yet the policy rate and the real wage remain stuck at their respective lower bounds, and the economy still experiences deflation of 5%.

6.2 Passive Monetary Policy

How do macroeconomic dynamics change if on top of additional fiscal transfers, monetary policy becomes passive? We follow Bianchi and Ilut (2017) in characterizing passive monetary policy through a temporarily smaller coefficient on inflation in the Taylor rule: the coefficient ϕ^π temporarily drops from 2 to 0.55. The central bank credibly announces this different regime in the second period after the shock. The passive regime lasts for the duration of the demand shock and beyond. In particular, even after the demand shock dissipates, the central bank remains passive with probability 0.6 each period and then returns to a coefficient of $\phi^\pi = 2$.

The green lines in Figure 8 show how the same macro variables as in Figure 7 respond to this policy. There is a jump in inflation from -5% to over 7% after the announcement, close to the observed inflation for 2021. Despite being less responsive to inflation, the central bank responds to the large rise in inflation through a higher reserve rate of 5%. On the real side,

Figure 8: Passive Monetary Policy: Macro Variables

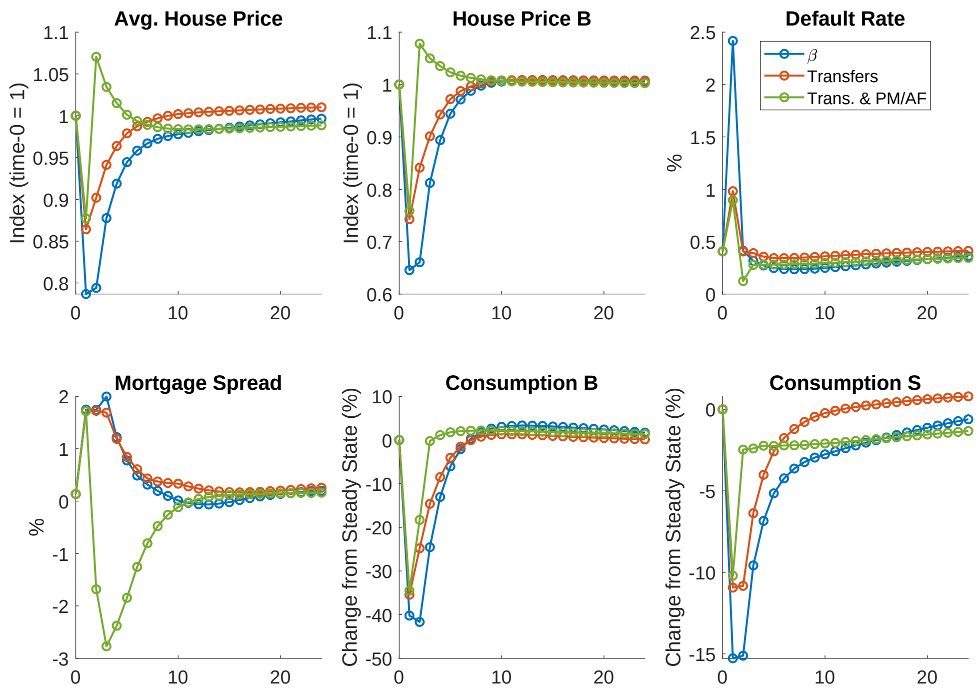


output and employment jump substantially, even though the economy is still experiencing the same negative demand shock. Inflation and the policy rate peak in the 3rd year after the start of the crisis. At this point, the economy has mostly recovered in terms of employment.

Figure 9 demonstrates the dramatic effect of the shock and policies on housing and mortgage market variables. The shock absent any additional policies (blue) would have caused a drop in house prices of about 20% on average and a spike in mortgage defaults of almost 2.5%. The drop in house prices for borrower households is even larger, with a decline of more than 25%. The rise of the default rate is due largely to the liquidity-driven nature of default in the model. Unemployed borrowers are forced to choose between defaulting on their mortgages or reducing their consumption. An increase in unemployment during a recession therefore causes a wave of mortgage defaults, even if house prices do not fall too.

The housing market looks substantially different under the transfer policy (red). With income replacement, the housing bust shrinks somewhat to a 14% drop, and the default rate rises only 1%. Looking at borrower and saver consumption, we can see that this social insurance prevents a wave of mortgage defaults despite a severe drop in consumption. Borrower consumption, in particular, would have declined by over 40% without government intervention, and still declines

Figure 9: Passive Monetary Policy: Housing Variables

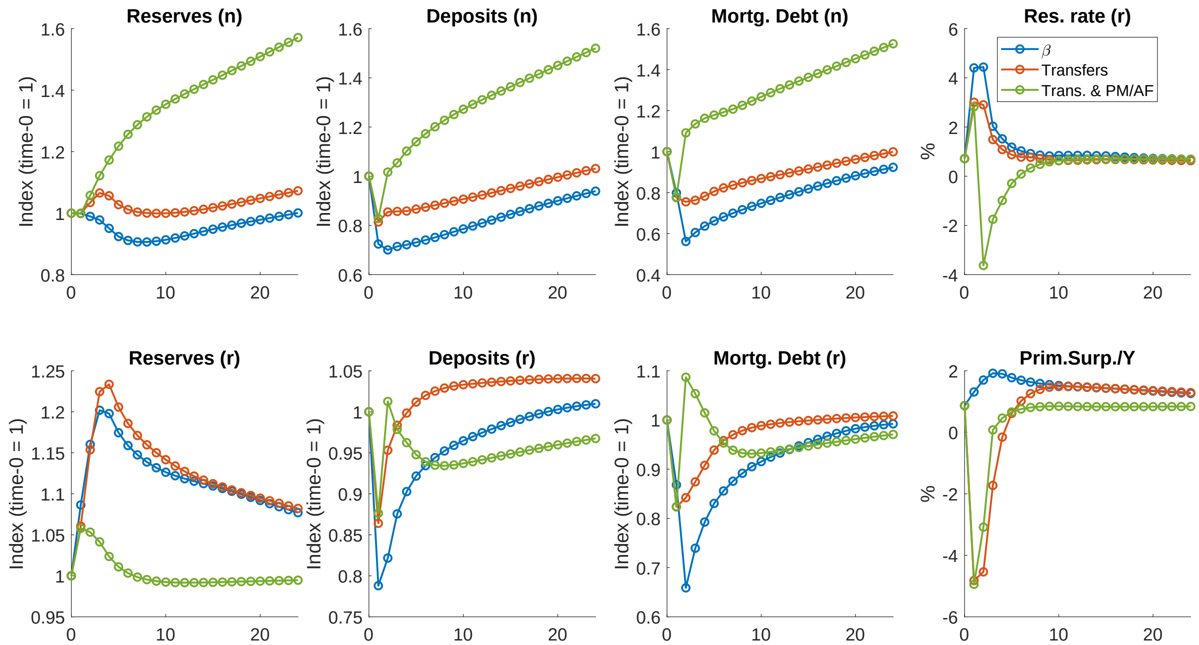


by 35% with transfers.

Housing market dynamics change dramatically with passive monetary policy. In the period of the regime shift, real borrower house prices jump by almost 10%, and the aggregate housing market booms by over 7% relative to the pre-pandemic level. Default rates decline below their pre-crisis frequency, and mortgage spreads even become negative, reflecting the fact that short term nominal rates are temporarily high. Inspecting consumption dynamics of both types of households reveals that the large rise in inflation causes substantial redistribution from savers to borrowers. Since borrowers have a higher marginal consumption propensity, this redistribution channel explains why the passive monetary regime is effective in boosting aggregate demand.

Figure 10 illustrates how these policies affect the nominal debt variables of the economy. With transfers only, reserves increase by 25% and deposits by 4% in real terms (bottom row), as the government runs large deficits by issuing reserves. Mortgage debt in real terms is roughly stable. Inflation caused by passive monetary policy (green line) eventually causes a decrease in reserves and deposits and a 8% decline in real mortgage debt 6 years after the start of the crisis. This is despite a larger increase in the nominal quantities of all these variables (top row),

Figure 10: Passive Monetary Policy: Nominal (n) and Real (r) Debt Variables



highlighting the cumulative effect of a protracted period of elevated inflation.

7 Conclusion

This paper analyzies the impact of fiscal and monetary policy on the Covid-19 recession and the inflation and house price boom that followed it. We theoretically show that while there are several channels by which fiscal stimulus can increase consumption demand, it only causes inflation after a recession if tax revenue is not raised after the recession to pay for borrowing in the recession. This post-recession inflation reduces the real return to savings and helps to stimulate consumption demand in the recession. In addition, fiscally-driven inflation inflates away the mortgage debt of credit-constrained homeowners. This redistribution causes a boom in house prices that is even greater than the inflation it causes.

Without any policy response, the Covid recession would have featured a massive 28% drop in consumption, deflation, a wave of mortgage defaults, and a drop in house prices. Unemployment insurance and other fiscal transfers reduce the drop in consumption by roughly half but do not cause either the inflation or house price boom observed in the data after the recession. However, if monetary policy is temporarily passive after the recession and does not increase more than one-for-one with inflation, a surge of inflation and a dramatic increase in house prices follows the recession. We believe our work is the first to consider the impact of inflation driven by massive fiscal stimulus in a setting with household as well as government debt. As a result, the government's loose policy prints away mortgage debt together with government debt, which is the crucial force that causes a large housing boom in our model.

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A Model Appendix

A.1 Solution to the Borrower Problem

This section derives a system of first-order conditions that characterize the optimal behaviour of the borrower. We first document that despite facing uninsurable idiosyncratic shocks, the borrower households aggregate to a representative agent. We then use this representative agent's value function in our first-order conditions.

Aggregation of Borrower. The borrower's Bellman equation in equation (48) has two key properties that make borrowers behave like a single representative agent. First, the borrower's set of choice variables scale linearly with its wealth. That is, if we let Let a_t be the set of choice variables chosen by the borrower at time t, a_t satisfies its budget constraint with a wealth level of 1 if and only if Wa_t satisfies the budget constraint with a wealth of W for any $W > 0$. Second, the borrower's utility function $u(c_t^{B,d}, h_{t-1}^B)$ is homogeneous of degree $1-\gamma$ in the two variables $u(c_t^{B,d}, h_{t-1}^B)$. By proposition 1 of Diamond and Landvoigt (2021), these two properties imply that the borrower's vale function takes the form

$$V(w_t^B, \mathcal{Z}_t) = v(\mathcal{Z}_t)\frac{(w_t^B)^{1-\gamma}}{1-\gamma}.$$

for some function $v(\mathcal{Z}_t)$. Moreover, this proposition also implies that the borrower's optimal choices scale linearly in its wealth. We define versions of the borrower's choice variables scaled by its wealth w_t^B

$$\hat{x} = \frac{x}{w_t^B}$$

for h_t^B, n_t^B, d_t^B, $d_{t+1}^{*,k}$, $c_{t+1}^{B,k}$, and $w_{t+1}^{B,k}$. Our proposition implies that borrowers of all wealth levels will choose these same scaled choice variables.

With the functional form in equation (A.1), the borrower's Bellman equation in equation (48) becomes

$$v(\mathcal{Z}_{t-1})\frac{(w_{t-1}^B)^{1-\gamma}}{1-\gamma} = \max_{\$d_{t-1}^B, n_{t-1}^B, h_{t-1}^B, \$m_{t-1}^B} \beta_B \mathrm{E}_t \Bigg[\max\{\max_{\$d_t^{*,nd} \geq 0} u(c_t^{B,nd}, h_{t-1}^B) + v(\mathcal{Z}_t)\frac{(w_t^{B,nd})^{1-\gamma}}{1-\gamma},$$

$$\max_{\$d_t^{*,d} \geq 0} \eta_{B,t}[u(c_t^{B,d}, h_{t-1}^B) + v(\mathcal{Z}_t)\frac{(w_t^{B,d})^{1-\gamma}}{1-\gamma}\}] \Bigg] \quad (77)$$

subject to equations (47) and 40-43. We therefore have the following recursion that characterizes the function $v(\mathcal{Z}_t)$.

$$v(\mathcal{Z}_t) = \max_{\hat{d}_t^B, \hat{n}_t^B, \hat{h}_t^B, \hat{m}_t^B} (1-\gamma)\beta_B \mathrm{E}_t \left[\max_{k\in\{nd,d\} \hat{d}_{t+1}^{*,k}\geq 0} (1 + (\eta_{B,t} - 1)\{k = d\})[\, u(\hat{c}_{t+1}^{B,k}, \hat{h}_t^B) + \frac{(\hat{w}_{t+1}^{B,k})^{1-\gamma}}{1-\gamma} v(\mathcal{Z}_{t+1}) \right], \tag{78}$$

subject to the same budget constraints.

Consumption Choices After Default Decision. Let $\kappa_{t+1,d}$ and $\kappa_{t+1,nd}$ be Lagrange multipliers on the non-negativity constraints for $\hat{d}_{t+1}^{*,nd}, \hat{d}_{t+1}^{*,nd}$ as κ_{t+1}. Then the first-order condition for the borrower's non-durable consumption at the default stage is

$$u_c(\hat{c}_{t+1}^{B,d}, \hat{h}_t^B) = (\hat{w}_{t+1}^{B,d})^{-\gamma} v(\mathcal{Z}_{t+1}) + \kappa_{t+1,d}. \tag{79}$$

$$u_c(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B) = (\hat{w}_{t+1}^{B,nd})^{-\gamma} v(\mathcal{Z}_{t+1}) + \kappa_{t+1,nd}. \tag{80}$$

The multipliers $(\kappa_{t+1,d}, \kappa_{t+1,nd})$ are 0 unless $\hat{d}_{t+1}^{*,d}$ and $\hat{d}_{t+1}^{*,nd}$ are respectively equal to 0.

Default Decision. Next, we characterize whether the borrower chooses to default on its mortgage at the default stage. The borrower defaults if any only if its post-default value function is greater than its post-no-default value function

$$\eta_{B,t}[u(c_t^{B,d}, h_{t-1}^B) + V(w_t^{B,d}, \mathcal{Z}_t)] > u(c_t^{B,nd}, h_{t-1}^B) + V(w_t^{B,nd}, \mathcal{Z}_t). \tag{81}$$

The borrower defaults if its realized utility shock $\eta_{B,t}$ is below a threshold value shock $\eta_{B,t}^*(\epsilon_t)$ that we characterize for both possible realizations of the income shock ϵ_t. Let $d_t^B = P_t{}^\$ d_t^B$,$d_t^* = P_t{}^\$ d_t^*$, and $m_t^B = P_t{}^\$ m_t^B$ be the borrower's "real" deposit holdings, real deposits not consumed, and real mortgage face value. If $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ is the inflation rate at time t, then we have that the household's consumption levels conditional on not defaulting and defaulting are respectively

$$c_{t+1}^{B,nd}(\epsilon_{t+1}) = \frac{d_t^B}{\pi_{t+1}} + (y_{t+1}^B + \epsilon_{t+1})n_t^B - \delta^h h_t^B - \frac{\iota + \delta^m \bar{q}^m}{\pi_{t+1}} m_t^B - d_{t+1}^{*,nd}(\epsilon_{t+1}). \tag{82}$$

$$c_{t+1}^{B,d}(\epsilon_{t+1}) = \frac{d_t^B}{\pi_{t+1}} + (y_{t+1}^B + \epsilon_{t+1})n_t^B - d_{t+1}^{*,d}(\epsilon_{t+1}). \tag{83}$$

Note this depends on the income shock through $d_{t+1}^{*,k}(\epsilon_{t+1})$ but not explicitly on the default utility shock $\eta_{B,t+1}$. The borrrower's wealth levels next period if it does and does not default are respectively

$$w_{t+1}^{B,d}(\epsilon_{t+1}^*) = d_{t+1}^{*,d}(\epsilon_{t+1}^*) + (1-\lambda)p_t^B n_{t-1}^B, \tag{84}$$

$$w_{t+1}^{B,nd}(\epsilon_{t+1}^*) = d_{t+1}^{*,nd}(\epsilon_{t+1}^*) + p_t^B n_{t-1}^B + p_t^h h_{t-1}^B - \frac{1-\delta^m}{\pi_{t+1}} m_{t-1}^B q_t^m. \tag{85}$$

The default threshold $\eta_{B,t+1}^*$ given ϵ_{t+1} solves the equation

$$\eta_{B,t+1}^*[u(\hat{c}_{t+1}^d(\epsilon_{t+1}), \hat{h}_t^B) + \frac{(\hat{w}_{t+1}^{B,d}(\epsilon_{t+1}))^{1-\gamma}}{1-\gamma} v(\mathcal{Z}_{t+1})] = u(\hat{c}_{t+1}^{B,nd}(\epsilon_{t+1}), \hat{h}_t^B) + \frac{(\hat{w}_{t+1}^{B,nd}(\epsilon_{t+1}))^{1-\gamma}}{1-\gamma} v(\mathcal{Z}_{t+1}). \tag{86}$$

Trading Stage. Taking as given the borrower's optimal decisions at the default stage, we derive first-order conditions that characterize its decisions at the trading stage. Plugging the household's optimal default and consumption decisions into its Bellman equation (equation (77)) yields

$$\begin{aligned} v(\mathcal{Z}_t) = (1-\gamma) \max_{\hat{d}_t^B, \hat{n}_t^B, \hat{h}_t^B, \hat{m}_t^B} \beta_B \mathrm{E}_t \Bigg[& \{\eta_{B,t+1} \geq \eta_{B,t+1}^*(\epsilon_{t+1})\} \left(u(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B) + \frac{(\hat{w}_{t+1}^{B,nd})^{1-\gamma}}{1-\gamma} v(\mathcal{Z}_{t+1}) \right) \\ & + \{\eta_{B,t+1} < \eta_{B,t+1}^*(\epsilon_{t+1})\} \eta_{B,t+1} \left(u(\hat{c}_{t+1}^{B,d}, \hat{h}_t^B) + \frac{(\hat{w}_{t+1}^{B,d})^{1-\gamma}}{1-\gamma} v(\mathcal{Z}_{t+1}) \right) \Bigg], \end{aligned} \tag{87}$$

subject to the budget constraint

$$1 = \frac{\hat{d}_t}{1+i_t} + p_t^B \hat{n}_t^B + p_t^h \hat{h}_t^B - q_t^m \hat{m}_t^B. \tag{88}$$

Let μ_t be the Lagrange multiplier on the budget constraint. By the envelope condition, the Lagrange multiplier is $\frac{d}{dw_t^B} V(w_t^B, \mathcal{Z}_t)|_{w_t^B=1} = v(\mathcal{Z}_t)$ The household has the following first order conditions.

FOC for $\hat{d}_t^B$:

$$\frac{\mu_t}{1+i_t} = \beta_B \mathrm{E}_t \left[\{\eta_{B,t+1} < \eta_{B,t+1}^*(\epsilon_{t+1})\} \frac{1}{\pi_{t+1}} u_c(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B) + \{\eta_{B,t+1} \geq \eta_{B,t+1}^*(\epsilon_{t+1})\} \frac{\eta_{B,t+1}}{\pi_{t+1}} u_c(\hat{c}_{t+1}^{B,d}, \hat{h}_t^B) \right] \tag{89}$$

FOC for $\hat{n}_t^B$:

$$\begin{aligned} \mu_t p_t^n = \beta_B \mathrm{E}_t \Big[& \{\eta_{B,t+1} < \eta_{B,t+1}^*(\epsilon_{t+1})\} \left(u_c(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B)[y_{t+1}^B + \epsilon_{t+1}] + (\hat{w}_{t+1}^{B,nd})^{-\gamma} v(\mathcal{Z}_{t+1}) p_{t+1}^n \right) \\ & + \{\eta_{B,t+1} \geq \eta_{B,t+1}^*(\epsilon_{t+1})\} \eta_{B,t+1} \left(u_c(\hat{c}_{t+1}^{B,d}, \hat{h}_t^B)[y_{t+1}^B + \epsilon_{t+1}] + (\hat{w}_{t+1}^{B,d})^{-\gamma} v(\mathcal{Z}_{t+1})(1-\lambda) p_{t+1}^n \right) \Big]. \end{aligned} \tag{90}$$

FOC for $\hat{h}_t^B$:

$$\mu_t p_t^h = \beta_B \mathrm{E}_t \Big[\{\eta_{B,t+1} < \eta^*_{B,t+1}(\epsilon_{t+1})\} \Big(u_h(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B) + u_c(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B)(-\delta^h) + (\hat{w}_{t+1}^{B,nd})^{-\gamma} v(\mathcal{Z}_{t+1})(\epsilon_{t+1} + p_{t+1}^h) \Big) + \{\eta_{B,t+1} \geq \eta^*_{B,t+1}(\epsilon_{t+1})\} \eta_{B,t+1} u_h(\hat{c}_{t+1}^{B,d}, \hat{h}_t^B) \Big]. \tag{91}$$

FOC for $\hat{m}_t^B$:

$$\mu_t q_t^m = \beta_B \mathrm{E}_t \left[\{\eta_{B,t+1} < \eta^*_{B,t+1}(\epsilon_{t+1})\} \left(u_c(\hat{c}_{t+1}^{B,nd}, \hat{h}_t^B) \frac{\iota + \delta^m \bar{q}^m}{\pi_{t+1}} + (\hat{w}_{t+1}^{B,nd})^{-\gamma} v(\mathcal{Z}_{t+1}) \frac{1-\delta^m}{\pi_{t+1}} q_{t+1}^m \right) \right]. \tag{92}$$

A.2 Solution to the Saver Problem

Given the saver's preferences

$$u^S(c_t^S, h_t^S, d_t^S) = \frac{\left((c_t^S)^{1-\theta-\psi}(h_t^S)^\theta (d_t^S)^\psi\right)^{1-\gamma}}{1-\gamma} - \chi 0 \frac{(n_t^S)^{1+\chi_1}}{1+\chi_1}, \tag{93}$$

its marginal utility of non-durable consumption is

$$\frac{\partial u^s}{\partial c_t^S} = \left((c_t^S)^{1-\theta-\psi}(h_t^S)^\theta (d_t^S)^\psi\right)^{-\gamma} (1-\theta-\psi)(c_t^S)^{-\theta-\psi}(h_t^S)^\theta (d_t^S)^\psi \tag{94}$$

$$= \left((c_t^S)^{1-\theta-\psi}(h_t^S)^\theta (d_t^S)^\psi\right)^{1-\gamma} (1-\theta-\psi)\frac{1}{c_t^S}. \tag{95}$$

The saver therefore has the (real) stochastic discount factor

$$M_{t,t+1}^S = \beta_S \left(\frac{c_t^S}{c_{t+1}^S}\right) \left(\frac{(c_{t+1}^S)^{1-\theta-\psi}(h_{t+1}^S)^\theta (d_{t+1}^S)^\psi}{(c_t^S)^{1-\theta-\psi}(h_t^S)^\theta (d_t^S)^\psi}\right)^{1-\gamma}. \tag{96}$$

For pricing nominal payoffs, the saver's nominal stochastic discount factor is $M_{t,t+1}^S \frac{1}{\pi_{t+1}}$.

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

$$\frac{\partial u^s}{\partial h_t^S} = \frac{\partial u^s}{\partial c_t^S} \frac{\theta c_t^S}{(1-\theta-\psi)h_t^S} \tag{97}$$

$$\frac{\partial u^s}{\partial d_t^S} = \frac{\partial u^s}{\partial c_t^S} \frac{\psi c_t^S}{(1-\theta-\psi)d_t^S} \tag{98}$$

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

$$p_t^h = \mathrm{E}_t \left[M_{t,t+1}^S \left(p_{t+1}^h - \delta^h\right)\right] + \tfrac{\theta c_t^S}{(1-\theta-\psi)h_t^S} \tag{99}$$

$$\frac{1}{1+i_t} = \mathrm{E}_t \left[M_{t,t+1}^S \tfrac{1}{\pi_{t+1}} \right] + \tfrac{\psi c_t^S}{(1-\theta-\psi)d_t^S}. \tag{100}$$

The saver's labor supply is given by

$$\chi_0 (n_t^S)^{\frac{-1}{\chi_1}} = \frac{\partial u^s}{\partial c_t^S} \omega_t.$$

A.3 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

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}, \tag{101}$$

with the price index

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

A.3.1 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

$$\frac{P_t(i)}{P_t} = \frac{\partial Y_t}{\partial Y_t(i)} = \left(\int_0^1 Y_t(i)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}-1} Y_t(i)^{\frac{\eta-1}{\eta}-1} \tag{102}$$

$$= (Y_t)^{\frac{1}{\eta}} Y_t(i)^{\frac{-1}{\eta}} \tag{103}$$

$$Y_t(i) = Y_t(\frac{P_t(i)}{P_t})^{-\eta}. \tag{104}$$

Plugging the final good's firms demand curve for intermediates (equation 104) into the firm's feasibility constraint in equation (101) yields

$$Y_t = \left(\int_0^1 (Y_t(\frac{P_t(i)}{P_t})^{-\eta})^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}} \tag{105}$$

$$1 = (P_t)^{\eta} \left(\int_0^1 P_t(i)^{-\eta}) \frac{\eta-1}{\eta} di \right)^{\frac{\eta}{\eta-1}} \tag{106}$$

$$(P_t)^{-\eta} = \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{\eta}{\eta-1}} \tag{107}$$

$$P_t = \left(\int_0^1 P_t(i)^{1-\eta} di \right)^{\frac{1}{1-\eta}}. \tag{108}$$

Each intermediate firm therefore faces the demand curve given by equation (104) where the final goods price P_t is given by equation (108) .

A.3.2 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

$$\min_{n_t,k_t} w_t n_t + r_t^K k_t \tag{109}$$

subject to the production feasibility constraint

$$(Z_t n_t)^\alpha (k_t)^{1-\alpha} \geq \bar{y}. \tag{110}$$

We denote the multiplier on the feasibility constraint in equation (115) as mc_t. The first order conditions are

$$w_t = mc_t (Z_t)^\alpha \alpha (n_t)^{\alpha-1} (k_t)^{1-\alpha}, \tag{111}$$

$$r_t^K = mc_t (Z_t)^\alpha (1-\alpha)(n_t)^\alpha (k_t)^{-\alpha}, \tag{112}$$

which implies

$$\frac{w_t}{r_t^K} = \frac{\alpha (n_t)^{\alpha-1}(k_t)^{1-\alpha}}{(1-\alpha)(n_t)^\alpha (k_t)^{-\alpha}} = \frac{k_t \alpha}{n_t(1-\alpha)} \tag{113}$$

$$(1-\alpha) w_t n_t = \alpha r_t^K k_t. \tag{114}$$

We plug equation (114) back into the production function (equation (115)) to solve for labor and capital demand

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

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

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

and

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

The total cost of production is equal to wages paid plus the rental cost of capital

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

Differentiating 115 with respect to $\bar{y}$ gives the marginal cost of production

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

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

$$0 = y'(p_t)\left(\frac{p_t}{P_t} - mc_t\right) + \frac{y(p_t)}{P_t} - \xi\left(\frac{p_t}{\bar{\pi}p_{t-1}} - 1\right)\frac{1}{\bar{\pi}p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right]. \quad (115)$$

The demand curve has derivative

$$y'(p_t) = -\frac{\eta}{P_t}Y_t\left(\frac{p_t}{P_t}\right)^{-\eta-1} \quad (116)$$

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

$$y'(p_t) = -\frac{\eta}{P_t}Y_t \quad (117)$$

Plugging equation (117) into the pricing FOC (and using $p_t = P_t$ and $\pi_t = \frac{p_t}{p_{t-1}}$) yields

$$0 = -\frac{\eta}{P_t}Y_t\left(\frac{p_t}{P_t} - mc_t\right) + \frac{Y_t}{P_t} - \xi\left(\frac{p_t}{\bar{\pi}p_{t-1}} - 1\right)\frac{1}{\bar{\pi}p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right] \quad (118)$$

$$0 = Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{p_t}{\bar{\pi}p_{t-1}} - 1\right)\frac{1}{\bar{\pi}p_{t-1}} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right] \quad (119)$$

$$0 = Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{\pi_t}{\bar{\pi}} - 1\right)\frac{\pi_t}{\bar{\pi}P_t} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\frac{\partial V^W(p_t, \mathcal{S}_{t+1})}{\partial p_t}\right]. \quad (120)$$

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

$$0 = Y_t\left(\frac{1}{P_t} - \eta\frac{1}{P_t} + \eta\frac{mc_t}{P_t}\right) - \xi\left(\frac{\pi_t}{\bar{\pi}} - 1\right)\frac{\pi_t}{\bar{\pi}P_t} + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\xi\left(\frac{\pi_{t+1}}{\bar{\pi}} - 1\right)\frac{\pi_{t+1}}{\bar{\pi}(P_t)}\right]. \quad (121)$$

$$\xi\left(\frac{\pi_t}{\bar{\pi}} - 1\right)\frac{\pi_t}{\bar{\pi}} = Y_t\left(\frac{P_t}{P_t}(1-\eta) + \eta mc_t\right) + \mathrm{E}_t\left[\mathcal{M}_{t,t+1}\xi\left(\frac{\pi_{t+1}}{\bar{\pi}} - 1\right)\frac{\pi_{t+1}}{\bar{\pi}}\right]. \quad (122)$$

which is the New Keynesian Phillips Curve for this sector.

A.4 Rebates of Mortgage Default Costs

Lump-sum rebates are

$$Reb_t = \nu \left(\mathcal{P}_t m^I_{t-1} - \frac{D^I_{t-1}}{\pi_t} \right) + F_{\eta_B,t} \left(\lambda p^B_t n^B_{t-1} + \zeta p^{h,B}_t h^B_{t-1} \right). \tag{123}$$

For non-defaulters, intermediaries receive mortgage payment $\iota + \delta^m \bar{q}^m$ at the liquidity stage and remaining market value $(1 - \delta^m) q^m_t$ at the trading stage. For defaulters, they recover the value of foreclosed homes $(1 - \zeta) p^{h,B}_t$ net of loss ζ, and after making maintenance payment δ^h, both proportional to household leverage $\frac{h^B_{t-1}}{m^B_{t-1}}$.

The price q^m_t endogenously reflects the riskiness of the mortgage, since the intermediary must be compensated for credit risk to be willing to lend.