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Fiscal Multipliers and Financial Crises

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Abstract

I study the effects of the US fiscal policy response to the Great Recession, accounting both for standard tools and financial sector interventions. A nonlinear model calibrated to the US allows me to study the state-dependent effects of different fiscal policies. I combine the model with data on the fiscal policy response to find that the fall in consumption would have been one-third larger in the absence of that response, for a cumulative loss of 7.18%. Transfers and bank recapitalizations yielded the largest fiscal multipliers through new transmission channels that arise from linkages between household and bank balance sheets.

JEL Codes: E4, E6, G01, G28

Keywords: fiscal multipliers, financial crises, bailouts, nonlinear methods

1 Introduction

The 2008 global financial crisis and subsequent Great Recession led to renewed interest in fiscal policy by both policymakers and academics, as governments around the world deployed extraordinary fiscal stimulus packages to fight the downturn. Many of these packages included the standard

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arsenal of policy tools: public purchases of goods and services and social transfers or tax rebates to households, both of which have been extensively studied. However, this period also saw unprecedented amounts of fiscal resources committed to interventions in the financial sector. As a concrete example, the American Recovery and Reinvestment Act of 2009 (ARRA, the "Obama stimulus") consisted of outlays equivalent to 2.5% of GDP at its peak, allocated to conventional fiscal policy tools. The Troubled Asset Relief Program (TARP), the umbrella program for most of the US Treasury's financial sector interventions, involved outlays of over 6% of GDP in the fourth quarter of 2008 alone — twice as large as the ARRA. Authors such as Mian and Sufi (2014) have argued that the US government devoted too many resources to supporting the financial sector, while others have disagreed, defending the crucial role played by the financial sector in intermediating resources and ensuring orderly household deleveraging (Geithner, 2015).

In this paper, I try to formalize and quantify some of these arguments by studying the effects of all these different fiscal tools in a quantitative model calibrated to the US. I find that these fiscal interventions were very important for stabilizing the economy: in their absence, the fall in aggregate consumption would have been almost one-third larger. In particular, I find that transfers to households and bank recapitalizations were the most important tools to achieve this goal.

To arrive at these results, I combine data with a model of fiscal policy, which I use as a measurement device to estimate shocks. I build on the analysis of Drautzburg and Uhlig (2015) and extend the workhorse New Keynesian model along several dimensions: heterogeneous agents and incomplete markets, a financial sector, and equilibrium default. These ingredients provide a role for traditional fiscal tools such as purchases and transfers, as well as for financial sector interventions such as equity injections and credit guarantees. In the model, borrowers finance housing purchases with long-term debt, subject to a loan-to-value (LTV) constraint. Credit is supplied by a financial sector, which raises deposits from savers, and is subject to a leverage constraint that binds when capital is low, hampering intermediation. Both borrowers and banks can default on their debts, and default decisions depend on leverage in each sector. Financial crises are modeled as shocks that raise the number of borrower defaults: this causes banks to post losses and reduce lending, negatively affecting borrower disposable income and private consumption. While these shocks are exogenous, their effects endogenously depend on the state of the economy.

The interaction between household and financial sector balance sheets augments the standard Keynesian channels through which conventional tools operate (Galí et al., 2007). By raising borrower disposable income, fiscal policy also raises house prices. This reduces household leverage, relaxing borrowing constraints directly and reducing default. In turn, banks post fewer losses and are able to lend more at lower rates, further raising borrower incomes. The government can also intervene directly in the financial sector. Bank recapitalizations directly facilitate the expansion of bank intermediation by relaxing constraints and moderating the financial accelerator. Guarantees on bank debt lower costs of funding, providing an implicit recapitalization. These linkages between household and bank balance sheets strengthen when both constraints bind, and provide a new channel through which fiscal policy can affect aggregate activity. Whether the constraints faced by borrowers and banks bind is thus important to determine the effectiveness of different types of fiscal tools, and the model solution technique allows me to capture the state-dependent effects of fiscal policies.[1]

I calibrate the model to the US, and use it to assess the fiscal policy response to the financial crisis of 2008 and the subsequent Great Recession. The calibration focuses on matching moments related to bank and household balance sheets while ensuring that the model generates responses to fiscal interventions that are consistent with leading empirical estimates such as those of Parker et al. (2013). I assemble a comprehensive dataset of the fiscal policy response, which I map into the model.[2] I then apply a particle filter to the calibrated model in order to estimate sequences of policy-invariant structural shocks that allow the model to match the path of aggregate consumption and a measure of default rates in the data. By taking into account the fiscal policy response, this procedure

[1]This state dependence cannot be captured using standard solution techniques based on log-linearization around a SS. For this reason, I solve the model with nonlinear methods, allowing me to study how the effects of policies and shocks vary with the state of the economy. This follows on the footsteps of an emerging literature that finds strong evidence for state-dependent effects of fiscal policy (Lindé and Trabandt, 2018).

[2]I draw a line between fiscal interventions approved by the US Congress and counting towards federal debt and the deficit, and unconventional monetary policy undertaken by the Federal Reserve, such as QE. This paper is about the former; the analysis could also be extended to study the latter.

estimates the distributions of structural shocks that allow me to study fiscal policy counterfactuals.

I find that fiscal interventions played an important role: aggregate consumption would have fallen by an additional third in the absence of a fiscal policy response, with a total cumulative loss of almost 7.18%, or $604 billion. I decompose the contribution of the different tools and find that transfers and bank recapitalizations had the largest effect on aggregate consumption. I argue that these large effects arise from the interaction between household and financial sector constraints. Finally, I use the estimated sequences of shocks to estimate time-varying fiscal multipliers for different policy tools in the US. Defining the fiscal multipliers for the financial sector interventions is not trivial, and I develop an approach suited for nonlinear models that is in the spirit of Lucas (2016), who argues that federal credit policies draw on the same pool of resources as other fiscal policies and should therefore be evaluated based on similar criteria. I find that the fiscal multiplier for government purchases is stable and close to 0.6 during normal periods and rises during the crisis, consistent with the literature (Auerbach and Gorodnichenko, 2012; Ramey and Zubairy, 2018).[3] The fiscal multipliers for transfers, bank recapitalizations, and guarantees, are very low during the pre-crisis expansion, but become very high during the 2008-2009 crisis, rising well above 1.

The effects of transfers rely on two transmission channels: the direct channel has to do with the fact that borrowers are more likely to be constrained during recessions, and thus their marginal propensity to consume (MPC) is higher.[4] The second, the indirect channel, requires both borrower and bank constraints to bind: by sustaining disposable income, transfers have first-order effects on house prices through the borrower stochastic discount factor (SDF) when the borrower constraint binds. Thus transfers endogenously reduce LTV and default rates, mitigating bank losses and relaxing their leverage constraint. This, in turn, allows banks to lend more and at lower rates. The strength of this second channel depends both on borrower MPC and on how tight the leverage con-

[3] See Canzoneri et al. (2016) for a model of state-dependent multipliers.

[4] See Oh and Reis (2012) for a description of this channel in the context of a heterogeneous agents New Keynesian model, and Kaplan and Violante (2014), who emphasize the role of asset liquidity. While I do not consider a full-blown heterogeneous agents model, I draw on these findings to introduce heterogeneity as in Campbell and Mankiw (1989). Savers are permanently unconstrained and internalize that current fiscal deficits are future tax liabilities, while borrowers are only occasionally constrained. Unlike most of the literature, I do not assume that these agents are permanently constrained, and thus their MPC varies with the state of the economy.

straint is for banks. For this reason it is particularly strong when the economy is in a recession and the financial sector is undercapitalized. Bank recapitalizations work in a similar way and operate mainly through this second channel, raising current lending and lowering the cost of funds, thus raising borrower disposable income.

This paper contributes to the literature on fiscal interventions in the financial sector. Philippon (2010) models the interaction between household and bank balance sheets in a static setting and evaluates the relative merits of transferring resources to households or banks, finding that the latter is preferable. I find that this may change with the state of the economy, depending on which sector is more constrained at a given point. Several papers have analyzed the impact of interventions on private incentives and their implications for moral hazard in the financial sector, focusing on how the expectation of bailouts may raise the likelihood that a crisis materializes in the first place (Farhi and Tirole, 2012; Jeanne and Korinek, 2020). While such anticipation effects exist in my model, they are not the focus of my analysis. This literature focuses on optimal policy from an ex-ante perspective, while I analyze the ex-post effects of fiscal interventions.[5] The rest of the paper is organized as follows: Section 2 describes the model, Section 3 describes the calibration, Section 4 explains the key mechanisms in the model, Section 5 describes the main quantitative exercise, and discusses the assumptions. Section 6 concludes.

2 Model

I develop a dynamic general equilibrium model with nominal rigidities and financial crises that can be used as a laboratory to study different types of fiscal interventions. Time is infinite and discrete. The economy is populated by five types of agents: households, who can be either borrowers or savers; financial intermediaries; a corporate sector consisting of intermediate goods producers and final goods retailers; a central bank (CB); and a fiscal authority.[6] There are two exogenous shocks in

[5] Kollmann et al. (2013) and Bianchi (2016) analyze equity injections in the context of dynamic stochastic models.

[6] The overall structure is reminiscent of the models developed by Iacoviello (2015) and Ferrante (2019). Figure A.9 in the appendix summarizes the structure of the model.

the model: a total factor productivity (TFP) shock to the production function and a credit risk shock that affects the rate at which borrowers default on their debt payments. Markets are incomplete, and all financial contracts take the form of risky debt except for government debt, which is safe.

2.1 Environment

2.1.1 Household Preferences

There are two types of households, borrowers and savers, indexed by $i = \{b, s\}$ in measures χ and $1-\chi$, respectively. They differ in terms of the preferences and the types of financial assets they can access. Savers can invest in bank deposits and government debt, while borrowers can own houses and borrow in long-term debt contracts. Savers own all firms and banks in the economy.

Both borrowers and savers seek to maximize the present discounted sum of utility flows,

$$V_t^i = \log(C_t^i) - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} + \xi^i \log(h_t^i) + \beta^i \mathbb{E}_t(V_{t+1}^i) \tag{1}$$

Household preferences differ in two dimensions: borrowers derive utility from houses and are less patient. Instantaneous utility is defined over streams of consumption C_t^i, labor N_t^i, and housing h_t^i. φ is the inverse of the Frisch elasticity of labor supply, and ξ^i is the preference parameter for housing. I assume that $\xi^b > 0 = \xi^s$, so that savers do not derive any utility from housing services.[7]

2.1.2 Savers

Savers maximize utility (1) subject to a sequence of budget constraints of the type

$$P_t C_t^s + Q_t^d P_t D_t + Q_t P_t B_t^g = (1-\tau) P_t w_t N_t^s + Z_t^d P_{t-1} D_{t-1} + P_{t-1} B_{t-1}^g - P_t T_t + \Gamma_t$$

where P_t is the price level, D_t are real deposits, B_t^g is real public debt, Q_t is the price of debt (the inverse of the nominal interest rate), w_t is the real wage, τ is a linear tax on labor, T_t are net lump-

[7]This is not a crucial assumption and is made for simplicity. All results hold as long as the housing markets in which borrowers and savers participate are segmented.

sum taxes/transfers from the government, and Γ_t are net profits and transfers from the corporate and financial sectors. Z^d_t is the payoff per unit of deposits, only realized at t due to the possibility of bank failure as explained later. Saver first-order conditions are standard and consist of asset-pricing conditions for deposits and for government debt as well as an intratemporal labor supply condition.[8] It is useful to define the saver's SDF for real payoffs as $\Lambda^s_{t,t+1} \equiv \beta^s \frac{C^s_t}{C^s_{t+1}}$.

2.1.3 Borrowers

Borrowers derive utility from housing services and borrow in long-term debt contracts to finance house purchases, which are offered by banks and have a face value of \$1 and a market price of Q^b_t. These contracts are geometrically decaying perpetuities with a coupon/decay rate of $\gamma \in [0, 1]$. To obtain partial default in equilibrium while keeping the model environment tractable, I assume a family construct for the borrower following Landvoigt (2016). The borrower family enters period t with an outstanding nominal debt balance $P_{t-1}\bar{B}^b_{t-1}$ and a total stock of housing h_{t-1}.[9]

At the beginning of the period, the borrower family is split into a continuum of members indexed by $i \in [0, 1]$, each receiving an equal share of the debt balance and housing stock $(P_{t-1}\bar{B}^b_{t-1}, h_{t-1})$. Each of these members is then subject to two idiosyncratic shocks: first, they receive a *moving* shock with probability m, which determines whether they have to sell their house and move or not. After the moving shock is realized, each member i receives a *housing quality* shock $\nu_t(i)$, drawn from some distribution $F^b_t[0, +\infty)$ and satisfying $\mathbb{E}_t[\nu_t(i)] = 1, \forall t$.

Family members who do not move (a fraction $1 - \mathrm{m}$) simply fulfill their debt payment in the current period $\gamma \times P_{t-1}\bar{B}^b_{t-1}$. Household members that move (a fraction m) decide whether to prepay their debt balance and sell their home or to default on the mortgage and walk away from their home. The debt balance prepayment is worth $P_{t-1}\bar{B}^b_{t-1}$, and the market value of their house is $P_t p^h_t \times \nu_t(i) h_{t-1}$ given the quality adjustment. Upon default, the lender seizes the housing assets that serve as collateral; that is, the house gets foreclosed.

Given the resale value of housing, each family member chooses to repay her maturing debt

[8] All equilibrium conditions are reported in Appendix A.1.

[9] Per capita variables are denoted with an upper bar. The aggregate level of debt is $B^b_{t-1} = \chi \bar{B}^b_{t-1}$.

balance or default and let the bank seize her housing assets. The cost of default is the loss of housing collateral. Let $\iota(\nu) \in \{0, 1\}$ denote the default choice by a member with house quality shock ν. After default and repayment decisions are made, members reconvene in the borrower household and make all relevant decisions for the current period. End-of-period debt balances for the borrower household equal new borrowings L_t plus non-prepaid balances net of the current coupon:

$$P_t \bar{B}_t^b = P_t L_t + (1 - \mathrm{m})(1 - \gamma) P_{t-1} \bar{B}_{t-1}^b \tag{2}$$

The borrower household jointly chooses consumption, labor supply, new borrowing, and new housing as well as the default rules for each individual member.[10] The real budget constraint is

$$\begin{aligned} &C_t^b + \frac{\bar{B}_{t-1}^b}{\Pi_t} \left[(1 - \mathrm{m})\gamma + \mathrm{m} \int [1 - \iota_t(\nu)] \mathrm{d}F_t^b \right] + p_t^h h_t^* \\ =&(1 - \tau) w_t N_t^b + Q_t^b L_t + p_t^h h_{t-1} \mathrm{m} \int \nu [1 - \iota_t(\nu)] \mathrm{d}F_t^b - T_t + T_t^b \end{aligned}$$

where T_t^b are lump-sum transfers from the government and h_t^* are new housing purchases. New borrowing L_t is defined by (2). The law of motion for the stock of housing is $h_t = h_t^* + (1 - \mathrm{m}) h_{t-1}$. The borrower family is subject to a LTV constraint on new borrowing: new debt balances contracted this period cannot exceed a fraction of the value of new housing purchases,[11]

$$L_t \leq \theta^{LTV} p_t^h h_t^* \tag{3}$$

The borrower household chooses $(C_t^b, L_t, N_t^b, h_t, \{\iota_t(\nu)\}_{\nu \in [0, +\infty)})$ to maximize (1) subject to (2)-(3). It can be shown that the optimal default decision is static and given by a threshold rule: the borrower optimally defaults on all debt prepayments for which $\nu < \nu_t^*$, where $\nu_t^* = \bar{B}_{t-1}^b / (\Pi_t p_t^h h_{t-1})$. Basically, a "mover" member of the borrower household behaves as having limited liability when it

[10] This arrangement is thus equivalent to one where borrower family members are identical agents with access to a full set of contingent claims that allow them to hedge any idiosyncratic risks within the group.

[11] A constraint on borrowing at origination is more realistic than a constraint on the total stock of debt. In practice, households are not subject to marginal calls on their mortgages by financial institutions.

comes the time to prepay and defaults if the remaining debt balance exceeds the market value of the house. In equilibrium, default is positive and partial and the default rate fluctuates with household leverage, which in turn depends on equilibrium objects such as the house price. Another relevant optimality condition is the asset-pricing equation for housing, which takes the form

$$p_t^h = \frac{\frac{\xi}{h_t} C_t^b + \mathbb{E}_t \left\{ \Lambda_{t,t+1}^b p_{t+1}^h [(1-\mathrm{m})(1-\lambda_{t+1}^b \theta^{LTV}) + \mathrm{m}\Psi_{t+1}^b(\nu_{t+1}^*)] \right\}}{1-\lambda_t^b \theta^{LTV}} \tag{4}$$

where λ_t^b is the Lagrange multiplier on the borrowing constraint (3); $\Lambda_{t,t+1}^b$ is the borrower's SDF for real payoffs, defined analogously to that of the saver; and $\Psi_{t+1}^b(\nu_{t+1}^*) \equiv \int_{\nu_t^*}^{\infty} \nu \mathrm{d}F_t^b(\nu)$ is a partial expectation term for the house quality shock. Condition (4) highlights that changes in borrower consumption have a first-order effect on house prices, both through the current utility dividend from housing services and through the SDF.

2.1.4 Corporate Sector

The corporate sector consists of final goods retailers and intermediate goods producers. Final goods retailers are perfectly competitive and employ a continuum of intermediate goods varieties indexed by $k \in [0,1]$ to produce the final good using a Dixit-Stiglitz aggregator $Y_t = \left[\int_0^1 Y_t(k)^{\frac{\varepsilon}{\varepsilon-1}} \mathrm{d}k\right]^{\frac{\varepsilon-1}{\varepsilon}}$, where ε is the elasticity of substitution across varieties.

There is a continuum of intermediate goods producers, each producing a different variety k. All firms are owned by the savers and have access to a linear production technology in labor given by $Y_t(k) = A_t N_t(k)$, where A_t is an exogenous aggregate TFP shock. Given the constant elasticity of substitution assumption, each of these firms faces a demand schedule of the type $Y_t(k) = \left[\frac{P_t(k)}{P_t}\right]^{-\varepsilon} Y_t$. I assume that firms are subject to menu costs à la Rotemberg:

$$d\left[P_t(k), P_{t-1}(k)\right] \equiv \frac{\eta}{2} Y_t \left[\frac{P_t(k)}{P_{t-1}(k)}\Pi^{-1} - 1\right]^2$$

where Π is the inflation target set by the CB and η is the menu cost parameter. Appendix A.2 presents the details on the firm's problem and shows that the first-order condition for an individual price-setting firm k combined with the assumption of a symmetric equilibrium yields a nonlinear Phillips curve that relates inflation to aggregate output:

$$\eta \frac{\Pi_t}{\Pi}\left(\frac{\Pi_t}{\Pi}-1\right)+\varepsilon\left(\frac{\varepsilon-1}{\varepsilon}-\frac{w_t}{A_t}\right)=\eta \mathbb{E}_t\left[\Lambda^s_{t,t+1}\frac{Y_{t+1}}{Y_t}\frac{\Pi_{t+1}}{\Pi}\left(\frac{\Pi_{t+1}}{\Pi}-1\right)\right]$$

2.1.5 Financial Sector

The modeling of the financial sector is reminiscent of Gertler and Karadi (2011) with some important differences. Banks engage in maturity transformation by borrowing in short-term deposits and lending in long-term debt: their balance sheet features a fixed-income maturity mismatch that exposes them to interest rate risk in addition to credit risk. The model therefore captures the two most important risk factors to which modern commercial banks are exposed. I assume that banks hold perfectly diversified portfolios of household debt, so that credit risk is systemic. Additionally, I assume that banks are exposed to idiosyncratic asset quality shocks: if these shocks are sufficiently low, a bank may be unable to repay all of its depositors in a given period, in which case it fails and its remaining assets are liquidated.[12]

There is a continuum of banks indexed by $j \in [0,1]$. Bank j enters the period with a portfolio of debt securities $b_{j,t-1}$ and deposits $d_{j,t-1}$. Each deposit entitles its owner to a unit repayment, while each debt security yields an aggregate payoff of Z^b_t. Each bank also receives an idiosyncratic shock $u_{j,t} \sim F^d$ on the return of its asset portfolio. This means that (nominal) earnings at the beginning of the period are

$$P_t e_{j,t} = u_{j,t} Z^b_t P_{t-1} b_{j,t-1} - P_{t-1} d_{j,t-1} \tag{5}$$

Banks that are unable to fully repay their depositors default. This means that $\exists u^*_{j,t}$ such that the bank defaults if and only if $u_{j,t} < u^*_{j,t}$, where $u^*_{j,t} = \frac{d_{j,t-1}}{Z^b_t b_{j,t-1}}$. The default threshold is equal to the bank's leverage divided by the aggregate return on the bank's assets. This means that periods of

[12] In practice, banks have other business lines that generate exposure to other types of risks beyond systemic ones. These idiosyncratic shocks thus represent risks that are not directly associated with household debt. This simplification allows me not to have to keep track of a joint distribution of banks and borrowers and to still obtain non-degenerate bank default risk in the model.

high household default, when Z_t^b is low, may also trigger waves of bank default, and this is more likely when bank leverage is high.

I assume that due to contractual frictions that are left unmodeled, banks are forced to pay out a constant fraction $1-\theta$ of their earnings as dividends every period. Thus $\theta \in [0,1]$ is the fraction of earnings that are retained as (book) capital. To fund their assets, banks need to use either retained earnings or new deposits. This gives rise to a flow of funds constraint, expressed in real terms as

$$Q_t^b b_{j,t} = \theta e_{j,t} + Q_t^d d_{j,t} \tag{6}$$

The bank also faces a leverage constraint, which constrains the market value of its assets not to exceed its ex-dividend market value. Let $V_{j,t}(e_{j,t})$ denote the real market value of the bank at the beginning of the period, before dividends are paid. The ex-dividend value of the bank is given by $\Phi_{j,t}(e_{j,t}) \equiv V_{j,t}(e_{j,t}) - (1-\theta)e_{j,t}$. The constraint imposes that this value must always exceed a fraction κ of the market value of assets,

$$\Phi_{j,t}(e_{j,t}) \geq \kappa Q_t^b b_{j,t} \tag{7}$$

This constraint effectively caps the amount of lending that banks can offer every period. Banks seek to maximize the present discounted value of their dividends. The bank's problem, conditional on not having defaulted this period, is then

$$V_{j,t}(e_{j,t}) = \max_{b_{j,t},d_{j,t}} \left\{ (1-\theta)e_{j,t} + \mathbb{E}_t \left[\int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} \max\left\{0, V_{j,t+1}(e_{j,t+1})\right\} \mathrm{d}F^d \right] \right\} \tag{8}$$

Banks solve (8) subject to the law of motion for earnings (5), the flow of funds constraint (6), and the capital requirement (7). A detailed derivation of the bank's problem may be found in Appendix A.3. In the appendix, I show that $\Phi_{j,t}(e_{j,t}) = \Phi_{j,t}\theta e_{j,t}$, where $\Phi_{j,t}$ can be interpreted as the marginal value of a dollar of earnings for the bank. Letting $\mu_{j,t}$ denote the Lagrange multiplier on the leverage constraint, we can write the solution to the bank's problem as

$$\mathbb{E}_t \left\{ \frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}} (1-\theta+\theta\Phi_{j,t+1}) \left[\Psi^d(u^*_{j,t+1}) \frac{Z^b_{t+1}}{Q^b_t} - \frac{1-F^d(u^*_{j,t+1})}{Q^d_t} \right] \right\} = \kappa\mu_{j,t}$$

where $\Psi^d(u^*_t) \equiv \int_{u^*_t}^{\infty} u \mathrm{d}F^d(u)$ is a partial expectation term. This asset-pricing condition highlights three potential sources of excess returns: current binding constraints via $\mu_{j,t}$; bank default/limited liability via $\Psi^d(u^*_t), F^d(u^*_t)$; and future binding constraints via $\Phi_{j,t+1}$. This last term comes from the envelope condition and is given by

$$\Phi_{j,t} = \frac{\mathbb{E}_t \left\{ \frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}} (1-\theta+\theta\Phi_{j,t+1})[1-F^d(u^*_{j,t+1})] \right\}}{Q^d_t(1-\mu_{j,t})} \tag{9}$$

Aggregation and Bank Entry Since the shocks $u_{j,t}$ are i.i.d. across banks and time, condition (9) does not depend on any bank-specific variable. This means that $\Phi_{j,t} \equiv \Phi_t, \forall j$. The appendix shows that the bank's problem is homogeneous of degree 1 in the level of current earnings $e_{j,t}$. Thus all banks take decisions that are proportional to their level of current earnings, implying that $(u^*_{j,t}, \mu_{j,t}) \equiv (u^*_t, \mu_t), \forall j$. While banks receive idiosyncratic shocks, they are able to readjust their portfolios every period such that there is no cross-sectional variation in ratios. This allows for simple aggregation of the banking system and allows me to focus the analysis on a representative bank whose earnings correspond to aggregate earnings for the banking system net of defaults.

Aggregate earnings P_tE_t consist of earnings of surviving banks $P_tE^s_t$ plus earnings of new banks $P_tE^n_t$. Earnings for surviving banks are given by

$$P_tE^s_t = P_{t-1}\theta \int_{u^*_t}^{\infty} [u_{j,t}Z^b_t b_{j,t-1} - d_{j,t-1}] \mathrm{d}F^d(u_{j,t}) = P_{t-1}\theta\{\Psi^d(u^*_t)Z^b_t B^b_{t-1} - [1-F^d(u^*_t)]D_{t-1}\}$$

where I have used the fact that $u_{j,t}$ shocks are i.i.d. across banks. Since a fraction $F^d(u^*_t)$ of existing banks fail every period, I assume that an equal mass of banks enters the market. Each of those banks is given a set-up transfer equal to $P_{t-1}\frac{\varpi}{F^d(u^*_t)}$, implying that $P_tE^n_t = \varpi P_{t-1}$ and thus real aggregate bank earnings evolve as

$$E_t = \Pi_t^{-1}\theta\{\Psi^d(u_t^*)Z_t^b B_{t-1}^b - [1 - F^d(u_t^*)]D_{t-1}\} + \varpi$$

Asset Returns Let λ_t^b, λ^d denote liquidation costs of default on household debt and deposits, respectively. Consider a bank that enters the period with a stock of debt securities worth B_{t-1}^b. Every period, a fraction $1 - \mathrm{m}$ of these mortgage holders pay their coupon γ and the remaining principal can be sold at price Q_t^b. Out of the remaining m, a fraction $1 - F_t^b(\nu_t^*)$ prepay in full. The remaining mortgages are foreclosed and liquidated by the banks (who immediately resell these houses to borrowers). The payoff per dollar of debt securities is therefore given by

$$Z_t^b \equiv (1-\mathrm{m})[(1-\gamma)Q_t^b + \gamma] + \mathrm{m}\left[1 - F_t^b(\nu_t^*) + (1-\lambda_t^b)\frac{1 - \Psi_t^b(\nu_t^*)}{\nu_t^*}\right]$$

where the value of recovered and resold houses is implicit in ν_t^*. Similarly, for bank deposits, we define the unit return as Z_t^d, which can be written as

$$Z_t^d = 1 - F^d(u_t^*) + (1-\lambda^d)\frac{1 - \Psi^d(u_t^*)}{u_t^*}$$

2.1.6 Housing

I assume that the housing market is segmented: only borrowers derive utility from housing services and choose to acquire housing in equilibrium. This implies that house prices are fully determined by the borrower's SDF. Movements in house prices are important in determining equilibrium default rates and generate pecuniary externalities through the borrowing constraint.[13] Foreclosed houses that are acquired by the banks are immediately resold back to the borrowers. For simplicity, I also assume that the supply of housing is fixed and normalized to 1, $h_t = 1, \forall t$. This assumption, coupled with the fact that $\mathbb{E}_t(\nu) = 1, \forall t$, means that the total quality-adjusted supply of housing in the economy is equal to 1 at every point in time, $h_t \int \nu \mathrm{d}F_t^b(\nu) = 1, \forall t$.

[13] Market segmentation is also assumed by Greenwald (2016), for example.

2.1.7 Labor Markets

I follow the literature (Debortoli and Gali, 2017) in assuming that the real wage schedule follows a rule of the type $w_t = \mu^w C_t^\sigma N_t^\varphi$, where μ^w is the gross wage markup, and is such that $w_t > (C_t^i)^\sigma (N_t^i)^\varphi, i = b, s$ at all times. I assume that labor is proportionally rationed between types, so $N_t^b = N_t^s = N_t$. This can be microfounded as the outcome of the problem for a wage-setting union, and is useful to rule out certain types of counterfactual behavior, such as borrower labor expanding during recessions.

2.1.8 Government

The government consists of separate and independent monetary and fiscal authorities.

Monetary Policy The CB conducts monetary policy by following a standard Taylor rule in which the policy rate Q_t^{-1} responds to deviations of GDP and inflation from their targets:

$$Q_t^{-1} = \bar{Q}^{-1} \left[\frac{\Pi_t}{\bar{\Pi}}\right]^{\phi_\Pi} \left[\frac{GDP_t}{G\bar{D}P}\right]^{\phi_Y}$$

where $G\bar{D}P, \bar{Q}$ are the steady state (SS) values of output and the (inverse of the gross) nominal interest rate. I define $GDP_t \equiv C_t + G_t$, that is, output net of resource costs.

Zero Lower Bound (ZLB) and Unconventional Monetary Policy (UMP) Wu and Xia (2016) argue that a "shadow" measure of the policy rate that can take negative values can proxy for the macroeconomic effects of UMP. I follow this approach, and so the current model features neither a ZLB nor an explicit modeling of UMP. In the quantitative exercise that follows, I show that the ZLB is not a necessary condition to generate state dependence of fiscal multipliers, particularly during periods of financial distress.[14] It is straightforward to extend the model to incorporate the main types of UMP conducted by the Fed (asset purchases and credit facilities), but this would come at great computational expense in the current setup with fiscal policy.[15] Section 5.5 further discusses

[14]See Christiano et al. (2011) for an analysis of fiscal multipliers at the ZLB.

[15]The full model has 11 state variables. Allowing for UMP shocks and stocks would increase the number of states to 15. I leave an analysis of UMP in the current framework for future research.

the role of the ZLB and UMP in light of the quantitative results.

Fiscal Policy Fiscal policy is conducted by a fiscal authority that is in charge of spending, taxation, and discretionary fiscal interventions. The government's budget constraint is

$$P_{t-1}B^g_{t-1} + P_tG_t + T^b_t + \sum_{\omega\in\Omega} \text{Net Costs}_\omega = \tau P_tY_t[1 - d(\Pi_t)] + P_tT_t + Q_tP_tB^g_t \qquad (10)$$

Expenditures, on the left-hand side, are: debt repayments, government purchases, and net costs of extraordinary fiscal measures $\omega \in \Omega$. On the right-hand side we have sources of funds: income and lump-sum taxes, and debt issuances. Income taxes are levied on corporate profits and labor income, which are equal to total output net of menu costs.

Since the focus of this paper is the analysis of extraordinary fiscal policy measures, I try to keep the rest of fiscal policy as simple as possible: I assume that both income taxes τ and regular government spending are fixed, thus $G_t = \bar{G}$ in the absence of extraordinary measures. In order to satisfy the intertemporal budget constraint, I allow lump-sum taxes to respond to deviations of public debt from its SS level according to a simple fiscal rule of the form $T_t = \phi_T \log\left(B^g_{t-1}/\bar{B}^g\right)$, where $\bar{B}^g$ is the SS level of public debt and ϕ_T is the speed of adjustment.

Modeling Financial Interventions While government purchases and transfers are standard in macroeconomic models, equity injections and credit guarantees are less common. Importantly, these policies involve contingent liabilities for the fiscal authority: ex-post, they can cost nothing in states of the world where no banks fail and the government fully recovers its investments, or be very expensive when the financial sector is distressed and unable to repay the government.

Equity injections are modeled after the Capital Purchase Program (CPP) of TARP, through which the Treasury directly acquired preferred stock securities in bank holding companies. Let $x^k_t \geq 0$ denote the government equity injection at t, as a percentage of equity. This claim entitles the government to a stream of dividends equal to a fraction θ^k of the bank's equity, and these dividends are paid before common stock. Importantly, the government loses this claim if the bank fails. At the time of purchase, this policy appears in the bank's budget constraint as a subsidy to current book equity, $Q^b_t B^b_t = (1 + x^k_t)E_t + Q^d_t D_t$, with a cost to the government equal to $x^k_t \theta E_t$. Let s^k_t denote the total share of bank equity that is currently owned by the government, with the law of motion given by

$$s^k_t = \frac{\theta^k[1 - F^d(u^*_t)]s^k_{t-1} + x^k_t}{1 + x^k_t}$$

Absent new injections, the claim decays at rate θ^k — potentially faster if these banks fail. From the point of view of the bank, this injection helps relax constraints in the short-run, but becomes expensive in the long-run as it reduces earnings that can be invested and/or paid out as dividends. Due to the preferred dividend payments, the law of motion for equity in the banking system becomes

$$\Pi_t E_t = \theta[1 - (1 - \theta^k)s^k_{t-1}] \left\{ \Psi^d(u^*_t) Z^b_t B^b_{t-1} - [1 - F^d(u^*_t)]D_{t-1} \right\} + \varpi$$

Credit guarantees are modeled similarly to deposit insurance: many of the extraordinary guarantee programs deployed by the Treasury and the Federal Deposit Insurance Corporation (FDIC) during this period were over non-deposit debt issued by financial institutions. Let $s^d_t \in [0, 1]$ be the fraction of bank debt that is guaranteed at $t + 1$. The law of motion for this variable is

$$s^d_t = \theta^d[1 - F^d(u^*_t)]s^d_{t-1} + x^d_t$$

where θ^d is the rate of decay of the guarantee and $x^d_t \in [0, \theta^d[1 - F^d(u^*_t)]s^d_{t-1}]$ are new guarantees announced this period. At each point in time, the guarantee entitles depositors to a guaranteed return equal to a fraction s^d_t of the investment at $t + 1$. The return for the depositor then becomes

$$Z^d_{t+1} = s^d_t + (1 - s^d_t) \left[1 - F^d(u^*_{t+1}) + (1 - \lambda^d) \frac{1 - \Psi^d(u^*_{t+1})}{u^*_{t+1}} \right]$$

The impact of these two policies in the government budget constraint can be written as

$$\begin{aligned}
\text{Net Costs}^k_t &= x^k_t E_t - (1 - \theta^g) s^k_{t-1} \Pi^{-1}_t \left\{ \Psi^d(u^*_t) Z^b_t B^b_{t-1} - [1 - F^d(u^*_t)]D_{t-1} \right\} \\
\text{Net Costs}^d_t &= s^d_{t-1} \frac{D_{t-1}}{\Pi_t} \left[F^d(u^*_t) - (1 - \lambda^d) \frac{\Psi^d(u^*_t)}{u^*_t} \right]
\end{aligned}$$

Note that after the initial investment, equity injections provide revenue for the government as banks repay their dividends and the government can earn more than it spent on injections, depending on the initial investment and the path of bank equity. Credit guarantees, on the other hand, have no upside for the government: there is a positive cost associated with bank failures and zero cost with no return otherwise.

2.2 Equilibrium

Equilibrium consists of allocations, prices, and policies such that (i) all agents choose allocations and optimize given prices and policies, (ii) prices clear markets given allocations and policies, and (iii) policies satisfy the government's budget constraint. Fiscal multipliers are defined over $GDP_t = C_t + G_t$.

3 Model Calibration and Solution Method

3.1 Calibration

The period in the model is a quarter. Most parameters are chosen so that the model's stochastic SS matches average moments of the US economy in 2000-06, prior to the 2008 financial crisis. The model has several parameters, which I group into four broad categories. The calibration is summarized in Table 1.

Standard Macro Parameters The discount factor is set at $\beta^s = 0.9951$ to generate an annualized real interest rate of 2% at the deterministic SS. The inverse Frisch elasticity of labor supply is set at $\varphi = 1$, which is standard in macroeconomic models. The elasticity of substitution across varieties is set at $\varepsilon = 6$, implying an average markup of 20% at the SS. η is set such that the slope of a linearized Phillips curve would coincide with that of a Calvo-type model where the probability of readjusting the price every period is equal to 20%, consistent with recent estimates in the literature. This procedure yields $\eta = 98.06$. The TFP shock follows an AR(1) process in logs,

$\log A_t = \rho_a \log A_{t-1} + \sigma_a \epsilon_t^a$. Since this is the only exogenous shock in the model besides the crisis and fiscal policy shocks, and given the nature of the quantitative exercise, I calibrate the persistence and volatility of TFP to match the persistence and volatility of aggregate consumption during the pre-crisis period.

Policy Parameters For the Taylor rule, I assume $\phi_\Pi = 2.5$ and $\phi_Y = 0.5/4$. The weight on output is standard, and the weight on inflation is chosen to match inflation volatility for the US. I assume that the CB pursues an annualized inflation target of 2%. For fiscal policy flows, I set $\bar{G}$ to be 20% of SS GDP, which is standard for the US in the 2000-06 period. The value of $\bar{B}^g$, the SS level of public debt, matters for determining the tax rate, as $\bar{\tau}$ balances the government's budget in SS. I set $\bar{B}^g$ to be equal to 60% of annual GDP, which is the average value for the 2000-06 period. At the SS, these values imply an income tax rate of 21.18%, which is higher than the US average (15.9%) but reflects the absence of any other taxes in the model. I assume that the fiscal policy rule parameter is $\phi_T = 0.01$. This number is lower than the estimates in Leeper et al. (2010), but ensures slow movements for taxes and large movements for public debt, consistent with the fiscal dynamics observed around the crisis.

Household Finance The model features a set of non-standard parameters related to household finance that I choose in order to match pre-crisis moments of the US economy. Maximum LTV at origination, which determines how binding is the constraint for the borrower, is set at a standard value of 85% (Greenwald, 2016). The fraction of agents that move every period m is set to match an aggregate LTV of 60% at the steady state. The housing preference parameter ξ is chosen to generate a ratio of household debt to GDP of 70% at the stochastic SS, the value in the year 2000.[16] The coupon rate $\gamma = 0.0188$ is chosen to match an effective mortgage duration of 4 years with prepayment taken into account.

The credit risk distribution F_t^b is assumed to be beta, with time-varying dispersion and a constant mean equal to 1. The distribution is thus characterized by a single time-varying parame-

[16]This might seem a relatively low number when compared to the value of household debt to GDP at the height of the housing boom, but this will be accounted for by the facts that household debt is strongly procyclical and the boom will be identified with an expansion in the quantitative exercise.

ter σ_t^b, which controls its dispersion (and the upper bound of the support). The beta assumption implies closed-form expressions for the distribution and partial expectation functions: $F_t^b(\nu_t^*) = \left[\sigma_t^b \nu_t^* / (\sigma_t^b + 1)\right]^{\sigma_t^b}$ and $\Psi_t^b(\nu_t^*) = 1 - \left[\sigma_t^b \nu_t^* / (\sigma_t^b + 1)\right]^{\sigma_t^b + 1}$. I assume that σ_t^b follows a two-state Markov chain, with a high- and a low-risk state, $\sigma_t^b \in \left\{\sigma^{b,\text{crisis}}, \sigma^{b,\text{normal}}\right\}$, where the low-risk state has a persistence of 0.99 and the high-risk state has a persistence of 0.90. This means that crises are infrequent but relatively persistent. The economy has an unconditional probability of 9.10% of being in a high-risk state. To choose the values of the states, I target a SS default rate of 0.5%, which is the average for the 2000-06 period. This yields $\sigma^{b,\text{normal}} = 2.93$. I set $\sigma^{b,\text{crisis}}$ to 30% of that value, which generates a default rate of 2%. These probabilities also imply that the economy spends, on average, two years in a financial crisis, consistent with the estimates by Jordà et al. (2016). Liquidation losses from mortgages are assumed to be equal to $\lambda^b = 0.30$ in the low-risk state and large $\lambda_h^b = 0.60$ in the high-risk state, which is in line with the evidence on loss-given-default rates for US bank secured loan portfolios (Ross and Shibut, 2015).

Fraction of Borrowers and Discount Factor Two crucial parameters are the fraction of borrowers χ and their discount factor β^b, which I pick to ensure that the model is able to replicate the estimates of Parker et al. (2013) of the impact of the 2008 Bush tax rebate on aggregate consumption. I choose χ, β^b to ensure that, given the state of the economy in 2008, a transfer to borrowers of the same magnitude as the tax rebates (relative to GDP) have the same impact on aggregate consumption: a 1.7% increase in the second quarter of 2008 and a 0.8% increase in the third. Setting $\chi = 0.45, \beta^b = 0.9946$ achieves the desired effect. The value for χ is broadly consistent with the fraction of borrowers estimated by other authors based on different datasets and targets. Broda and Parker (2014) estimate that around 40% of households in the US are liquidity constrained, based on Nielsen survey data, and Elenev et al. (2016) use several waves of the SCF to estimate that the fraction of the population with negative fixed-income positions is equal to 47%. The value for β^b is close to that of β^s and ensures that borrowers are unconstrained at the stochastic SS.

Banking The retained earnings parameter $\theta = 0.90$ and the transfer to starting banks $\varpi = 0.009$ are set to jointly match: (i) a net payout rate of 2.5%, consistent with the evidence in Baron (2020), and (ii) a mortgage lending spread of 2% at the stochastic SS. These values ensure that the bank constraint does not bind at the SS. The distribution for bank idiosyncratic shocks is a generalized beta with support $[\underline{u}, \bar{u}]$ given by $F^d(u) = (u^{\sigma^d} - \underline{u}^{\sigma^d})/(\bar{u}^{\sigma^d} - \underline{u}^{\sigma^d})$. I set $\sigma^d = 1, \underline{u} = 0.925, \bar{u} = 1.075$, which ensures that the mean asset quality shock is equal to 1, and that the probability of bank default is zero at the SS. Along with $\lambda^d = 0.10$, this distribution ensures that the spread between deposits and government bonds is close to 0.25% annualized, the average TED spread in the pre-crisis period, and that it rises to close to 2.00% at the peak of the crisis. The leverage constraint parameter is chosen to match a leverage ratio of around 10 for large US commercial banks, $\kappa = 0.1$.

3.2 Model Solution

One important object of the analysis in this paper is the state dependence of the effects of different fiscal policy tools. For this reason, traditional solution methods such as a first-order approximation around a deterministic SS are not sufficient. For example, credit guarantees have an impact mostly through precautionary motives, which would not adequately be captured by solution techniques that disregard higher-order terms. Furthermore, the model features two occasionally binding constraints that influence this state dependence. For this reason, higher-order approximation methods do not suffice either. To capture these nonlinearities and precautionary motives, I solve the model using a global solution method. In particular, I use a collocation-based method that combines time iteration with multilinear interpolation (Judd et al., 2002).

The occasionally binding constraints for the banks and the borrowers pose technical challenges. For this reason, I opt to use multilinear interpolation as opposed to global shape-preserving methods (such as higher-order splines or Chebyshev polynomials), as this method is more flexible at dealing with the strong nonlinearities that occur in the points of the state space where constraints start binding. The model is solved by discretizing the state space $\mathcal{S}_t$, approximating the minimal set of variables needed to compute the equilibrium in a functional space, and updating these approximated guesses using time iteration. The computational details of the solution method as well as robustness and accuracy checks regarding the numerical solution can be found in Appendix B.1. For reference,

Parameter	Description	Value	Target
		Standard Parameters	
β^s	Discount factor saver	0.9951	Annualized real interest rate of 2%
φ	Frisch elasticity	1	Standard
ε	Micro elasticity of substitution across varieties	6	20% markup in SS
η	Rotemberg Menu Cost	98.06	Prices adjusted once every five quarters
		Policy Parameters	
$\bar{G}$	SS Govt. Spending	$0.2 \times Y$	20% for the US
$\bar{B}^g$	SS Govt. Debt	$0.6 \times (4 \times Y)$	60% of Annual GDP, 2000-06 average
$\bar{\Pi}$	Trend Inflation	$1.02^{0.25}$	$2\%$for the US
ϕ_Π	Taylor rule: Inflation	2.5	Standard, inflation volatility
ϕ_Y	Taylor rule: Output	$0.5/4$	Standard
ϕ_τ	Fiscal rule	0.01	Leeper et al. (2010)
		Borrower Parameters	
χ	Fraction of borrowers	0.45	Response of consumption to ESA'08 in Parker et al. (2013)
β^b	Discount factor borrower	0.9946	Response of consumption to ESA'08 in Parker et al. (2013)
θ^{LTV}	Maximum LTV at origination	0.85	Greenwald (2016)
m	Fraction of movers	0.0537	Aggregate LTV of 60%, 2000-06 average
ξ	Housing preference	0.1109	Debt to GDP of 70%, 2000 value
σ^b	House quality distr.	2.9329	Annual default rate of 0.5%, 2000-06 average
λ^b	Loss given default	0.3	FDIC data
γ	Maturity of debt	0.0188	Effective mortgage maturity 4 yrs
		Banking Parameters	
θ	Retained earnings	0.9	Net payout rate of 2.5% (Baron, 2020)
κ	Leverage constraint	0.1	Book leverage of 10
ϖ	Transfer to new banks	0.009	Annual lending spread of 2%
λ^d	Liquidation costs	0.10	Annual TED spread of 0.12%
		Shock Parameters	
ρ_a	Persistence of TFP	0.9	Pre-crisis persistence of detrended consumption
σ_a	SD of TFP innovations	0.005	Pre-crisis volatility of detrended consumption
$\sigma^{b,\text{risky}}$	House quality during crises	0.879	Annual default rate of 2% during crises
$\lambda^{b,\text{risky}}$	Loss given default during crises	0.60	FDIC data
$\Pr(\text{crisis}_t \mid \text{crisis}_{t-1})$	Crisis persistence	0.90	Jordà et al. (2016)

Table 1: Summary of the calibration.

the full model features 11 state variables: bank deposits D_{t-1}, household debt B^b_{t-1}, government debt B^g_{t-1}, TFP A_t, risk shock σ^b_t, government spending G_t, transfers T^b_t, equity injections x^k_t, stock of government-owned equity s^k_{t-1}, new credit guarantees x^d_t, and stock of guarantees s^d_{t-1}.

4 Financial Crisis

A crisis in the model is a period of high credit risk, when $\sigma^b_t = \sigma^{b,\text{crisis}}$. This is an exogenous shock to borrower default risk: as the house quality distribution is hit by a mean-preserving spread, the default rate rises for the same level of household leverage ν^*_t. This causes immediate losses for banks through reduced debt repayments in the current period. Further losses are caused by a financial accelerator effect that arises from the interaction between the banks' leverage constraint and the fact that debt is long term. If current losses are large enough to make the banks' constraint bind, spreads rise further, which is achieved by falling prices of debt securities. Since debt is long term, this triggers capital losses. Banks may start defaulting, which further erodes bank capital by decreasing the price of deposits Q^d_t.

For borrower households, a financial crisis has offsetting effects on disposable income. On one hand, the rise in the number of defaults raises disposable income, since the household no longer has to pay part of its current debt. On the other hand, the supply of new credit may be disrupted for two reasons: first, a persistent credit risk shock raises borrowing rates; second, if bank losses are large enough to trigger the financial accelerator, the losses not only disrupt prices but also quantities of debt. Thus a financial crisis can result in no new debt being issued as bank capital is depleted. If the latter effect dominates the former, borrower consumption falls. If this fall is large enough, it may trigger a fall in aggregate demand, which in turn results in lower labor income and further reduces disposable income for the borrower. These effects are amplified whenever the borrower is constrained, since these will be the states when the borrowers' MPC is higher, and thus aggregate demand is more dependent on fluctuations of borrower consumption.

Figure 1 plots the behavior of the model around financial crises, starting from low- and high-

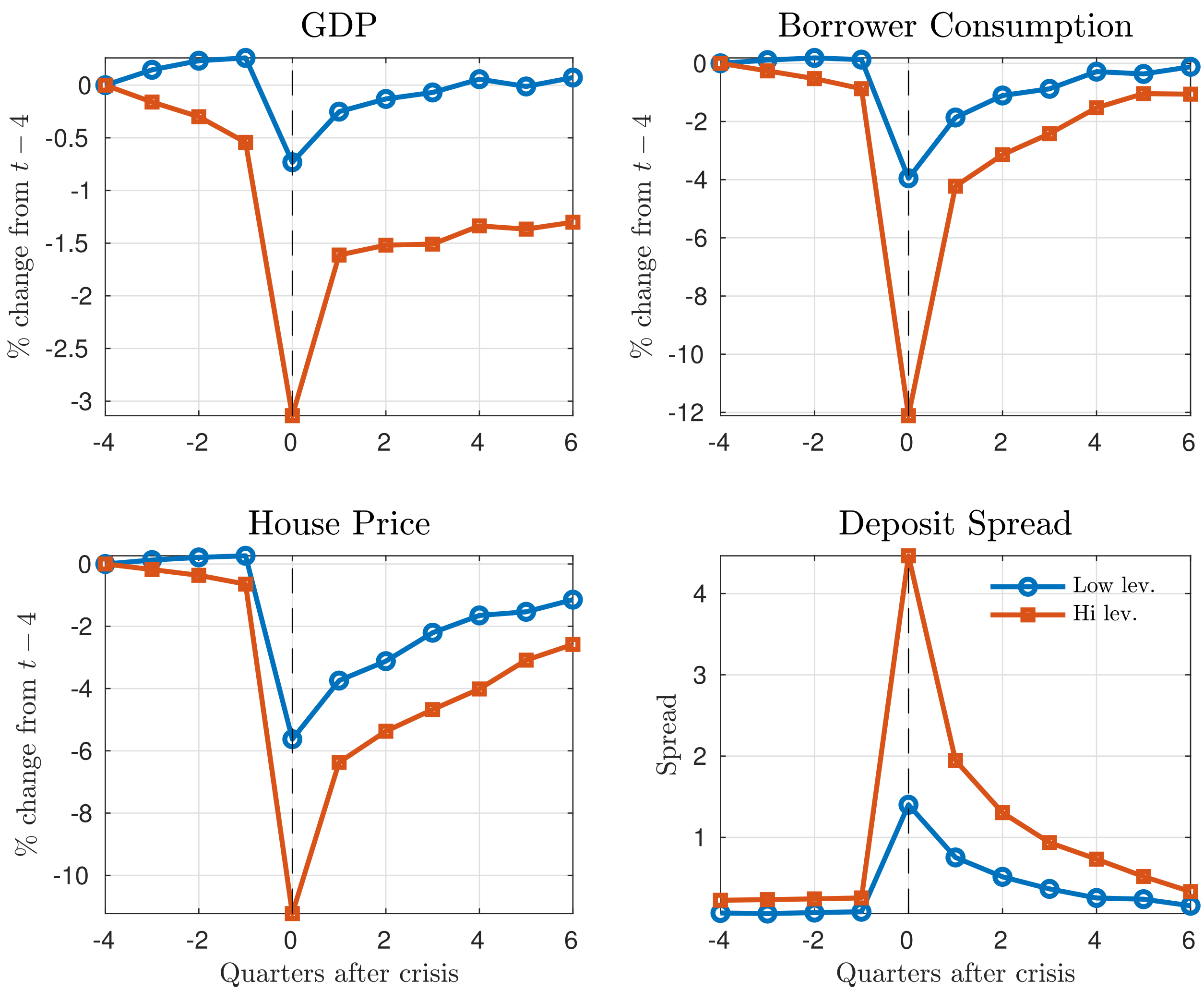


Figure 1: Typical financial crisis in low- and high-leverage states. The vertical axis measures variables in % deviations from their values at $t-4$, where t is the crisis shock period. Circles represent an economy with low starting leverage. Squares represent an economy with high starting leverage.

leverage states. To generate this figure, I simulate the model for a long number of periods and extract all sequences of periods where the economy enters a crisis. I then select all sequences where both household and bank leverage are below their 5th percentiles when the crisis event is triggered, and call these “low-leverage crises.” Similarly, I select all sequences where both household and bank leverage are above their 95th percentiles when the crisis event is triggered, and call these “high-leverage crises.”[17] The median path for low-leverage crises is shown as circles, while the median path for high-leverage crises is shown as squares. Low-leverage crises entail modest drops in GDP, borrower consumption, and house prices. These drops are much more significant when the crisis event is triggered and the economy is in a state of high leverage: since both bank and household leverage are procyclical, this will typically be the case after periods of TFP expansions.

In both cases, as the crisis shock hits, the default rate instantly jumps, generating portfolio losses for banks. If banks are away from their constraint — which happens when their leverage is low — their equity can absorb these losses without the constraint binding. This means that while credit spreads rise (due to a persistent increase in default risk), quantities of credit are not significantly affected. When leverage is high, however, the constraint binds, and while banks would like to lend more (as equilibrium returns are high), their constraint prevents them from doing so. If borrowers are away from their constraint, this should not have much of an impact, as they are at their Euler equation and should be able to smooth consumption. The problem arises when household leverage is also high and the LTV constraint starts binding. In this situation, borrowers behave as hand-to-mouth agents, and their consumption is determined by disposable income. The rise in credit spreads (fall in Q_t^b) and fall in the quantity of credit both contribute to reducing borrower disposable income, which is transmitted almost one-to-one to borrower consumption. This fall in borrower consumption amplifies the crisis: first, through the SDF, it makes house prices fall, which further tightens the LTV constraint; second, through aggregate demand externalities, it causes a fall in GDP and wages, which further depresses disposable income.

As a result, the effects of the financial shock on GDP, consumption, and house prices are greatly

[17] Bank leverage is defined as $\frac{D_{t-1}}{B_{t-1}^b}$, while household leverage is defined as $\frac{B_{t-1}^b}{p_t^h}$.

dependent on the state of the economy at the time of the shock, in particular on the levels of household and bank leverage. Crises that hit when leverage is high result in much deeper recessions as well as slower recoveries.

5 Fiscal Policy during the Great Recession

This section presents the main quantitative exercise of the paper. Using the model as a measurement device, I assess the effectiveness of US fiscal policy during the recent financial crisis and subsequent Great Recession. I first collect data on the different discretionary fiscal policies enacted by the US government during this period. Using these observed sequences of policies, I use a particle filter to estimate the sequences of structural shocks that allow the model to replicate the behavior of data observables. Importantly, these shocks are estimated by accounting for the model's endogenous responses to policy and so are truly invariant to fiscal policy. I then use these estimated shocks and the model to conduct counterfactual experiments.

5.1 Data and Measurement

The first step in the procedure is to use the structural model to measure the sequences of shocks experienced by the US economy during the financial crisis. The model admits two types of exogenous states: structural non-policy shocks $\mathcal{Z}_t \equiv (a_t, \sigma_t^b)$ and fiscal policy shocks $\Omega_t \equiv (G_t, T_t^b, x_t^k, x_t^d)$. I collect data on $\{\Omega_t\}_{t=0}^T$ directly and then estimate $\{\mathcal{Z}_t\}_{t=0}^T$ using the model and data. To this end, I use a particle filter. The procedure is equivalent to asking the following question: given the series of observed fiscal shocks, what are the sequences of non-policy shocks that allow the model to match the time series for the observables?

5.1.1 Standard Data Series

As observables, I use aggregate consumption and default rates on bank loans. The time period that I consider runs from 2000Q1 to 2015Q4. To validate the estimation exercise, I also compare the model-implied paths of bank credit spreads and house prices to the data.[18]

Since there is no investment in the model, I focus on matching the path of aggregate consumption instead of GDP. The path of aggregate consumption is informative of the path of TFP innovations. Real aggregate consumption net of housing is the data counterpart of $C_t = \chi C_t^b + (1-\chi)C_t^s$. I use quarterly personal consumption expenditures (PCE) from the Federal Reserve Bank of St. Louis FRED database (series code PCEC), subtract the housing component (DHSGRC0), and deflate the resulting series using the PCE price index (PCEPI). I detrend this series using the approach proposed by Hamilton (2018), which involves estimating the following OLS regression

$$\log C_{t+8} = \alpha + \sum_{i=0}^{4} \beta_i \log C_{t-i} + \epsilon_t^c \tag{11}$$

and obtain detrended consumption as $\hat{\epsilon}_t^c$.

The default rate in the model is the default rate conditional on the moving shock F_t^b times the fraction of agents that receive that shock, that is $\text{default}_t = \mathrm{m} \times F_t^b$. This series is chosen as an observable as it is relatively low and stable outside of financial crises. When the financial shock hits, the default rate can be subject to large jumps. For that reason, it contains useful information to identify the risk shock σ_t^b. I take a series on delinquency rates on bank loans from FRED (DRALACBS).

The credit spread in the model is simply the difference between the price of the one-period deposit and that of a risk-free bond, $\text{spread}_t^d = \log Q_t - \log Q_t^d$. Outside of financial crises, the credit risk of deposits is very low and their price mostly tracks the risk-free rate. When the financial shock hits, however, a wave of mortgage defaults can trigger large jumps in the deposit spread. The corresponding series in the data is the TED spread (TEDRATE), which consists of the spread between the 3-month LIBOR and the yield on the 3-month Treasury bill and is a common measure of bank funding costs.

Finally, house prices are detrended using the same method as aggregate consumption. I take the

[18]The data series for the observable and validation series (detrended consumption, default rates, TED spread, and detrended house prices) are plotted in Figure A.10 in Appendix F.

an all-transactions house price index for the US (USSTHPI), deflate it, and estimate a regression analogous to (11) on $\log(p_t)$, from where I obtain detrended house prices as $\hat{\epsilon}^p_t$.

5.1.2 Fiscal Policies

While the previous data series are standard, the mapping of observed fiscal measures onto the policies considered in the model requires some further work. I compile a list of discretionary fiscal policy measures undertaken by the US government during the Great Recession and map each of these into one of the model's policies. The general classification is based on the following criteria: G_t are policies that consist of direct purchases of goods and services by the government, also including goods that correspond to transfers in kind. T^b_t are policies that involve direct or indirect monetary transfers to households; tax rebates, cuts, and/or incentives; incentive payments and program funding directed at homeowners; and creditor relief and support. x^k_t are equity injections and transfers to the financial sector, even indirect ones. Lastly, x^d_t are credit and asset guarantees and emergency lending facilities aimed at the financial sector.

Most of the policies I focus on were implemented and funded directly by the US Treasury under one of the three large pieces of legislation concerning fiscal policy: the ESA of 2008 (February 2008, the "Bush stimulus"), the Housing and Economic Recovery Act of 2008 (HERA, July 2008), the Emergency Economic Stabilization Act of 2008 (October 2008, which included TARP), and the ARRA of 2009 (February 2009). Additionally, I consider policies enacted by independent government agencies and corporations for which the US Treasury is ultimately liable, such as the FDIC. Table 2 provides a summary of the policies considered.[19]

Mapping Fiscal Policy Data to the Model Panel (a) of Figure 2 plots the resulting data series, normalized by US GDP in 2007Q1. The vertical dashed line corresponds to 2008Q1, when Lehman Brothers failed. The bulk of traditional fiscal policy consisted of transfers, which exceeded 2% of GDP immediately before the failure (ESA tax rebates), as well as in the beginning of 2009 (ARRA programs). The magnitude of fiscal interventions in the financial sector, through equity injections

[19] Appendix D provides more detail on the data collection and construction procedure.

Instrument	Description	Policies	Sources	p_ω	ω^{crisis}
G/Y	Govt. purchases	ARRA: consumption expenditures, gross investment, transfers and grants to state and local governments including Medicaid and Education.	BEA	0.90	0.8%
T^b/Y	Transfers	ESA: tax rebates. HERA: home buying tax credits. ARRA: losses in current tax receipts (incl. Making Work Pay), current transfer payments (incl. unemployment extension), Cash for Clunkers, HOPE, Neighborhood Stabilization Program. TARP: Making Home Affordable (incl. HAMP), transfers to Federal Housing Agency, Hardest Hit Fund.	US Treasury, BEA	0.50	1.6%
x^k	Equity injections	TARP: Capital Purchase Program, Community Development Capital Initiative, Targeted Investment Program (BofA and Citi), Systemically Significant Failing Institutions Program (AIG), bailout of Fannie Mae and Freddie Mac, Public-Private Investment Program, Automotive Industry Financing Program (Chrysler & GM), Auto Supplier Support Program, Treasury MBS purchase program.	US Treasury	0.50	17.9%
x^d	Guarantees	TARP: Asset Guarantee Program, Term Asset-Backed Securities Loan Facility, Small Business Credit Liquidity Initiative, Treasury MMF Guarantees. FDIC: Temporary Liquidity Guarantee Program.	US Treasury, FDIC, FRB	0.50	13.3%

Table 2: Summary of fiscal policies considered and maximum likelihood estimates for the fiscal shock processes. Underlined acronyms stand for the umbrella programs: ARRA is the American Recovery and Reinvestment Act of 2009, ESA is the Economic Stabilization Act of 2008, HERA is the Housing and Economic Recovery Act of 2008, TARP is the Troubled Asset Relief Program of 2008. See Appendix D for the details on data collection and estimation.

and asset guarantees, exceeded that of traditional fiscal policy. Equity injections reached 8% of GDP in 2008Q4, as the CPP of TARP was implemented. The value of debt guaranteed by the government almost reached 4% of GDP by the end of 2009.

In order to map these series to the model, I target the size of the interventions relative to (stochastic SS) GDP. For government spending and transfers this is straightforward. For equity injections and credit guarantees, I extract series for (x_t^k, x_t^d) that correspond to the same amount of effective and potential outlays as a percentage of GDP as observed in the data.[20]

Throughout, I treat fiscal policies as exogenous shocks, as is standard in the macroeconomics literature. An analysis of optimal fiscal policy is beyond the scope of this paper.[21] I model discretionary policies as low-probability, transitory shocks. Letting each policy instrument by $\omega_t \in \{G_t, T_t^b, x_t^k, x_t^d\} \equiv \Omega_t$, I assume that ω_t follows a two-state Markov chain with state vector $\{\omega^{\text{normal}}, \omega^{\text{crisis}}\}$ where the normal state has persistence equal to 0.99 and the crisis state has persistence equal to $p_\omega \in [0, 1]$.

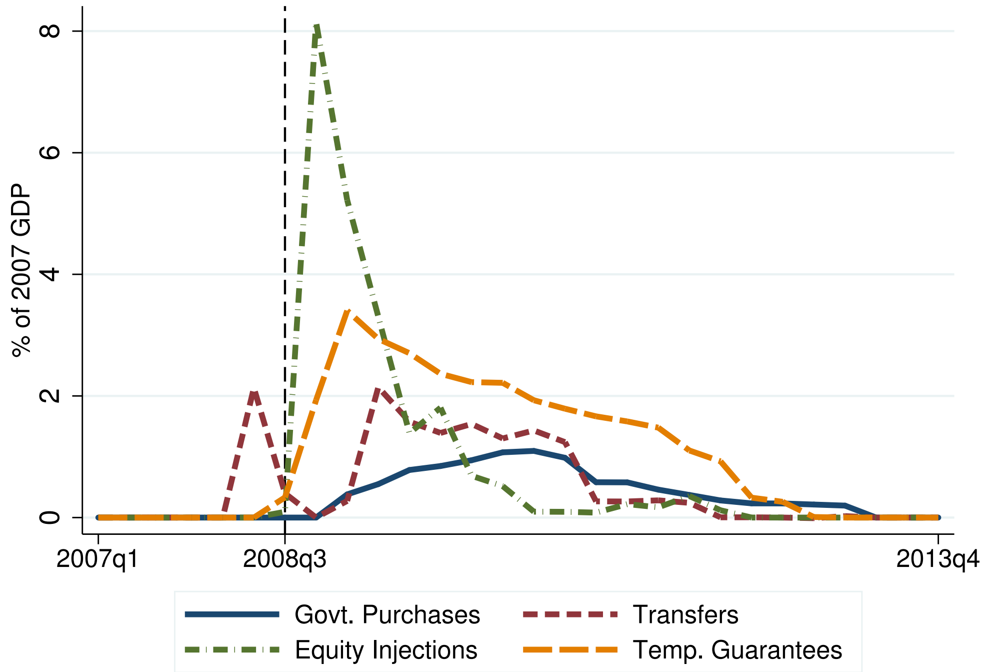
The normal state is equal to $\bar{G}$ for government spending and zero for all other instruments. The crisis state is set to be of a magnitude equivalent to the size of the interventions conducted by the US government during the Great Recession. While stark, this structure captures the essence that crisis policies are both unlikely and transitory.

I estimate $(\omega^{\text{crisis}}, p_\omega)$ using maximum likelihood as the parameters of a hidden Markov model as in Hamilton (1989) over the sample period 2000Q1-2015Q4. Since my sample period is short and does not include any other financial crises, I exogenously calibrate the probability of the policy being activated and estimate the probability of exiting the policy regime. The resulting estimates are in the last two columns of Table 2.[22] Finally, I use the estimated/measured series (x_t^k, s_t^k) as

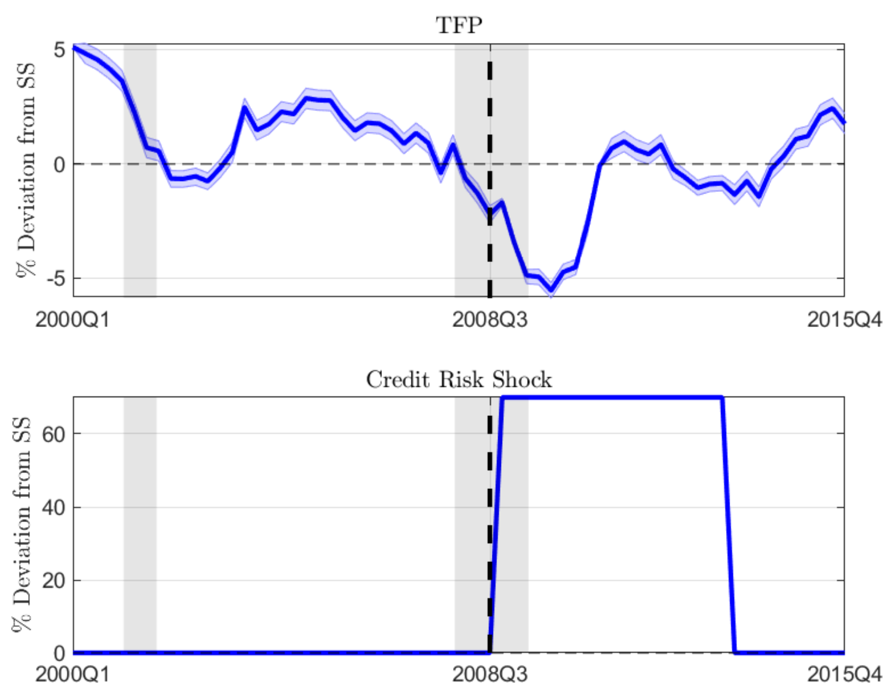
[20] For equity injections, I assume that the observed data series measure $y_t^k = x_t^k \theta E_{ss}/Y_{ss}$ and obtain x_t^k by inverting that expression. For credit guarantees, I assume that the measured series is $y_t^d = s_t^d D_{ss}/Y_{ss}$ and compute x_t^d after estimating s_t^d.

[21] In the baseline exercise, fiscal policies are assumed to be purely exogenous shocks that do not follow fiscal rules. I make this assumption for several reasons. First and foremost, I do so for simplicity, as this assumption allows me to better distill the effects of a purely exogenous perturbation in the economy. Second, this paper is about the effects of discretionary fiscal policies, which are typically less expected and likely to follow fiscal rules in the same manner as automatic stabilizers do. See Appendix E.2 for an extension of the model with endogenous fiscal policy rules.

[22] A detailed description of the procedure can be found in Appendix D.2. Figure A.6 in the appendix plots the time series for each policy along with the discretized counterparts. Appendix C analyzes the response of the economy to



(a) Discretionary fiscal policy measures enacted during the Great Recession, normalized by 2007Q1 GDP. Sources: BEA, US Treasury, FDIC, own calculations. Note: plotted here are the series for G, T^b, x^k, s^d. That is, the stock of credit guarantees as opposed to the fiscal shock.



(b) Filtered series for the medians of the structural shocks, along with 90% confidence intervals.

Figure 2: Data fiscal policy series and estimated shock sequences.

well as (x_t^d, s_t^d) to estimate the rate of decay of the stocks of financial sector interventions. This yields $\theta^k = 0.942$ and $\theta^d = 0.913$.

5.1.3 Measuring the Structural Shocks

Armed with sequences of policies and the calibrated model, I use a particle filter as in Fernández-Villaverde and Rubio-Ramírez (2007) to extract sequences of conditional densities for the structural shocks that allow the model to match the observed paths for aggregate consumption and default rates. Intuitively, the filter allows me to "invert" the model and generate the series of TFP and credit risk shocks, $\{\mathcal{Z}_t\}_{t=0}^T$, that allow the model to replicate $\{C_t, \text{default}_t\}_{t=0}^T$, given $\{\Omega_t\}_{t=0}^T$. [23]

Crucially, since these shocks are measured by taking into account the endogenous response of the model's variables to the fiscal policy shocks, they are the appropriate sequences of shocks for studying fiscal policy counterfactuals. The filter does not generate a single sequence for the structural shocks, but rather a sequence of densities conditional on the observables. Letting $Y^T \equiv \{C_t, \text{default}_t, \Omega_t\}_{t=0}^T$ stand for the sequence of observables, the particle filter estimates $\{p(\mathcal{Z}_t|Y^T\}_{t=0}^T$, that is, the best guess for the distribution of the structural shocks at each point in the sample given *all* information available over the entire sample. Since the output of the filter is a distribution, it allows us to compute statistics and generate confidence intervals.

Panel (b) of Figure 2 plots the median of the filtered densities for the shocks along with 90% confidence intervals for the TFP shock. As expected, there are no significant exogenous movements in credit risk prior to the financial crisis. The filter extracts positive credit risk starting at the end of 2008, around the time of the Lehman shock. The overall path of the implied TFP series is very similar to that of aggregate consumption by construction: besides the fiscal policies, which I assume to be shocks that are observed without measurement error, the filter and the model can only fit consumption and the default rate using two shocks. The only significant large movement in

each policy shock in isolation.

[23] Since the model is nonlinear and one of the shocks is a discrete random variable, there does not exist (generically) a combination of shocks that generates the outcomes in the data. This is why a filter with measurement error is needed and a standard "inversion" is impossible without further assumptions. The technical and computational details for the particle filter procedure are described in Appendix B.3.

defaults takes place around the financial crisis, and this identifies the credit risk shock. All other variation, which includes all fluctuations in consumption before and after the Great Recession and which is not attributable to the fiscal policy shock series, must therefore be absorbed by movements in TFP.

The top panels of Figure 3 plot the paths of filtered consumption and default rates vs. the data. Since we are trying to match two continuous observables with one continuous and one discrete shock, the match for the default rates is not perfect, but the estimation procedure captures the broad movements in this variable. The bottom panels of Figure 3 plot the paths of filtered credit spreads and house prices, two untargeted series, vs. the data. The model does a relatively good job in capturing the level of credit spreads, as well as the large spike in 2008. It is also able to capture the large collapse in house prices during the crisis and subsequent recovery, even though it fails to account for the large increase in the period leading to the recession.[24]

5.2 Counterfactual: No Fiscal Policy

Given the estimated/observed sequences of shocks, $\{\mathcal{Z}_t, \Omega_t\}_{t=0}^{T}$, we can now ask the following question: what would the Great Recession have looked like in the absence of a fiscal policy response? Generically, the model maps $\{\mathcal{Z}_t, \Omega_t\}_{t=0}^{T}$ and a set of initial conditions for the endogenous states X_0 into a sequence of endogenous variables $Y^T = f(\{\mathcal{Z}_t, \Omega_t\}_{t=0}^{T}, X_0)$. Since the particle filter retrieves estimates for $(\{\mathcal{Z}\}_{t=0}^{T}, X_0)$, we can evaluate the counterfactual path of endogenous variables $Y^{T,\text{CF}}$ by setting $\Omega_t = \Omega^{\text{normal}}, \forall t \geq 0$.

Panel (a) of Figure 4 plots the baseline path for consumption and credit spreads (with policy, and thus matching the data) versus the model-implied no fiscal policy counterfactual. The plots run from 2007 to the end of 2013, a period during which most of the policies were active (the baseline and the counterfactual are exactly the same before any policy is active, by construction). The first panel of the figure displays the main result of the paper, which is that aggregate consumption

[24]The model is very simple when it comes to the housing market and abstracts from a number of features that have been shown to be important to account for realistic movements in house prices as in (Kaplan et al., 2020).

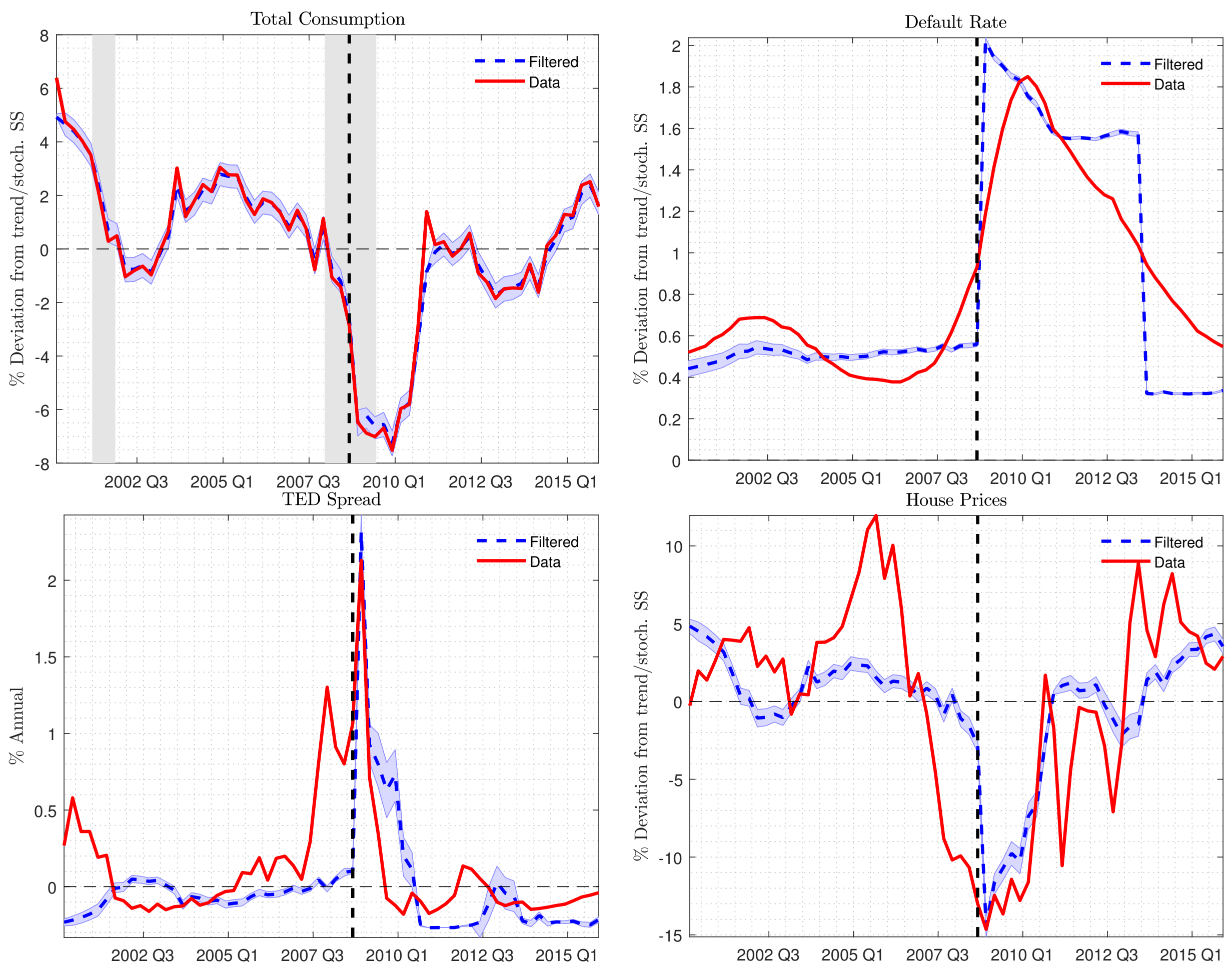
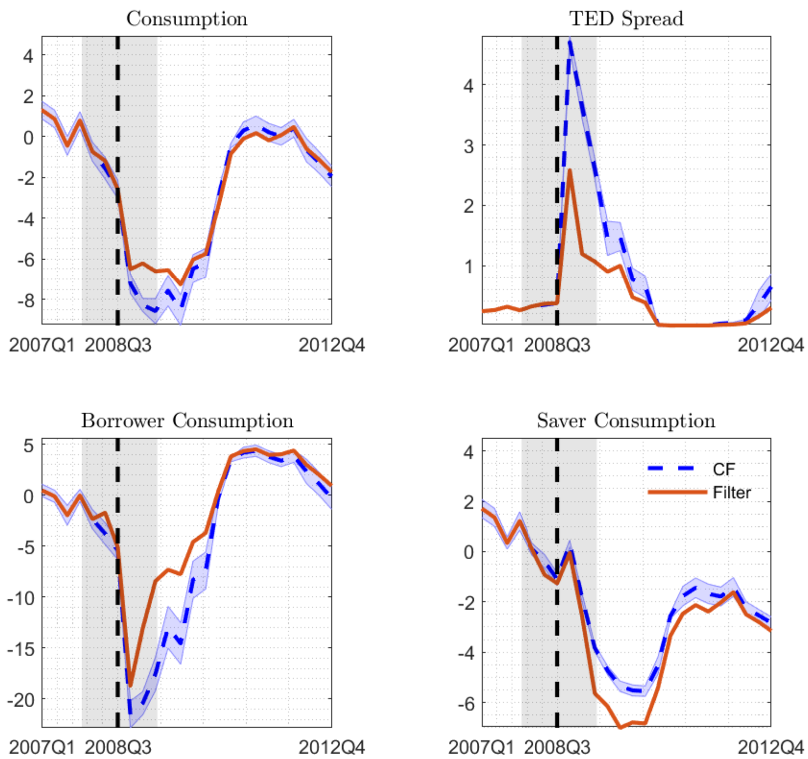
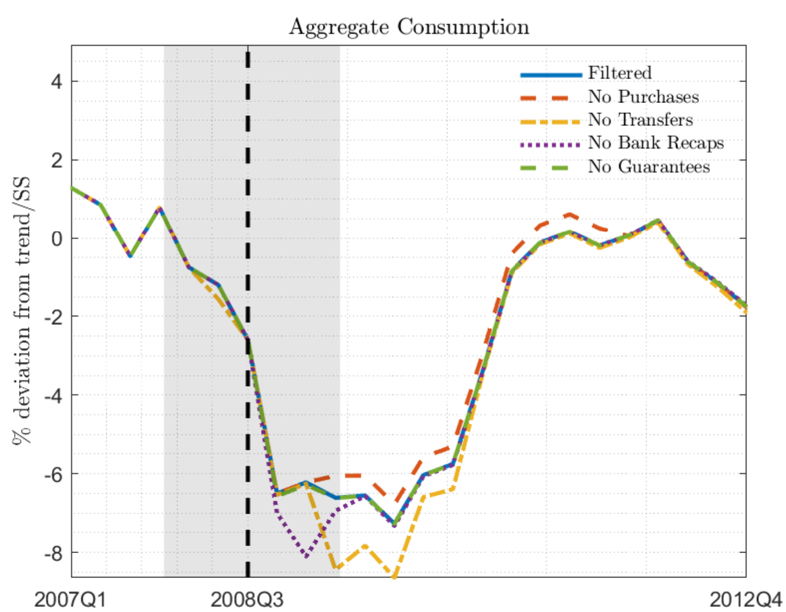


Figure 3: Estimated paths for observables and validation series vs. data.



(a) Baseline sequences (solid orange) vs. no fiscal policy counterfactuals (dashed blue).



(b) Counterfactual decomposition for the path of aggregate consumption.

Figure 4: Counterfactual decomposition exercises.

would have fallen by one-third more in the absence of fiscal policy during the year 2009. That is, instead of falling to 6% below trend, it would have fallen to over 8%. The cumulative loss for this period (2007Q1 - 2013Q4) of no fiscal policy response is 7.18%, or $ 604.4 billion of aggregate consumption.[25] The recovery, however, would have been faster due to general equilibrium forces: while fiscal policy moderates the crisis, agents internalize the burden of future taxes, slowing the recovery. The second panel shows that the TED spread would have been significantly higher after Lehman in the absence of a policy response: over 4% instead of 2.5%, almost 50% higher. The remaining two panels decompose the movements of aggregate consumption between borrowers and savers, and show how most of the effect of fiscal policy on aggregate consumption can be attributed to the stabilizing effects of the ESA, TARP, and ARRA, which helped sustain borrower consumption right before Lehman (2008 ESA), and allowing for a faster recovery of borrower consumption in 2009 (TARP and the ARRA). The final panel shows that the ESA and the ARRA essentially acted as a transfer from savers to borrowers: since they are not constrained, savers are Ricardian in the sense that they internalize future taxes that are associated with the fiscal interventions.

5.3 Decomposition: Which Policies Mattered the Most?

A natural extension of the main counterfactual exercise is to deactivate one type of policy at a time, which allows us to understand the relative contribution of each of these tools. Panel (b) of Figure 4 plots aggregate consumption in the full policy benchmark (which coincides with the data) as well as the path of aggregate consumption that is obtained by shutting off one policy at a time. The figure shows that, by far, bank recapitalizations and transfers were the most important of the fiscal policy stabilization tools during the Great Recession. Notice that, due to the nonlinear nature of the model, there is not a linear map between turning off one policy at a time and turning off *all* policies. The reason is that the effects of these policies interact and can cancel each other. Credit guarantees

[25]The "Okun gap" reported here is a back-of-the-envelope calculation that corresponds to the integral of the difference in the paths of the baseline and counterfactual lines for consumption over the 2007Q1-2013Q4 period. The dollar value is obtained by multiplying that integral by the dollar value of nominal PCE net of housing in 2007Q4. This is the full integral which also accounts for when the counterfactual rises above the baseline.

also had a positive effect, albeit small and not clearly visible in the figure. Government purchases seem to have had a negative impact overall, and consumption would have recovered faster in their absence: this is equivalent to saying that the multiplier of government purchases is smaller than 1, as it crowded out private consumption even during the crisis.

5.4 Fiscal Multipliers during the Great Recession (and beyond)

The nonlinear nature of the model as well as the fact that the effects of fiscal policy depend on the current state of the economy make the definition of the multiplier nontrivial. In this model, the fiscal multiplier is not a number, but rather a function of the states of the economy $\mathcal{M}^{\omega}(\mathcal{S}_t)$. Throughout, I focus on long-term discounted multipliers as defined in Mountford and Uhlig (2009):

$$\mathcal{M}_T^{\omega}(\mathbb{S}_t) = \frac{\sum_{t=0}^{T} \prod_{j=1}^{t} Q_j \left(\text{GDP}_t^{\text{Stimulus}} - \text{GDP}_t^{\text{No Stimulus}}\right)}{\sum_{t=0}^{T} \prod_{j=1}^{t} Q_j \left(\text{Spending}_t^{\text{Stimulus}} - \text{Spending}_t^{\text{No Stimulus}}\right)} \tag{12}$$

where Spending is defined as the left-hand side of the government budget constraint in (10). This definition of the multiplier measures the dollar impact on GDP per dollar of (net) fiscal spending, taking into account the discounted future path of the endogenous variables, and thus potentially allowing the fiscal multiplier to account for the effects of future financing of current spending. While an increase in government purchases can have a stabilizing impact in the short run, the increased tax burden may depress demand in the long run, a factor emphasized by Drautzburg and Uhlig (2015) in their analysis of the ARRA stimulus. Other policies may have delayed effects that would not be fully captured by measuring only the response of the variables on impact (i.e., productive public investment, not considered in this paper). By taking into account the paths of both GDP and spending over T periods, the long-run multiplier addresses these concerns while using the risk-free interest rate to discount future outcomes.[26]

Since the model is nonlinear, the impact of fiscal policy depends on the state of the economy. Different fiscal policy tools can have a larger or smaller impact over time, depending on the com-

[26] Since it is not obvious which interest rate should be used to discount future periods in this context, I use the interest rate at the stochastic SS, but the results are qualitatively robust to this choice.

bination of states experienced by the US economy at each point in time. These multipliers are straightforward to compute given knowledge of these states, which is provided by the particle filter. Figure 5 plots fiscal multipliers for each policy tool over time, with T set to 20 quarters. For a given policy, these multipliers are computed either by activating that policy if non-active in that period, or by deactivating it if active.[27] This analysis is conducted for impulses of the magnitudes estimated in the previous subsection, using the observed fiscal policy response during the financial crisis. This is important to the extent that these multipliers are also size dependent.

The figure shows considerable variation over time, showing that the state of the economy is crucial for the effectiveness of fiscal policy.[28] Multipliers for transfers, recapitalizations, and guarantees rise considerably during the financial crisis and tend to be relatively low during other periods. The government purchases multiplier fluctuates around 0.6, rising at the onset of the crisis. The transfer multiplier is typically lower than the purchases multiplier and close to zero during expansion periods, but it rises considerably during the crisis, to 1.5, which is consistent with the large role of transfers for stabilization. Recapitalizations also have multipliers that are typically low but rise to over 1.4 during the crisis. The multiplier for credit guarantees follows a similar pattern, as the effectiveness of these two policies is directly related to the tightness of the banks' leverage constraint. This policy yields a very large multiplier, over 2. These facts provide further evidence on the stabilizing role of these three fiscal policy tools during the financial crisis.

The "normal-times" estimates for the spending and transfer multipliers are in line with the literature, specifically the fact that transfers are typically a less effective form of fiscal stimulus even when targeted (Oh and Reis, 2012).[29] One of the contributions of this paper is to compute fiscal multipliers for financial sector interventions. There are not many estimates for the aggregate effects of these policies, which complicates external validation. Veronesi and Zingales (2010) estimate that

[27] These multipliers are ex-post in the sense that they are computed given an estimated sequence of shocks for the US economy. Appendix E.5 discusses ex-ante measures of fiscal multipliers that account for uncertainty regarding future states of the economy.

[28] Sims and Wolff (2018) conduct a similar exercise, using a second-order approximation of a canonical New Keynesian model and focusing on output and welfare multipliers of government purchases.

[29] This is in spite of the fact that this model does not include many of the traditional channels of transmission for government consumption.

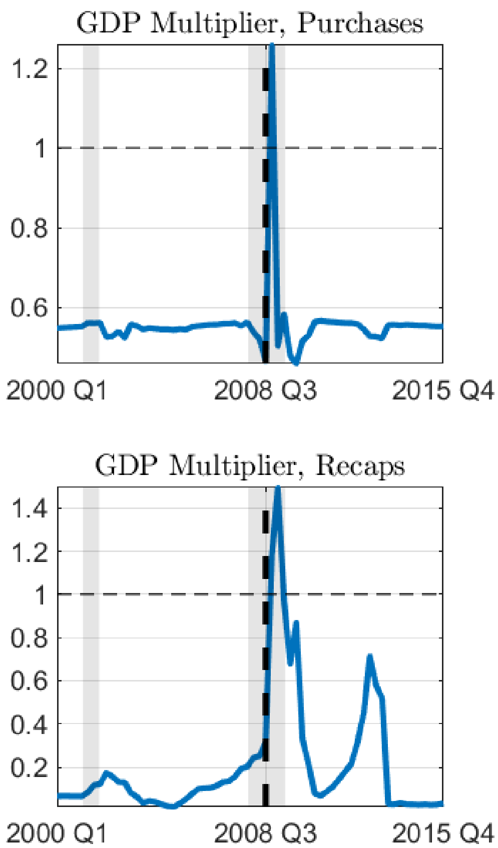


Figure 5: Estimated time series for fiscal multipliers, 20-quarter horizon. See text for details.

the CPP component of TARP raised the value of bank financial claims by \$130 billion, generating a net benefit of \$86-109 billion. In a similar back-of-the-envelope calculation, I find that the increase in the value of bank equity (including preferred) in 2008Q4, relative to the no policy counterfactual, corresponds to 1.78% of steady state consumption, or \$149.84 billion using again as reference the value of PCE consumption in 2007Q1. The value is of the same order of magnitude and slightly higher, as I consider other programs beyond the CPP.

Why were Transfers, Recaps, and Guarantees so Effective? The previous analysis highlights the extent to which the effectiveness of fiscal policy is state dependent: both transfers and bank recapitalizations were extremely effective at the height of the financial crisis but had limited effects in other periods. This is due to a new transmission channel for fiscal policy that arises from stronger linkages between household and bank balance sheets in times when the respective constraints bind.

Let us consider the case of transfers. When the LTV constraint binds, and only when it does, an extra dollar in transfers has a direct effect on borrower consumption and, therefore, a first-order effect on the borrower's SDF. Through consumption and the SDF, transfers help sustain house prices. This, in turn, contributes to reducing leverage directly and reducing default rates. A reduction in default rates results in more profits and helps relax the bank's leverage constraint, if it binds. In this case, by relaxing the constraint, it induces the bank to extend more credit, and at lower spreads. These two effects have a direct and positive impact on borrower disposable income, which in turn helps sustain both borrower and aggregate consumption. Bank recapitalizations — either directly through equity injections or indirectly through credit guarantees — work in a similar way but attack a different element of the cycle described above: by relaxing banks' constraints, they induce more credit at lower spreads, raising disposable income and consumption and lowering defaults. Importantly, this transmission channel requires *both* constraints to bind at the same time and will be weakened if either constraint does not bind. That is why these policies were so effective during the Great Recession but display very low multipliers in other times.[30]

[30]The estimated paths for the Lagrange multipliers are shown in Appendix F.

5.5 Discussion

ZLB As explained in section 2.1.8, the model does not explicitly include a ZLB or UMP. The presence of the ZLB is likely to affect the model estimates in several different ways; I focus on two potential mechanisms that both suggest that I may be underestimating the effects of fiscal policy. First, I am allowing the policy rate to go negative, which further stimulates private expenditure through the usual transmission channel, and therefore means that the recession is not as severe as it would be in the presence of a ZLB. Given that the effects of fiscal policy are state-dependent and larger during recessions, when constraints are likely to bind, by underestimating the magnitude of the recession, I should also be underestimating the effects of fiscal policy. Second, this also means that the CB will be actively responding to inflationary pressures caused by fiscal policy even when interest rates are negative (whereas it would be inactive with a ZLB). This increased activism contributes to offsetting the expansionary effects of fiscal policy. In summary, the absence of the ZLB (i) causes a milder recession and (ii) results in a more active CB, both of which contribute to underestimating fiscal multipliers.

The filtered series for the FFR becomes negative in 2008Q4, with the policy rate falling from 4% to -1.4%. Given the absence of interest rate smoothing, changes in the rate are more abrupt but qualitatively follow what is observed in the data. The estimates in Wu and Xia (2016) show that the shadow FFR becomes negative in July 2009, breaks -1.4% in mid-2011, and remains negative through the end of 2015. The filtered series for the FFR rebound more quickly. This is due to the simplicity of the policy rule, which is not able to account for factors such as forward guidance. This is compounded by the fact that the negative TFP shock is inflationary, as is standard in this class of models. Along with the above discussion regarding the ZLB, all of this suggests that I may be underestimating fiscal multipliers due to an overactive CB.[31]

[31] Appendix E.4 repeats the baseline exercise for different parametrizations of the Taylor rule. I show that raising the coefficient on inflation and/or output contributes to making the crisis smaller and shorter and reduces the size of the estimated fiscal multipliers. This is to be expected, as the financial crisis manifests itself as a demand recession whose effects can be offset by a more active and unconstrained CB.

Private Investment and Physical Capital The absence of nonresidential investment and physical capital in the model may matter for the transmission of fiscal policy. Contrary to other models (Gertler and Karadi, 2011; Iacoviello, 2015), the financial sector does not intermediate capital between households and firms, but rather between different types of households. This means that I abstract from the effects of financial sector disruptions on the accumulation of physical capital, which can have prolonged effects on output. The absence of this channel means that I could be underestimating the effects of fiscal policy, as I do not account for the fact that the recapitalization of the financial sector can lead to a faster recovery of investment during a recession, and hence to a lower decrease in the economy's stock of physical capital. On the other hand, as shown by Drautzburg and Uhlig (2015), the increase in public debt raises real interest rates, which can crowd out private investment and means that I could be overestimating multipliers.

Moral Hazard and Endogenous Policy Rules One cost of fiscal policies that is not fully accounted for by fiscal multipliers comes from thow expectation of intervention alters behavior: the commitment to bailouts may generate moral hazard and induce more risk-taking (Farhi and Tirole, 2012). The fact that agents anticipate fiscal interventions with a certain probability does generate some moral hazard in the baseline economy. Compared to an economy with no fiscal policy shocks, the stochastic SS of the baseline economy features more leverage and higher credit spreads (both for banks and borrowers). Moral hazard is amplified in an economy with endogenous policy rules, where policy activation is more likely in the crisis state. This endogenous policy economy features even larger levels of leverage, debt to GDP, default, and spreads at the stochastic SS than the baseline.[32]

Robustness Appendix E considers other variations of the baseline model, such as equal transfers to both households and alternative parametrizations of the Taylor and tax rules. Overall, the main results are qualitatively robust.

[32] See Appendix E.2 for details on the endogenous policy economy and for a comparison of the stochastic SSs for the three economies.

6 Conclusion

This paper develops a model of fiscal policy that allows for a comprehensive assessment of the policy response to the 2008 financial crisis and subsequent Great Recession in the US. Importantly, it explicitly models the relationship between the balance sheets and constraints faced by the household and financial sectors. It contributes to the existing literature on fiscal policy along two dimensions: (i) it allows for the analysis of the spillovers of conventional fiscal policy through the financial system, identifying new transmission channels, and (ii) it allows for the analysis of fiscal policy tools that affect the financial sector directly. In particular, I show how the interaction between borrower and bank balance sheets augment traditional Keynesian effects of fiscal policy.

The nonlinear solution of the model captures the fact that the effects of different fiscal policies vary with the state of the economy, and I show that this state dependence is very important in a quantitative application. Policies such as transfers, bank recapitalizations, and credit guarantees generate very low fiscal multipliers during normal times but very high positive ones when financial intermediation is constrained and aggregate demand is depressed. Using the model as a measurement device, I estimate distributions for policy-invariant structural shocks, which allow me to conduct counterfactual exercises. I find that transfers and bank recapitalizations were crucial to sustaining aggregate consumption in 2008 and 2009.

The present work abstracts from other important policy interventions that occurred during this period, namely the Fed's quasi-fiscal unconventional policies and Dodd-Frank's overhaul of financial regulation. Incorporating these would require a more detailed modeling of the monetary authority and the financial system, respectively, both of which are beyond the scope of this paper. The current analysis also does not consider the ZLB, which, as discussed, may mean that the true effects of fiscal policy are underestimated. I leave all these as avenues for future research.

References

Auerbach, A. J. and Y. Gorodnichenko (2012): "Measuring the Output Responses to Fiscal Policy," *American Economic Journal: Economic Policy*, 4, 1–27.

Baron, M. (2020): "Countercyclical Bank Equity Issuance," *The Review of Financial Studies*, 33, 4186–4230.

Bianchi, J. (2016): "Efficient Bailouts?" *American Economic Review*, 106, 3607–59.

Broda, C. and J. A. Parker (2014): "The Economic Stimulus Payments of 2008 and the aggregate demand for consumption," *Journal of Monetary Economics*, 68, S20–S36.

Campbell, J. Y. and N. G. Mankiw (1989): "Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence," *NBER Macroeconomics Annual 1989*, 4, 185–246.

Canzoneri, M., F. Collard, H. Dellas, and B. Diba (2016): "Fiscal Multipliers in Recessions," *The Economic Journal*, 126, 75–108.

Christiano, L., M. Eichenbaum, and S. Rebelo (2011): "When Is the Government Spending Multiplier Large?" *Journal of Political Economy*, 119, 78 – 121.

Debortoli, D. and J. Gali (2017): "Monetary Policy with Heterogeneous Agents: Insights from TANK models," CREI.

Drautzburg, T. and H. Uhlig (2015): "Fiscal Stimulus and Distortionary Taxation," *Review of Economic Dynamics*, 18, 894–920.

Elenev, V., T. Landvoigt, and S. Van Nieuwerburgh (2016): "Phasing out the GSEs," *Journal of Monetary Economics*, 81, 111–132.

Farhi, E. and J. Tirole (2012): "Collective Moral Hazard, Maturity Mismatch, and Systemic Bailouts," *American Economic Review*, 102, 60–93.

Fernández-Villaverde, J. and J. F. Rubio-Ramírez (2007): "Estimating Macroeconomic Models: A Likelihood Approach," *Review of Economic Studies*, 74, 1059–1087.

Ferrante, F. (2019): "Risky lending, bank leverage and unconventional monetary policy," *Journal of Monetary Economics*, 101, 100–127.

Galí, J., J. D. López-Salido, and J. Vallés (2007): "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, 5, 227–270.

Geithner, T. F. (2015): *Stress Test: Reflections on Financial Crises*, Broadway Books.

Gertler, M. and P. Karadi (2011): "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58, 17–34.

Greenwald, D. (2016): "The Mortgage Credit Channel of Macroeconomic Transmission," 2016 Meeting Papers 1551, Society for Economic Dynamics.

Hamilton, J. D. (1989): "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," *Econometrica*, 57, 357–84.

——— (2018): "Why you should never use the Hodrick-Prescott filter," *The Review of Economics and Statistics*, 100, 831–843.

Iacoviello, M. (2015): "Financial Business Cycles," *Review of Economic Dynamics*, 18, 140–164.

Jeanne, O. and A. Korinek (2020): "Macroprudential Regulation versus mopping up after the crash," *Review of Economic Studies*, 87, 1470–1497.

Jordà, O., M. Schularick, and A. M. Taylor (2016): "The great mortgaging: housing finance, crises and business cycles," *Economic Policy*, 31, 107–152.

Judd, K., F. Kubler, and K. Schmedders (2002): "A solution method for incomplete asset markets with heterogeneous agents," Available at SSRN.

Kaplan, G., K. Mitman, and G. L. Violante (2020): "The Housing Boom and Bust: Model Meets Evidence," *Journal of Political Economy*, 128, 3285–3345.

Kaplan, G. and G. L. Violante (2014): "A Model of the Consumption Response to Fiscal Stimulus Payments," *Econometrica*, 82, 1199–1239.

Kollmann, R., M. Ratto, W. Roeger, and J. in't Veld (2013): "Fiscal policy, banks and the financial crisis," *Journal of Economic Dynamics and Control*, 37, 387–403.

Landvoigt, T. (2016): "Financial Intermediation, Credit Risk, and Credit Supply during the Housing Boom," Unpublished, available at SSRN.

Leeper, E. M., M. Plante, and N. Traum (2010): "Dynamics of fiscal financing in the United States," *Journal of Econometrics*, 156, 304–321.

Lindé, J. and M. Trabandt (2018): "Should we use linearized models to calculate fiscal multipliers?" *Journal of Applied Econometrics*, 33, 937–965.

Lucas, D. (2016): "Credit Policy as Fiscal Policy," *Brookings Papers on Economic Activity*, 52, 1–57.

Mian, A. and A. Sufi (2014): *House of Debt: How They (and You) Caused the Great Recession, and How We Can Prevent It from Happening Again*, The University of Chicago Press.

Mountford, A. and H. Uhlig (2009): "What are the effects of fiscal policy shocks?" *Journal of Applied Econometrics*, 24, 960–992.

Oh, H. and R. Reis (2012): "Targeted transfers and the fiscal response to the great recession," *Journal of Monetary Economics*, 59, S50–S64.

Parker, J. A., N. S. Souleles, D. S. Johnson, and R. McClelland (2013): "Consumer Spending and the Economic Stimulus Payments of 2008," *American Economic Review*, 103, 2530–53.

Philippon, T. (2010): "Debt Overhang and Recapitalization in Closed and Open Economies," *IMF Economic Review*, 58, 157–178.

Ramey, V. A. and S. Zubairy (2018): "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data," *Journal of Political Economy*, 126, 850–901.

Ross, E. J. and L. Shibut (2015): "What Drives Loss Given Default? Evidence from Commercial Real Estate Loans at Failed Banks," FDIC CFR WP 2015-03, Federal Deposit Insurance Corporation.

Sims, E. and J. Wolff (2018): "The Output And Welfare Effects Of Government Spending Shocks Over The Business Cycle," *International Economic Review*, 59, 1403–1435.

Veronesi, P. and L. Zingales (2010): "Paulson's gift," *Journal of Financial Economics*, 97, 339–368.

Wu, J. C. and F. D. Xia (2016): "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," *Journal of Money, Credit and Banking*, 48, 253–291.

A Model Appendix

A.1 Full List of Model Conditions

Savers:

$$Q_t = \mathbb{E}_t\left(\frac{\Lambda^s_{t+1}}{\Pi_{t+1}}\right) \tag{1}$$

$$Q^d_t = \mathbb{E}_t\left(\frac{\Lambda^s_{t+1}}{\Pi_{t+1}} Z^d_{t+1}\right) \tag{2}$$

$$\Lambda^s_{t+1} = \beta^s \frac{C^s_t}{C^s_{t+1}} \tag{3}$$

Banks:

$$\Pi_t E_t = [1-(1-\theta^g)s^k_{t-1}]\theta\left\{\Psi^d(u^*_t)Z^b_t B^b_{t-1} - [1-F^d(u^*_t)]D_{t-1}\right\} + \varpi \tag{4}$$

$$Q^b_t B^b_t = (1+x^k_t)E_t + Q^d_t D_t \tag{5}$$

$$\kappa Q^b_t B^b_t \leq \Phi_t E_t \perp \mu_t \geq 0 \tag{6}$$

$$\Lambda^k_{t+1} = \frac{\Lambda^s_{t+1}}{\Pi_{t+1}}(1-\theta+\theta\Phi_{t+1})[1-(1-\theta^g)s^k_t] \tag{7}$$

$$\mu_t \kappa = \mathbb{E}_t\left\{\Lambda^k_{t+1}\left[\frac{\Psi^d(u^*_{t+1})Z^b_{t+1}}{Q^b_t} - \frac{1-F^d(u^*_{t+1})}{Q^d_t}\right]\right\} \tag{8}$$

$$\Phi_t = (1+x^k_t)\frac{\mathbb{E}_t\left\{\Lambda^k_{t+1}[1-F^d(u^*_{t+1})]\right\}}{Q^d_t(1-\mu_t)} \tag{9}$$

$$u^*_t = \frac{D_{t-1}}{Z^b_t B^b_{t-1}} \tag{10}$$

Borrowers:

$$B_t^b \leq \chi \mathrm{m} \theta^{LTV} p_t^h + B_{t-1}^b \frac{1-\gamma}{\Pi_t}(1-\mathrm{m}) \perp \lambda_t^b \geq 0 \tag{11}$$

$$\nu_t^* = \frac{B_{t-1}^b}{\chi \Pi_t p_t^h} \tag{12}$$

$$p_t^h = \frac{\xi (C_t^b)^\sigma + \mathbb{E}_t \left\{ \Lambda_{t+1}^b p_{t+1}^h \left[(1-\mathrm{m})(1-\theta^{LTV} \lambda_{t+1}^b) + \mathrm{m} \Psi_{t+1}^b \right] \right\}}{1 - \lambda_t^b \theta^{LTV}} \tag{13}$$

$$Q_t^b - \lambda_t^b = \mathbb{E}_t \left\{ \frac{\Lambda_{t+1}^b}{\Pi_{t+1}} \left\{ (1-\mathrm{m}) \left[(1-\gamma)(Q_{t+1}^b - \lambda_{t+1}^b) + \gamma \right] + \mathrm{m} \left[1 - F_{t+1}^b(\nu_{t+1}^*) \right] \right\} \right\} \tag{14}$$

$$(1-\tau) w_t N_t + \frac{Q_t^b B_t^b}{\chi} + \frac{T_t^b}{\chi} = C_t^b + \frac{B_{t-1}^b}{\chi \Pi_t} \left\{ \mathrm{m}[1 - F_t^b(\nu_t^*)] + (1-\mathrm{m})[(1-\gamma) Q_t^b + \gamma] \right\}$$

$$+ \mathrm{m} p_t^h [1 - \Psi_t^b(\nu_t^*)] + T_t \tag{15}$$

$$\Lambda_{t+1}^b = \beta^b \frac{C_t^b}{C_{t+1}^b} \tag{16}$$

Asset payoffs:

$$Z_t^b = (1-\mathrm{m})[Q_t^b(1-\gamma) + \gamma] + \mathrm{m} \left[1 - F_t^b(\nu_t^*) + (1-\lambda_t^b) \frac{1 - \Psi_t^b(\nu_t^*)}{\nu_t^*} \right] \tag{17}$$

$$Z_t^d = s_{t-1}^d + (1 - s_{t-1}^d) \left[1 - F^d(u_t^*) + (1-\lambda^d) \frac{1 - \Psi^d(u_t^*)}{u_t^*} \right] \tag{18}$$

Phillips curve, resource constraint, production function, and wage rule:

$$\eta \mathbb{E}_t \left\{ \Lambda_{t+1}^s \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi} \left(\frac{\Pi_{t+1}}{\Pi} - 1 \right) \right\} - \varepsilon \left(\frac{\varepsilon - 1}{\varepsilon} - \frac{w_t}{A_t} \right) = \eta \frac{\Pi_t}{\Pi} \left(\frac{\Pi_t}{\Pi} - 1 \right) \tag{19}$$

$$C_t + G_t + \lambda_t^b \mathrm{m} \chi p_t^h [1 - \Psi_t^b(\nu_t^*)] + \lambda^d Z_t^b \frac{B_{t-1}^b}{\Pi_t} [1 - \Psi^d(u_t^*)] = Y_t \left[1 - \frac{\eta}{2} \left(\frac{\Pi_t}{\Pi} - 1 \right)^2 \right] \tag{20}$$

$$Y_t = A_t N_t \tag{21}$$

$$w_t(1-\tau) = \mu^w C_t^\sigma N_t^\varphi \tag{22}$$

Monetary and fiscal policy:

$$\frac{1}{Q_t} = \frac{1}{\bar{Q}} \left[\frac{\Pi_t}{\Pi}\right]^{\phi_\pi} \left(\frac{GDP_t}{G\bar{D}P}\right)^{\phi_Y} \tag{23}$$

$$GDP_t = C_t + G_t \tag{24}$$

$$\tau Y_t[1 - d(\Pi_t)] + Q_t B_t^g + T_t = \frac{B_{t-1}^g}{\Pi_t} + G_t + T_t^b + \text{Net Costs}_t^k + \text{Net Costs}_t^d \tag{25}$$

$$T_t = \phi_T \log\left(\frac{B_{t-1}^g}{\bar{B}^g}\right) \tag{26}$$

$$\text{Net Costs}_t^k = x_t^k E_t - (1-\theta^g) s_{t-1}^k \Pi_t^{-1} \left\{\Psi^d(u_t^*) Z_t^b B_{t-1}^b - [1 - F^d(u_t^*)] D_{t-1}\right\} \tag{27}$$

$$\text{Net Costs}_t^d = s_{t-1}^d \frac{D_{t-1}}{\Pi_t} \left[F^d(u_t^*) - (1-\lambda^d)\frac{\Psi^d(u_t^*)}{u_t^*}\right] \tag{28}$$

Cumulative distribution functions and partial expectations for risk shocks:

$$F_t^b(\nu_t^*) = \left[\frac{\sigma_t^b \nu_t^*}{\sigma_t^b + 1}\right]^{\sigma_t^b} \tag{29}$$

$$\Psi_t^b(\nu_t^*) = 1 - \left[\frac{\sigma_t^b \nu_t^*}{\sigma_t^b + 1}\right]^{\sigma_t^b + 1} \tag{30}$$

$$F^d(u_t^*) = \frac{(u_t^*)^{\sigma^d} - \underline{u}^{\sigma^d}}{\bar{u}^{\sigma^d} - \underline{u}^{\sigma^d}} \tag{31}$$

$$\Psi^d(u_t^*) = \frac{\sigma^d}{\sigma^d + 1} \frac{\bar{u}^{\sigma^d+1} - (u_t^*)^{\sigma^d+1}}{\bar{u}^{\sigma^d} - \underline{u}^{\sigma^d}} \tag{32}$$

A.2 Price Setter's Problem and the Phillips curve

The problem of the firm follows Rotemberg (1982). Given the aggregate state $\mathbb{S}_t$ and the production function $Y_t(i) = A_t N_t(i)$, the firm's recursive problem is

$$V[P_{t-1}(i); \mathbb{S}_t] = \max_{P_t(i), Y_t(i)} \left\{P_t(i) Y_t(i) - W_t \frac{Y_t(i)}{A_t} - \frac{\eta}{2} P_t Y_t \left(\frac{P_t(i)}{\Pi P_{t-1}(i)} - 1\right)^2 + \mathbb{E}_t \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} V[P_t(i); \mathbb{S}_{t+1}]\right\}$$

subject to the demand curve $Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon} Y_t$. The first-order condition to this problem is

$$\begin{aligned}
&\eta \frac{P_t Y_t}{\Pi P_{t-1}(i)} \left(\frac{P_t(i)}{\Pi P_{t-1}(i)} - 1\right) + P_t(i)^{-\varepsilon} P_t^{\varepsilon} Y_t \left[\varepsilon - 1 - \varepsilon \frac{W_t}{A_t} \frac{1}{P_t(i)}\right] \\
=&\mathbb{E}_t \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} \eta \frac{P_{t+1} P_{t+1}(i) Y_{t+1}}{\Pi P_t(i)^2} \left(\frac{P_{t+1}(i)}{\Pi P_t(i)} - 1\right)
\end{aligned}$$

In a symmetric equilibrium, all firms choose the same price $P_t(i) = P_t$. Thus the above condition becomes the New Keynesian Phillips curve,

$$\eta \frac{\Pi_t}{\Pi} \left(\frac{\Pi_t}{\Pi} - 1\right) + \varepsilon \left(\frac{\varepsilon - 1}{\varepsilon} - \frac{w_t}{A_t}\right) = \eta \mathbb{E}_t \Lambda_{t,t+1}^s \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi} \left(\frac{\Pi_{t+1}}{\Pi} - 1\right)$$

A.3 Solution to the Bank's Problem

To solve the bank's problem, we start by writing the bank's franchise/continuation value as

$$\begin{aligned}
\Phi_{j,t}(e_{j,t}) &\equiv \mathbb{E}_t \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} V_{j,t+1}(e_{j,t+1}(u)) \mathrm{d}F^d(u) \\
&= \mathbb{E}_t \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} [(1-\theta) e_{j,t+1}(u) + \Phi_{j,t+1}(e_{j,t+1}(u))] \mathrm{d}F^d(u)
\end{aligned}$$

We now guess, to later verify, that the bank's franchise value is linear in current earnings,

$$\Phi_{j,t}(e_{j,t}) = \Phi_{j,t} \theta e_{j,t}$$

Under this assumption, we can reformulate the bank's problem as

$$\Phi_{j,t} \theta e_{j,t} = \max_{b_{j,t}, d_{j,t}} \mathbb{E}_t \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) e_{j,t+1}(u) \mathrm{d}F^d(u)$$

subject the law of motion for earnings, the balance sheet constraint, and the leverage constraint. Replacing for the first two, we can write the bank's Lagrangian as

$$\Phi_{j,t}\theta e_{j,t} = \max_{b_{j,t}} \mathbb{E}_t \int_{u^*_{j,t+1}}^{\infty} \frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}}(1-\theta+\theta\Phi_{j,t+1}) \left[\left(u\frac{Z^b_{t+1}}{Q^b_t} - \frac{1}{Q^d_t}\right) Q^b_t b^b_{j,t} + \frac{\theta e_{j,t}}{Q^d_t}\right] \mathrm{d}F^d(u)$$
$$+\mu_{j,t}\left[\Phi_{j,t}\theta e_{j,t} - \kappa Q^b_t b^b_{j,t}\right]$$

The first-order condition with respect to $b_{j,t}$ is then

$$\mathbb{E}_t \int_{u^*_{j,t+1}}^{\infty} \frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}}(1-\theta+\theta\Phi_{j,t+1}) \left(u\frac{Z^b_{t+1}}{Q^b_t} - \frac{1}{Q^d_t}\right) \mathrm{d}F^d(u) = \mu_{j,t}\kappa$$

Applying the envelope theorem and rewriting the Lagrangian then yields

$$\Phi_{j,t} = \frac{\mathbb{E}_t\left\{\frac{\Lambda^s_{t,t+1}}{\Pi_{t+1}}(1-\theta+\theta\Phi_{j,t+1})[1-F^d(u^*_{j,t+1})]\right\}}{Q^d_t(1-\mu_{j,t})}$$

thus confirming our conjecture that the value was linear in earnings.

A.4 Technology Shock

To understand the model's dynamics, it is instructive to look at the response of the economy's variables to a standard technology shock. Figure A.1 plots generalized impulse response functions (GIRF) of macroeconomic and financial variables to a one-standard-deviation TFP shock. Variables are expressed in percentage deviations from their stochastic SS value, which is also used as the starting point for the impulse.[33] Details on how these GIRF are computed can be found in Appendix B.4.

GDP responds positively to a TFP shock, as is normal in this class of models. Importantly, since borrowers have a higher MPC and labor incomes rises, their consumption increases relatively

[33] I use the term "stochastic SS" in the sense of the risky SS of Coeurdacier et al. (2011), which is the point to which the economy converges in the absence of exogenous innovations, even when agents expect that these might occur. It differs from the non-stochastic SS to the extent that it features precautionary behavior by the agents.

more in response to a TFP shocks. As the final panel illustrates, this effect is complemented by lower spreads on their borrowing. Bank funding spreads fall on impact for two main reasons: first, as borrower consumption increases and house prices rise, the default rate on mortgages falls. This results in a fall in credit risk that passes through to banks, leading to lower spreads. Second, and as explained before, banks run a maturity mismatch and are thus exposed to interest rate risk. As inflation falls and the CB lowers interest rates, bank profits rise. As banks are better capitalized and the likelihood of their leverage constraint binding in the future falls, the excess premium they demand on lending also falls. As credit is procyclical and more persistent than house prices, household and bank leverage eventually rises, leading to a rise in spreads some periods after the TFP shock.

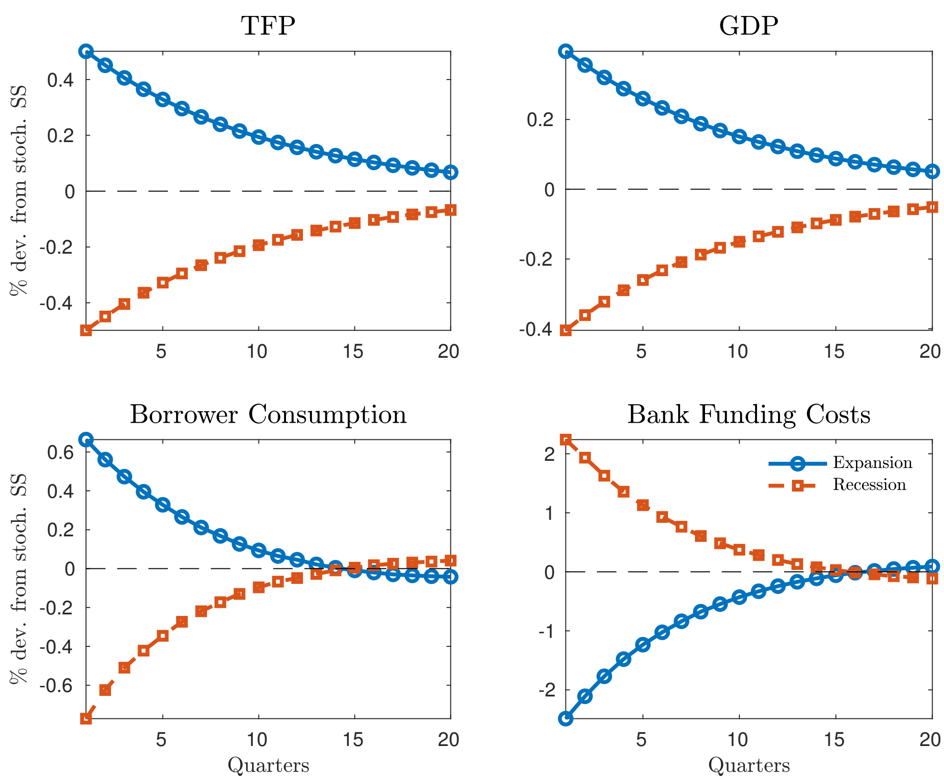


Figure A.1: Generalized impulse response functions to TFP shock.

A.5 Why a BANK and not a HANK?

The main reason why I focus on a two-agent New Keynesian model with banks (B-TANK, or "BANK") as opposed to a full-blown heterogeneous agents New Keynesian model (HANK) is so that I can capture the effects of aggregate risk and the anticipation of occasionally (aggregate) binding constraints, two aspects which are not yet computationally feasible in a HANK environment. Common solution methods for HANK models involve either combining aggregate shocks with aggregate dynamics that are linear to a first order, or studying the effects of unanticipated aggregate shocks. Neither of these approaches can capture the precautionary behavior that induces agents to move closer or further away from their respective constraints, which is essential to generating the state-dependent effects of shocks and policies that are illustrated in the next section, and which are crucial for the results. At the stochastic SS, both borrowers and banks are unconstrained, implying that the aggregate MPC in this economy is relatively low. As borrowers move closer or further away from their constraint, the MPC in this economy will vary over time. This allows me to capture relatively realistic MPC dynamics with aggregate risk. Finally, this global solution with aggregate risk allows me to use a particle filter that combines a nonlinear model and macroeconomic data to estimate structural shocks and use those shocks to conduct policy counterfactuals.

B Computational Appendix

B.1 Model Solution

I adopt a global solution method that combines time iteration (Judd, 1998), parametrized expectations (den Haan and Marcet, 1990), and multilinear interpolation. Given a vector of state variables $\mathbb{S}_{t-1}$ and innovations ϵ_t, one can use the equilibrium conditions described in Appendix A to compute the values of all endogenous variables $\mathcal{Y}_t$ in the current period,

$$\mathcal{Y}_t = f(\mathbb{S}_{t-1}, \epsilon_t)$$

The procedure consists of approximating f (an infinite-dimensional object) using a finite approximation $\hat{f}$ chosen from some space of functions. The approximation is obtained by solving for $\hat{f}$ exactly at a finite number of grid points and interpolating between these when evaluating the equilibrium at points of the state space that do not belong to the grid.

In practice, it is not necessary to approximate all elements of $\mathcal{Y}_t$. Given knowledge of the current states and innovations $(\mathbb{S}_{t-1}, \epsilon_t)$, as well as of a restricted set of endogenous variables $\mathcal{X}_t \subset \mathcal{Y}_t$ ("policies"), one can use the model's static equilibrium conditions to back out the remaining elements of $\mathcal{Y}_t$. For the specific case of my model, we have that this vector of states and innovations is

$$\mathcal{S}_t \equiv (\mathbb{S}_{t-1}, \epsilon_t) = (D_{t-1}, B^b_{t-1}, B^g_{t-1}, A_t, \sigma^b_t, \Omega_t)$$

Policies $\mathcal{X}_t$ are typically variables that either appear inside expectation terms (and so we need to be able to evaluate them for different values of $\mathbb{S}_{t+1}$) and/or variables that cannot be determined statically without solving a nonlinear equation. Based on these criteria, I pick the following variables as the policies to solve for:

$$\mathcal{X}_t = (C^s_t, Q^b_t, p^h_t, \Pi_t, C^b_t, Q^d_t, \lambda^b_t, \mu_t)$$

I adopt some ideas from parametrized expectations algorithms: for a given $\mathcal{S}_t$, I can describe the model's equilibrium as a set of nonlinear equations of the type

$$m\left\{\mathbb{E}_t\left[h\left(\mathcal{X}_{t+1}, \mathcal{S}_{t+1}, \mathcal{S}_t\right)\right], \mathcal{X}_t, \mathcal{S}_t\right\} = 0$$

The idea is to construct a grid over the states and innovation $\mathcal{S}_t$, fix the expectations terms $\mathbb{E}_t h(\cdot)$ at each of these points, and solve a simpler system of nonlinear equations for $\mathcal{X}_t$. Since the system is relatively simple (as I am fixing the value of the expectations terms for each grid point), it is possible to compute the Jacobian analytically, which greatly improves the speed and precision of the algorithm.

The algorithm then proceeds as follows:

1. Generate a discrete grid for the state variables, $\{g_i\}_{i=1}^N = \mathbb{G} = G_D \times G_{B_b} \times G_{B_g} \times G_A \times G_\sigma \times G_\Omega$.

2. Approximate $\mathcal{X}_t, \mathbb{E}_t h(\cdot)$ over $\mathbb{G}$ by choosing an initial guess and a functional space to define the approximant. As the initial guess, I use the model's non-stochastic SS. This means that I can guess a value for each variable $X_t \in \mathcal{X}_t$ and each expectation term $\mathbb{E}_t h(\cdot)$ at each grid point. Call these sets of values $X^0 = \{x_i^0\}_{i=1}^N$, and $H^0 = \{h_i^0\}_{i=1}^N$. As an approximant, I use piecewise linear functions (multilinear interpolation). This approximant allows me to evaluate X^0, H^0 outside of the grid points at any combination of values for the states.

3. Given these initial guesses for the policies $\mathcal{X}^0$ and expectation terms, solve the model by using time iteration. Set $\mathcal{X}^\tau = \mathcal{X}^0$, and $H^\tau = H^0$.

   (a) For each point in the grid, g_i, solve a system of residual equations for the value of the policies at that grid point. Given my guesses for the expectation terms, this is a set of nonlinear equations of the type

   $$m\left\{h_i^\tau, \mathcal{X}^\tau, g_i\right\} = 0$$

   As mentioned, since the expectation terms are fixed at each point, this system should be simple enough so as to allow analytical computation of the Jacobian. Solving for $\mathcal{X}^\tau$ allows us to obtain a series of values for the policies at each point in the grid $\{\mathcal{X}_i^{\text{new}}\}_{i=1}^N$.

   (b) Given values for these points, compute a convergence criterion for each element of $\mathcal{X}$ as

   $$\rho_i^X = \max_i \|\mathcal{X}_i^{\text{new}} - \mathcal{X}_i^\tau\|$$

   (c) Update the guess for each point in the grid:

   $$\mathcal{X}_i^{\tau+1} = \lambda \mathcal{X}_i^{\text{new}} + (1-\lambda)\mathcal{X}_i^\tau$$

   where λ is some dampening parameter. Reevaluate (update) the policy approximant.

   (d) Use the updated policies and the model's equilibrium conditions to update the expectations terms $H^{\tau+1}$. Compute these expectations using the policy interpolants, and Gauss-Hermite quadrature for the TFP process (with 15 points).

(e) If ρ_i^X is below some pre-defined level of tolerance, stop. Otherwise, return to step (a).

Intuitively, time iteration works by guessing some functional form for the endogenous variables inside of the expectations terms and iterating backwards until today's policies are consistent with the expected future policies at each point in the state space. The innovation with respect to standard time iteration methods is that expectations are fixed at each point of the grid when solving for policies, which considerably speeds up computations. Solving models with these type of methods can be particularly challenging since very few convergence results exist (unlike, for example, value function iteration).

B.1.1 Occasionally Binding Constraints

o deal with occasionally binding constraints, I apply the procedure described in Garcia and Zangwill (1981) and used by Judd et al. (2002). This involves rewriting inequality conditions and redefining Lagrange multipliers such that equilibrium conditions can be written as a system of equalities and standard methods for solving nonlinear systems of equations can be applied. As a concrete example, take the bank's leverage constraint and the associated Lagrange multiplier $\mu_t \geq 0$. I define an auxiliary variable $\mu_t^{\text{aux}} \in \mathbb{R}$ such that

$$\mu_t = \max(0, \mu_t^{\text{aux}})^2$$

and the inequality to which the complementarity condition $\mu_t \geq 0$ is associated reads

$$\Phi_t \theta E_t = \kappa Q_t^b B_t + \max(0, -\mu_t^{\text{aux}})^2$$

Notice then that whenever $\mu_t^{\text{aux}} \geq 0$, the inequality holds as an equality and $\mu_t \geq 0$. On the other hand, when we have that $\mu_t^{\text{aux}} < 0$, this variable becomes the residual for the inequality, which implies that $\Phi_t \theta E_t > \kappa Q_t B_t$ and $\mu_t = 0$. Defining this auxiliary variable as the square of a $\max$ operator ensures that the system is differentiable with respect to this variable, which is helpful when using Newton-based methods to solve the nonlinear system of equilibrium conditions.

B.1.2 Grid Construction

Grid boundaries for endogenous states are chosen to minimize extrapolation, which is important given the use of linear extrapolation. I use linear grids for all endogenous variables. In principle, it is helpful to make grids denser in regions of the state space where constraints start/stop binding. That is not easy in this model: given the large number of states, these regions can be ill behaved. Given that bank and household debt are very positively correlated, using rectangular grids is computationally costly, since it involves solving the model for many points that will never be visited during stochastic simulations. One approach to dealing with this issue is to use grid rotations based on singular value decompositions. Since my grid is constructed manually, I instead opt for redefining the state variables. In particular, I use $\text{lev}_{t-1} = \frac{D_{t-1}}{B^b_{t-1}}$ instead of D_{t-1} as a state.

The final grid for the full version of the model contains 9 points for D, 9 points for B_b, 4 points for B_g, 5 points for A, 2 points for σ^b, and 2 points for each of the fiscal policies. The final grid with the 11 state variables contains 466,560 points. The results are robust to expanding the size of the grid, especially for the endogenous states.

B.2 Accuracy Checks

Even though the model solution is exact at the specified grid points, the simulated economy may travel to regions of the state space that do not correspond to any grid point; at these points, the equilibrium conditions are not guaranteed to hold exactly. To check accuracy of the model solution, I follow the standard procedure in the literature and evaluate the residuals at these points. To do so, I first simulate the model economy for 5,000 periods. Then, I evaluate the residual equations used to solve the model at each of the points of the state space that were "visited" in that simulation. Histograms with the decimal log of the absolute value of the residuals as a percentage of aggregate consumption are shown in Figure A.2 for each residual equation. Most equations present average errors of order -3 or lower, which are standard in the literature.

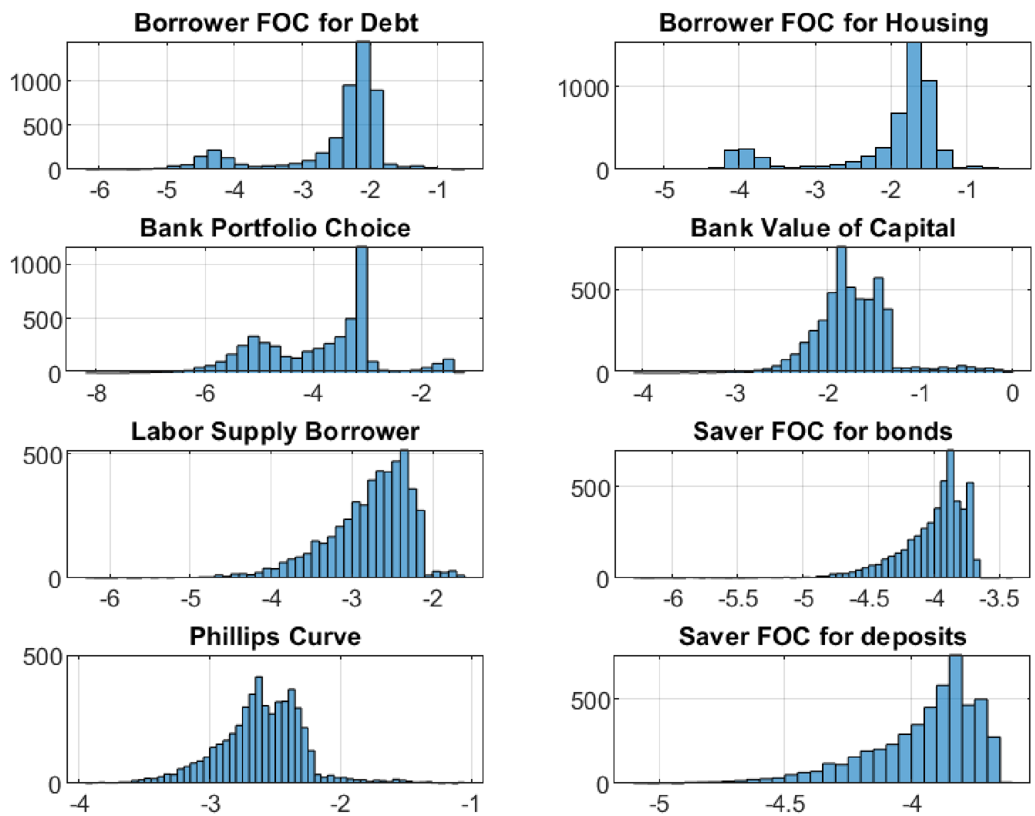


Figure A.2: Residual equation errors for a 5,000 period simulation, as a percentage of aggregate consumption and in decimal log basis.

B.3 Particle Filter

In this section, I describe the particle filter used to extract the sequences of structural shocks from the data.

B.3.1 Nonlinear State Space Model

The first step to writing the particle filter is to write the model in nonlinear state space form. The general structure of these models consists of two blocks: a state transition function f and an observation function g:

$$x_t = f(x_{t-1}, \epsilon_t; \gamma)$$
$$y_t = g(x_t; \gamma) + \eta_t$$

where γ is a vector of structural parameters, x_t is a vector of state variables, y_t is a vector of observable variables, ϵ_t are structural shocks, and η_t are measurement errors. The structural shocks follow some distribution with density function m, and measurement errors are assumed to be additive and Gaussian,

$$\eta_t \sim \mathcal{N}(\mathbf{0}, \mathbf{\Sigma})$$

For the current model, we consider

$$x_t = (\text{lev}_t, B^b_t, B^g_t, A_t, \sigma^b_t, \Omega_t)$$
$$y_t = (C_t, \text{spread}_t, \Omega_t)$$

The structural shocks are the innovations to $(A_t, \sigma^b_t, \Omega_t)$, and all variables are observed with some measurement error that is Gaussian and uncorrelated across variables. For the endogenous observables, (C_t, spread_t), I set the standard deviation of the measurement error equal to 10% of the standard deviation of the data series. For the policies, Ω_t, I set the standard deviation of the measurement error to be 1% of the standard deviation of the data series. In other words, the policy impulses are observed almost perfectly.

B.3.2 Likelihood Function

Given a sample of observables $y^T = \{y_t\}^T_{t=0}$, we can apply the typical factorization and write the likelihood given parameters γ as

$$\mathcal{L}(y^T; \gamma) = \prod_{t=1}^{T} p(y_t | y^{t-1}; \gamma)$$

We can further decompose the period-by-period conditional density $p(y_t|y^{t-1};\gamma)$ as

$$\mathcal{L}(y^T;\gamma) = \prod_{t=1}^{T} \int p(y_t|x_t;\gamma)p(x_t|y^{t-1};\gamma)\mathrm{d}x_t$$

The first term is easy to evaluate: $p(y_t|x_t;\gamma)$ is given from the observation equation and the density function for the measurement error. Given the assumption that measurement error is additive and Gaussian, $\eta_t \sim \mathcal{N}(0,\Sigma)$, we can simply write

$$p(y_t|x_t;\gamma) = \phi[y_t - g(x_t;\gamma)]$$

where ϕ is the (multivariate) standard normal density.

The harder part is to evaluate the second term, $p(x_t|y^{t-1};\gamma)$, which is a complicated function of the states. This is where the particle filter is helpful, since it allows us to compute this conditional density by simulation.

B.3.3 Bootstrap Filter

Our goal is to evaluate $p(x_t|y^{t-1};\gamma)$ at each t. The particle filter is a way of obtaining a sequence of state densities conditional on past observations, $\{p(x_t|y^{t-1};\gamma)\}_{t=0}^{T}$. Throughout the procedure, we have to keep track of a sequence of sampling weights, $\{\{\pi_t^i\}_{i=1}^N\}_{t=0}^T$. It proceeds as follows:

1. **Initialization**. Set $t = 1$ and initialize $\{x_0^i, \pi_0^i\}_{i=1}^N$ by taking N draws from the model's ergodic distribution and set $\pi_0^i = \frac{1}{N}, \forall i$.

2. **Prediction**. For each particle i, draw $x_{t|t-1}^i$ from the proposal density $h(x_t|y^t, x_{t-1}^i)$. This involves randomly drawing one vector of structural innovations ϵ_t^i and computing

$$x_{t|t-1}^i = f(x_{t-1}^i, \epsilon_t^i)$$

3. **Filtering**. Assign to each draw $x^i_{t|t-1}$ a particle weight given by

$$\pi^i_t = \frac{p(y_t|x^i_{t|t-1};\gamma)p(x_t|x^i_{t|t-1};\gamma)}{h(x_t|y^t, x^i_{t-1})}$$

   Noting that

$$p(y_t|x^i_{t|t-1};\gamma) = \phi(y_t - g(x^i_{t|t-1};\gamma))$$

   we can compute each particle weight as

$$\pi^i_t = \frac{p(y_t|x^i_{t|t-1};\gamma)}{\sum_{i=1}^N p(y_t|x^i_{t|t-1};\gamma)}$$

   This generates a swarm of particle weights that add up to 1: $\{\pi^i_t\}_{i=1}^N$.

4. **Sampling**. Sample N values for the state vector with replacement, from $\{x^i_{t|t-1}\}_{i=1}^N$ using the weights $\{\pi^i_t\}_{i=1}^N$. Call this set of draws $\{x^i_t\}_{i=1}^N$, and set the weights back to $\pi^i_t = \frac{1}{N}, \forall i$.

These steps generate a sequence of $\{\{x^i_{t|t-1}\}_{i=1}^N\}_{t=0}^T$, which can then be used to generate $\{\{p(y_t|x^i_{t|t-1};\gamma)\}_{i=1}^N\}_{t=0}^T$ This then allows us to evaluate the likelihood as

$$\mathcal{L}(y^T;\gamma) \simeq \prod_{t=1}^T \frac{1}{N}\sum_{i=1}^N p(y_t|x^i_{t|t-1};\gamma)$$

B.3.4 Filtered States

At the end of the process, we have a sequence of simulated swarms of particles for each time period $\{\{x^i_t\}_{i=1}^N\}_{t=0}^T$. These can be treated as empirical conditional densities for the state, given the observed data until t, or y^t.

B.3.5 Other Details

I use a swarm of 100,000 particles to run the filter. To initialize the filter, I obtain the initial conditions for the states by running a long simulation of the model without financial crises and drawing $\{x^i_0\}_{i=1}^N$ by sampling uniformly from that simulation.

B.4 Generalized Impulse Response Functions

In the context of a nonlinear stochastic model, impulse response functions do not have as a straightforward interpretation. In linear models, certainty equivalence holds and shocks are additive. This means that we can study the response of macroeconomic variables to a shock with respect to a trivial benchmark: the path of those variables in the absence of shocks, that is, the deterministic SS. This is no longer the case in a nonlinear stochastic model, since the economy may respond to a shock differently depending on its initial state and the impact of shocks is not linearly additive.

To define a benchmark against which the path of the economy should be compared, we therefore need to take a stance on two aspects: first, *where* to start the simulation in the state space, since the economy may react to the same shock differently depending on its initial states, and, second, *what* to compare the simulation against. I compute GIRFs as follows: let $Y_t = f(Y_{t-1}, \epsilon_t)$ denote the equilibrium of the model at time t as a function of state variables Y_{t-1} as well as innovations ϵ_t. First, I simulate the model for a large number of periods without any shocks in order to obtain its stochastic SS, which I use as a starting point for all exercises unless otherwise noted.

I draw R different sequences of shocks of length T, $\{\epsilon_{r,t}\}_{t=1,r=1}^{T,R}$, and simulate the model R times starting from the stochastic SS. This gives me R different sequences of simulated endogenous variables, $\{Y_{r,t}^{\text{base}}\}_{t=1,r=1}^{T,R}$. Using the exact same sequences of innovations, I resimulate the model R times but adding a 1% positive (negative) shock to the TFP process in the first period of the simulation. This generates "shocked" sequences $\{Y_{r,t}^{\text{shock}}\}_{t=1,r=1}^{T,R}$. Then, for each period t and variable Y, I take the difference between the average behavior of that variable under the shocked sequences and the base sequences. The GIRF is thus formally defined as

$$GIRF_t(Y) = \frac{\frac{1}{R}\sum_{r=1}^{R} Y_{r,t}^{\text{shocked}} - \frac{1}{R}\sum_{r=1}^{R} Y_{r,t}^{\text{base}}}{Y^{\text{stoch. SS}}} \tag{33}$$

The only difference between the sequences of base and shocked innovations is that $\epsilon_{r,t}^{\text{shocked,TFP}} = \epsilon_{r,t}^{\text{base,TFP}} + x\%$, where x is the magnitude of the shock.

C State-Dependent Effects of Fiscal Policy and the Collateral-Default Channel

In this appendix, I describe the effects of the different fiscal tools considered and how these change with the state of the economy. I focus on how the transmission of fiscal policy is augmented by a novel channel that depends on the interaction between borrower and bank balance sheets. This *collateral-default channel* arises from the interaction between (i) the pecuniary externality caused by the borrowing constraint, (ii) the structure of the default decision, and (iii) banks' pricing of debt securities. Since housing markets are segmented, houses are priced with the borrower's SDF: this implies that current borrower consumption has a first-order effect on the value of collateral. Any policy that raises borrower disposable income, especially when this agent has a high MPC, also raises collateral values. This has two effects: the direct effect is a relaxation of the borrowing constraint, allowing for an increase in net borrowing and further raising current income. The indirect effect is a fall in the number of defaults. This raises profits for the bank and helps relaxing its constraint (and/or reduce its likelihood of binding). This, in turn, lowers lending spreads and expands intermediation capacity. Thus the bank can lend more and at lower rates, again raising current income for the borrower.

Crucially, this channel requires *both* the borrower and the bank constraints to bind. This is the key feature that explains why the effects of fiscal policy are state dependent in this model.

Targeted Transfers Figure A.3 plots the effects of a one-time transfer for an economy that experiences a normal sequence of shocks (solid blue line), and for an economy that simultaneously experiences a high-risk shock (dashed orange line). The different panels show how the collateral-default channel is active during a crisis, greatly raising the effectiveness of transfers, but not during normal times. The first panel shows that the transfer shock is the same in either economy (i.e., the government spends the same amount). During a crisis, if borrowers are constrained, their consumption responds one for one to the transfer. This raises house prices, lowers default rates, and relaxes bank constraints, which in turn lower mortgage spreads. All of this feeds back into borrower consumption, leading to a positive effect on GDP.

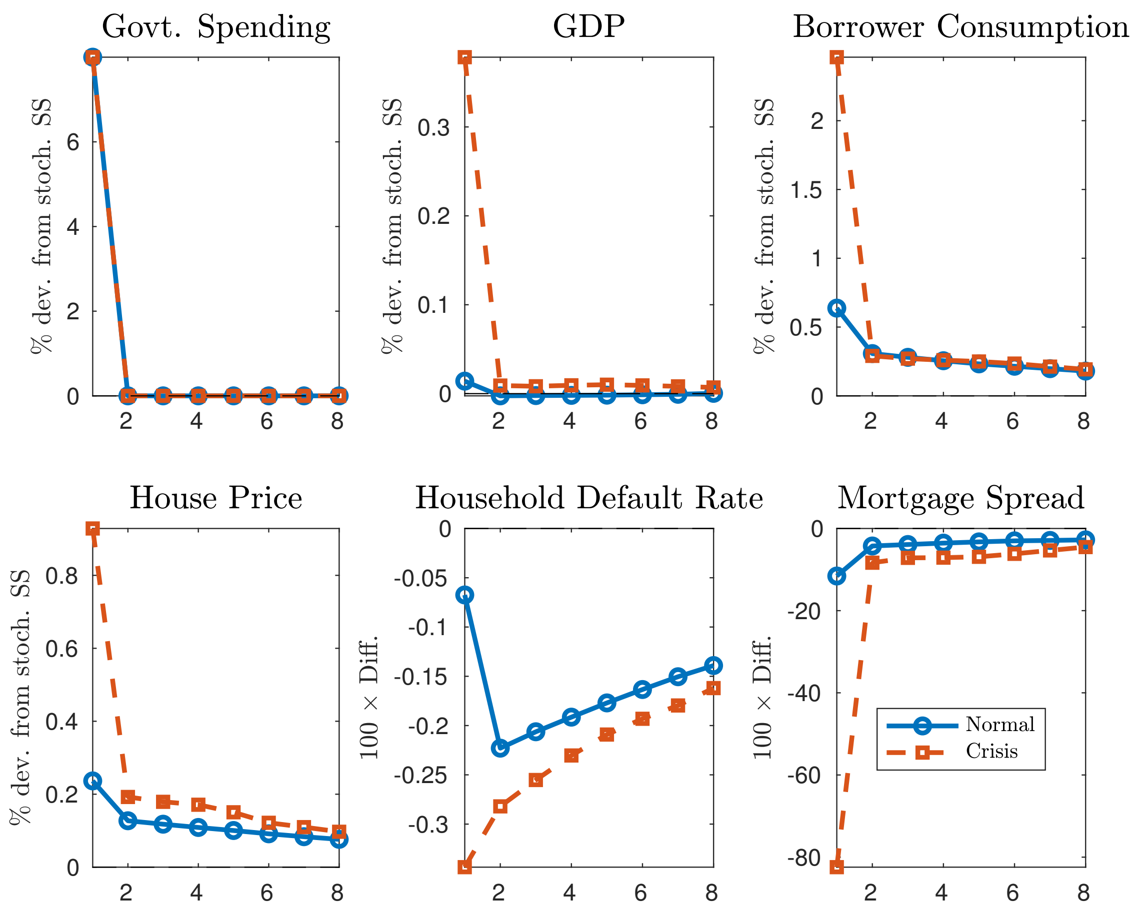


Figure A.3: GIRF of transfers, crisis and non-crisis.

Bank Recapitalizations As explained in the main text, equity injections are modeled as preferred equity purchases by the government. These asset purchases pay a dividend and may be fully repaid, depending on the evolution of the bank default rate after the injection is made.

On impact, these equity injections raise the amount of funds available for banks to lend. This reduces their need for borrowing (in deposits), which directly reduces leverage in the following periods. This is the only direct effect if banks are unconstrained, which may have some positive macroeconomic effects to the extent that it may reduce risk going forward, but it is not first order. Recapitalizations have first-order effects only when the bank constraint binds: they work through the financial accelerator, raising prices for mortgages and reducing credit spreads both for borrowers and for banks (as bank credit risk falls due to lower leverage). By relaxing the bank constraint, recapitalizations allow banks to extend more credit and at lower cost to the borrower. This has a direct effect on borrower disposable income, affecting aggregate demand if borrowers are also constrained. If borrowers are unconstrained, this improvement in the terms of credit is not (at least, fully) transmitted to aggregate demand.

Figure A.4 plots the response of the economy to an equity injection equal to 20% of initial bank capital during normal and crisis times. First, since the transfer is proportional and bank equity is depressed during crises, the effective amount of spending is much lower during a financial crisis. This is consistent with the notion that recapitalization programs are particularly cost effective during financial crises, when bank stocks are "cheap." Government spending is less than half during a crisis, but GDP expands by more. Borrowers benefit from expanded lending at lower costs. House prices jump on impact, and the default rate falls.

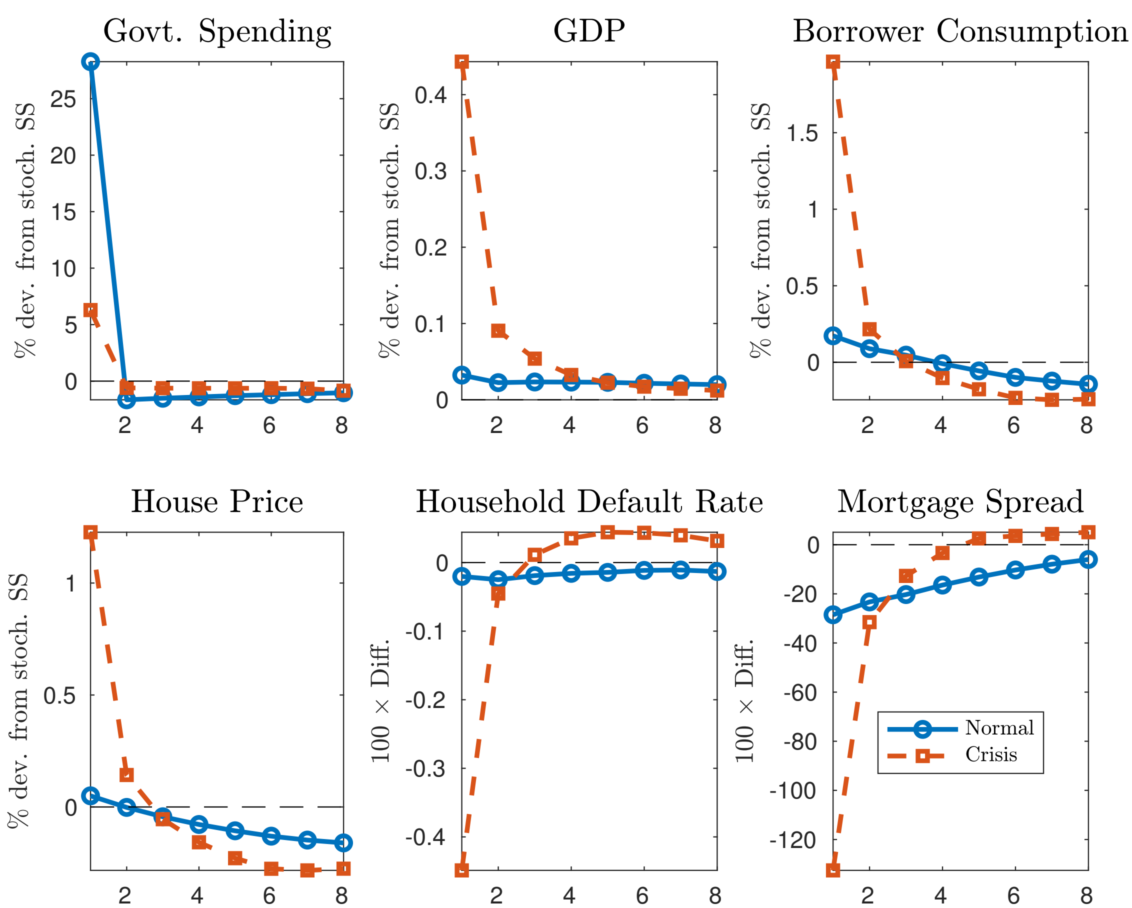


Figure A.4: GIRF of bank recapitalizations, crisis and non-crisis.

Credit Guarantees The final fiscal instrument that I consider are credit guarantees on bank deposits: at t, the government announces a (persistent) credit guarantee on a share x_t^d of bank deposits at $t+1$. The stock of guarantees s_t^d decays at rate $1-\theta^d$ as well as based on the default rate in the banking system.

On impact, this policy acts only through precautionary motives and can be a very cost-effective tool. The government effectively subsidizes bank borrowing, which helps banks recapitalize. Again, if banks are unconstrained, it results only in a reallocation of deposits to equity. If banks are unconstrained, however, recapitalization can affect directly the quantity and cost of mortgage credit.

The crucial point regarding credit guarantees is that their announcement (and commitment) can have stabilizing effects that generate large nonlinearities regarding the effective amount spent in equilibrium. Net fiscal costs at t from guarantees announced at $t-1$ are given by

$$\text{Net Fiscal Costs}_t = s_{t-1}^d \times \frac{D_{t-1}}{\Pi_t}\left[F^d(u_t^*) - (1-\lambda^d)\frac{1-\Psi^d(u_t^*)}{u_t^*}\right]$$

When the government announces s_{t-1}^d, bank borrowing D_{t-1} falls, contributing to a fall in defaults in the following period, $u_t^* \downarrow$. If this impact is large enough, an interesting non-monotonicity can arise: a *larger* program of credit guarantees can result in *lower* equilibrium spending. As the government commits to guaranteeing a larger fraction of bank debt, the economy stabilizes and less banks default in equilibrium. This is a logic similar to the one used to justify the role of emergency lending facilities and other lender-of-last-resort types of interventions during financial crises.

Figure A.5 plots the response of macro and financial variables to a 10% credit guarantee during normal and crisis times. The first thing to notice is that median spending with credit guarantees is basically zero, both during crisis and normal periods. Importantly, there is still a small positive effect on GDP and borrower consumption, attributable to the precautionary effects described above. While no banks default at the stochastic SS, the probability of default is not zero, as there is a positive (but small) probability of entering either a financial crisis and/or a very severe TFP recession in which banks default in equilibrium.[34] Credit guarantees operate by affecting the return on deposits

[34] This is consistent with the observation in the data that, in the years preceding the financial crisis, CDS spreads

in these states of the world; this reduces banks' cost of funding. Since banks are unconstrained, this reduction in the cost of funding is partially passed through to borrowers as lower costs of lending. Borrower consumption expands on impact due to lower borrowing costs and then falls below SS. The reason is that the guarantee in this experiment is transitory, while credit risk is not: by sustaining credit, this policy effectively prevents deleveraging.

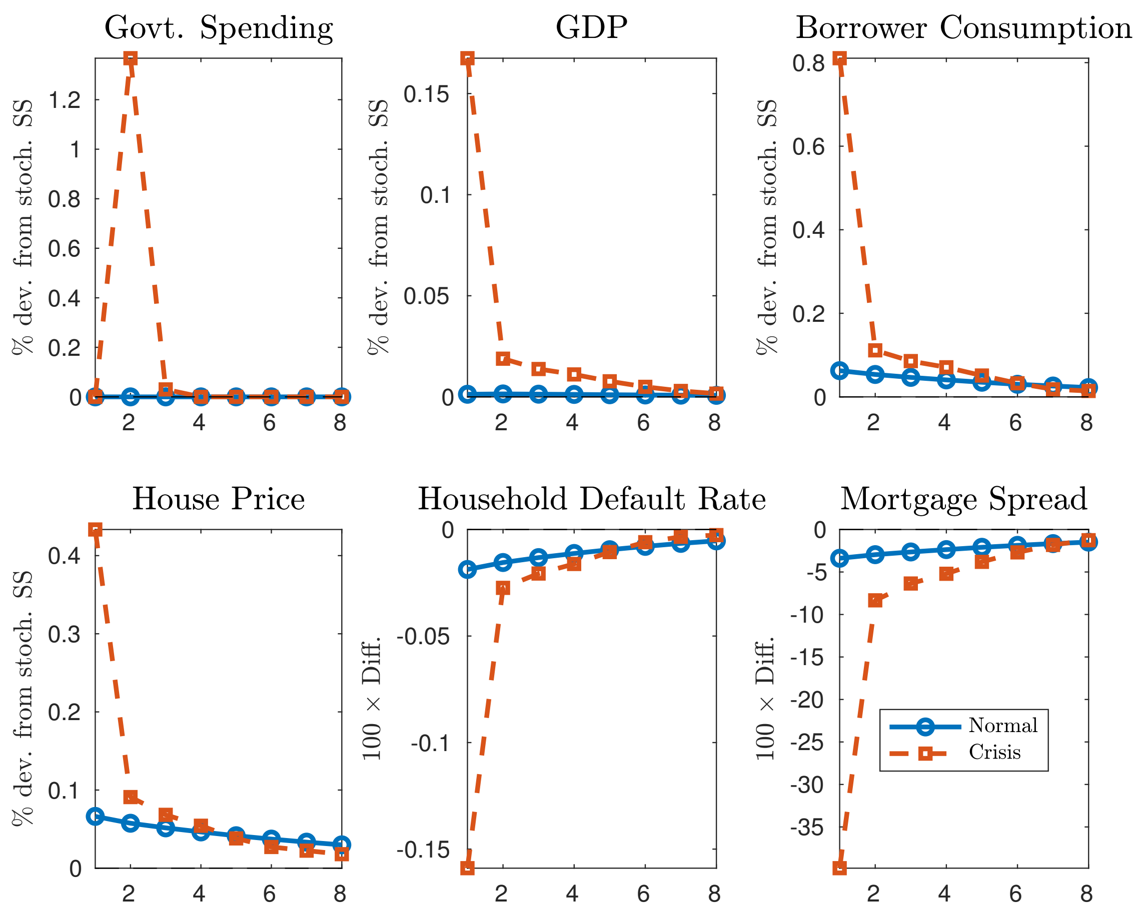


Figure A.5: GIRF of credit guarantees, crisis and non-crisis.

Fiscal Multipliers of Credit Guarantees The above analysis demonstrates that it is not obvious how to apply the concept of fiscal multipliers to credit guarantees. In the absence of a financial crisis, the government does not spend any resources on the credit guarantee, while still generating a small but positive impact on GDP and consumption due to precautionary motives. This implies that the ex-post multiplier, that is, the multiplier computed with the effective amount spent on guar-

were not zero even though no bank failures were observed.

antees, is equal to infinity. Lucas (2016) provides a detailed discussion of this issue, acknowledging the deep measurement problem that is faced by researchers and policymakers when trying to assess the macroeconomic impact of government guarantee programs. Since these are contingent liabilities for the government, it is more sensible to adopt a fair-value approach to the cost of these guarantees instead of directly measuring the effective outlays (as this approach would generate infinite fiscal multipliers in many cases); this approach accounts for the market risk of these programs.

The Congressional Budget Office (CBO) computes fair-value subsidy estimates every year for a range of different government credit programs in the US. The models used to compute these subsidy estimates are mostly based on measures of the interest rate spread between guaranteed and non-guaranteed debt contracts with otherwise similar characteristics (for example, the spread between jumbo and agency-conforming loans in the case of mortgages). An estimate of the total subsidy can then be computed by multiplying this spread by the total amount of guaranteed debt outstanding. This approach is conceptually similar to the one used by the CBO and is straightforward to implement in this model. Starting from the expression for the fiscal multiplier (12), I replace the term $\text{Spending}_t^{\text{Stimulus}} - \text{Spending}_t^{\text{No Stimulus}}$ with an estimate of the total subsidy per dollar of debt, obtained as

$$\text{Fair Value}_t^{\text{Stimulus}} = (Q_t^{d,\text{Guaranteed}} - Q_t^{d,\text{Non-Guaranteed}}) \times D_t^{\text{Stimulus}} \tag{34}$$

A more sophisticated calculation would take into account the value of debt that would be issued by banks in the absence of the government policy. I adopt the above calculation because it is more transparent and has a very natural interpretation. Since all credit programs are blanket guarantees in the model (i.e., they apply to all banks), the price of non-guaranteed bank debt is a counterfactual object that can be computed as

$$Q_t^{d,\text{Non-Guaranteed}} = \mathbb{E}_t \frac{\Lambda_{t+1}^s}{\Pi_{t+1}} \left[1 - F^d(u_{t+1}^*) + (1-\lambda^d) \frac{1 - \Psi^d(u_{t+1}^*)}{u_{t+1}^*} \right]$$

D Fiscal Policy Data

D.1 Construction of Fiscal Policy Dataset

In this appendix, I describe the collection and construction of the discretionary fiscal policy series in greater detail.

Government Purchases The only discretionary fiscal policy measure that included government purchases of goods and services was the ARRA — and even then, these were far from being the bulk of the package: by mid-2010, it was estimated that only 2% of the total outlays of this program were associated with direct purchases by the federal government, as estimated by Cogan and Taylor (2012). The Bureau of Economic Analysis (BEA) has estimated the dollar impact of the ARRA on federal government sector transactions in the National Income and Product Accounts, the national accounting system of the US. I rely on the BEA's estimates to measure a quarterly time series of discretionary government purchases of goods and services for the federal government. These estimates are available from 2009Q1, the beginning of the program, through 2013Q1. In particular, I treat the sum of *Consumption expenditures* and *Gross investment* as the measure of federal purchases undertaken under the ARRA.

Estimating purchases by states and local governments is not as straightforward. A significant portion of the ARRA consisted of transfers and grants to state and local governments, which could then potentially be used for purchases of goods and services (grants for school and infrastructure construction, for example). The bulk of these grants is allocated to Medicaid and education, which I also treat as government purchases following Dupor and Guerrero (2017).[35] I therefore add *Medicaid* and *Education* to the above measure.

Transfers to Households Several types of policies involved transfers to households, either explicitly or implicitly. I aggregate a relatively wide range of policies into this measure, which are of three broad types: (a) tax cuts and rebates, (b) social transfers (i.e., unemployment benefits), and

[35]This allocation is likely underestimated, however, since higher Medicaid transfers from the federal government may in turn lead state governments to allocate less of their own funds to Medicaid and more funds to purchases.

(c) homeowner/borrower relief.

The ARRA included several tax credit and social transfer policies as well as the aforementioned Medicaid transfers to state and local governments. Again, I use the BEA estimates to compute total transfers made under ARRA programs. I take (minus) revenue losses on *Current Tax Receipts* (these include tax benefits given as part of programs such as Making Work Pay) plus *Government Social Benefits*. Additionally, I include amounts disbursed under the CARS program (Cash for Clunkers).

Another large tool of US discretionary fiscal policy in the Great Recession was the tax rebates included in the ESA of 2008. This consisted, primarily, of tax rebates targeted at low- and middle-income households. The impact of these tax rebates on household and aggregate consumption and demand has been studied by Parker et al. (2013) and Broda and Parker (2014). The program was nominally allocated \$106 billion, with the Department of the Treasury disbursing \$79 billion in the second quarter of 2008 and an additional \$15 billion in the third quarter.

HERA, enacted in 2008, included a series of programs aimed at supporting homeowners who were struggling to meet their mortgage payments. For simplicity, and given that these programs involve implicit transfers of wealth to borrowers (who are also the homeowners in the model), I classify them as transfers. Using data collected from the website of the US Treasury and from pieces of legislation, I include as transfers amounts disbursed under two major programs: HOPE (a program that eased refinancing for distressed homeowners), and the Neighborhood Stabilization Program, which involved grants to state agencies to assist in the acquisition, rehabilitation, and resale of foreclosed homes.

TARP also included a host of similar programs aimed at helping homeowners in need. Many of these programs involved government-sponsored debt restructuring through incentive payments to mortgage lenders. I collect data on amounts allocated and effectively disbursed under TARP programs from the website of the US Treasury.Three major TARP programs are classified as transfers: Making Home Affordable (MHA), the Federal Housing Agency Refinance Program (FHA-RP), and the Hardest Hit Fund (HHF). The MHA, through its main pillar, the Home Affordable Modification Program (HAMP), provided mortgage lenders with incentive payments to restructure or refinance mortgages and/or give temporary forbearance so as to avoid foreclosure. The MHA was allocated $30 billion, of which about half was actually disbursed. The FHA-RP was targeted at homeowners who were current on their payments but underwater. The FHA would help these homeowners to refinance their mortgages with new ones that were adjusted for lower house values. While the FHA-RP was allocated over $1 billion, less than $60 million had actually been disbursed by 2016. Finally, the HHF consisted of extra funds made available by the Treasury to the state housing agencies in those states that were hardest hit by unemployment. They were mostly channeled towards foreclosure prevention, and many of the policy tools and effects thus overlap with those of HAMP. The HHF was allocated $9.6 billion, of which $6.5 billion were actually disbursed.

Equity Injections and Transfers to the Financial Sector Equity injections in financial institutions were arguably the most visible face of TARP. They were conducted through several programs, most notably through the CPP, which involved the purchase of preferred stock and warrants of commercial and investment banks and led to total disbursements of $245 billion. A similar but considerably smaller program, the Community Development Capital Initiative (CDCI), was also launched for credit unions. Additional programs that involved direct equity purchases of financial firms by the government were also launched for institutions that were deemed systemically important (the Treasury Investment Program, targeted at Bank of America and Citigroup), for AIG, and for the government-sponsored enterprises Fannie Mae and Freddie Mac.

Under this category, I also consider some programs that while not direct transfers, could be interpreted as implicit subsidies to financial companies: the Public-Private Investment Program (PPIP), the Automotive Industry Financing Program (AIFP), the Auto Supplier Support Program (ASSP), Treasury MBS purchases, and the Small Business Lending Fund (SBLF). The PPIP allowed the Treasury to invest in certain distressed securities along with private investors, thus raising those assets' valuations in hope of jumpstarting certain asset markets. The AIFP and ASSP involved credit guarantees and equity injections for major automakers and their suppliers, indirectly shielding the holders of those debt securities from losses (mostly financial companies). Finally, the SBLF consisted of subsidies to banks that would lend to small businesses.

I collect data on fund attribution under all of these programs from the website of the US Department of the Treasury.

Credit and Asset Guarantees In this category, I include not only direct credit and asset guarantee programs, but more broadly any lender-of-last-resort interventions that were deployed by the US Treasury and the FDIC. The important distinguishing feature of this type of interventions is that they involve, in one way or another, the creation of a contingent liability for the public agency.

Direct Treasury guarantee programs include the (aptly named) Asset Guarantee Program, through which the Treasury provided a \$5 billion asset guarantee to Citigroup[36]; the commitment of \$100M to the Term Asset-Backed Securities Loan Facility of the Federal Reserve; the Money Market Fund Guarantee program; and the Small Business and Community Lending Initiative.

Indirectly, the Treasury was also liable for the Temporary Liquidity Guarantee Program operated by the FDIC, which guaranteed all transaction accounts and some unsecured senior debt issued by participating banks. The program was initiated in late 2008, and at its peak over \$340 billion of bank debt was guaranteed under the program.

I collect data on funds committed and maturity of the guarantees for all the programs mentioned above. For the purpose of the model, the relevant metric is not funds disbursed, but rather funds committed as a percentage of outstanding financial debt.

D.2 Discretization of Fiscal Policy Series

As stated in the main text, I assume that each fiscal policy series ω_t follows a two-state Markov process described by

$$\omega_t = [\omega^{\text{normal}}, \omega^{\text{crisis}}]^T \qquad \text{and} \qquad \mathbf{P}^\omega = \begin{bmatrix} .995 & .005 \\ 1 - p^\omega & p^\omega \end{bmatrix}$$

[36] A \$7.5 billion asset guarantee was also negotiated with Bank of America but never implemented.

Our goal is to estimate $\theta = (\omega^{\text{crisis}}, p^{\omega})$ given the observed path of the policy over the sample $\{\omega_t\}_{t=0}^{T} \equiv \omega^T$. Since this is basically a hidden Markov model, I use the so-called Hamilton filter (Hamilton, 1989) to construct the likelihood function and estimate these parameters using maximum likelihood.

To do this, let x_t denote the "hidden state," which is the policy discretization, and assume that the policy is observed subject to some measurement error,

$$\omega_t = x_t + \epsilon_t$$

where $\epsilon_t \sim \mathcal{N}(0, \sigma)$ and x_t follows the two-state Markov chain described above. I set σ, the standard deviation of measurement error, equal to 10% of the standard deviation of the data series. We want to solve

$$\max_{\theta} \mathcal{L}(\omega^T; \theta)$$

which requires constructing the likelihood function. Generically,

$$\mathcal{L}(\omega^T; \theta) = \prod_{t=1}^{T} \Pr(\omega_t | \omega_{t-1}; \theta)$$

and we can write

$$\Pr(\omega_t | \omega_{t-1}; \theta) = \int \Pr(\omega_t | x_t; \theta) \Pr(x_t | \omega_{t-1}; \theta) \mathrm{d}x_t$$

Since we assume x_t to be a discrete process with values $\{x_1, \ldots, x_j, \ldots, x_N\}$, the conditional density is simply

$$\Pr(\omega_t | \omega_{t-1}; \theta) = \sum_{j=1}^{N} \Pr(\omega_t | x_t = j; \theta) \Pr(x_t = j | \omega_{t-1}; \theta)$$

The first term is easy to evaluate for any j, since it comes from the measurement-error equation. The second term is trickier, for which the filter is helpful. Let $\xi_{t|t}$ be a $N \times 1$ vector of conditional probabilities $[\Pr(x_t = j | \omega^t; \theta)]_{j=1}^{N}$, and let $\xi_{t+1|t}$ be the vector of $\Pr(x_{t+1} = j | \omega^t; \theta)$. Then, we have that

$$\xi_{t+1|t} = (\mathbf{P}^{\omega})^T \xi_{t|t}$$

and the filtering step is given by

$$\xi_{t+1|t+1} = \frac{\Pr(\omega_{t+1}|x_{t+1}, \omega^t; \gamma) \odot \xi_{t+1|t}}{\sum_{j=1}^{N} \Pr(\omega_{t+1}|x_{t+1} = j, \omega^t; \gamma) \odot \xi_{t+1|t}(j)}$$

where $\odot$ is the Hadamard product (element-wise multiplication). Given an initial condition $\xi_{0|0}$, this filtering procedure allows us to easily construct the likelihood function. The likelihood function can then be maximized with respect to the parameters using standard procedures.

As the initial condition, I set $\xi_{0|0} = [1, 0]^T$, since the first period of the sample is 2000Q1, when no discretionary policy was in place. To estimate the sequence of states $\{x_t\}_{t=0}^{T}$, I use the backward sampler that works as follows: draw x_T from $\xi_{T|T}$. Given $x_T = k$, compute

$$\xi_{T-1|T}(j) = \Pr(x_T = k|x_{T-1} = j) \times \frac{\xi_{T-1|T-1}(j)}{\xi_{T|T-1}(k)}$$

Sample x_{T-1} using $\xi_{T-1|T}$. Then, repeat the process and iterate backwards until x_1. The discretized series along with the original series are plotted in figure A.6.

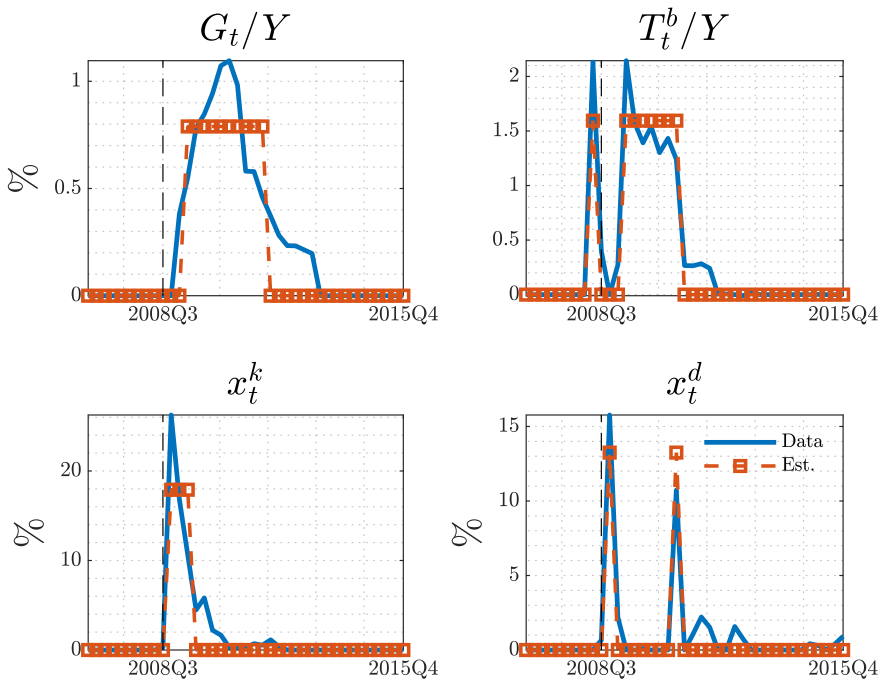


Figure A.6: Implied series for discretionary fiscal policy in the model (solid blue) and discretized series (orange squares).

E Model Extensions and Robustness

E.1 Unconditional Transfers

In the baseline model, it is assumed that only borrowers receive transfers, due to the targeted nature of most transfer programs deployed during the Great Recession. Some programs, however, were less targeted and plausibly benefited less constrained and wealthier households as well. One example of such programs was the CARS (Car Allowance Rebate System) program, better known as "cash for clunkers" that provided a total of \$3 billion in incentives for households to trade older motor vehicles for newer, more fuel efficient ones.

To address concerns such as these, I repeat the analysis assuming that savers also receive the same transfer T_t^b as borrowers. This is a relatively extreme assumption, but it is useful to bound the effects of the transfer program in the model. Naturally, making fiscal policy less targeted lowers the effectiveness of the total fiscal policy package: the cumulative drop in consumption is now of

5.95%, or $ 500.88 billion of 2007 non-housing aggregate consumption (vs. 7.18% and $ 604.4 billion in the baseline case). Figure A.7 plots the estimated time series for the fiscal multiplier for transfers in this case, and shows that while smaller, the transfer multiplier is still above 1, falling from about 1.5 to 1.2 at its peak.

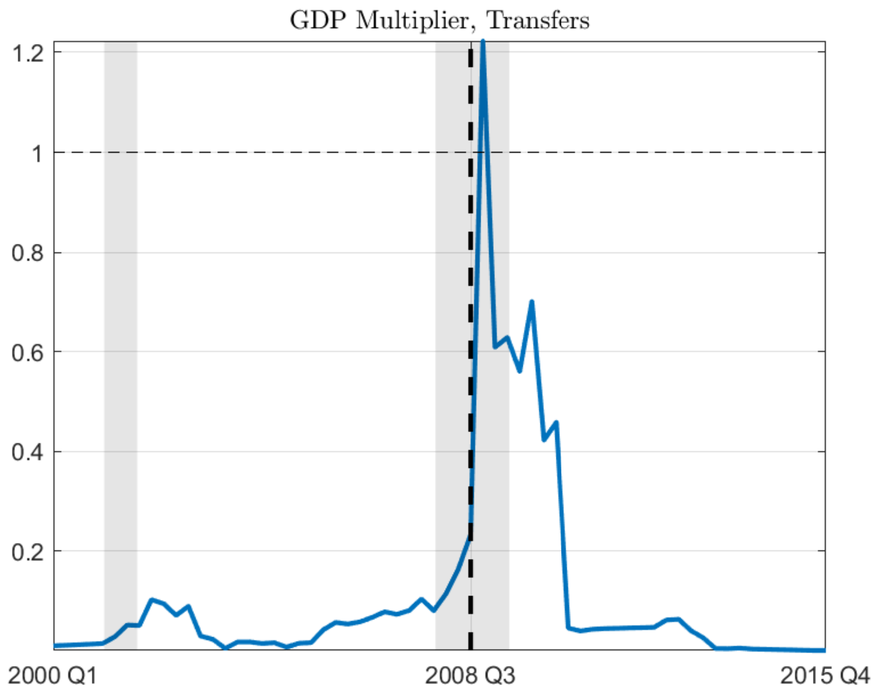


Figure A.7: Estimated time series for fiscal multipliers, 20-quarter horizon, transfers to both agents.

E.2 Endogenous Fiscal Policy and Moral Hazard

I extend the baseline model to allow for "endogenous" fiscal policy rules, in the sense that they are still governed by a Markov chain, but the parameters of the chain are allowed to depend on whether the economy is in the crisis state or not. I assume that in normal times, when outside of the crisis state, the Markov chain for each policy is the same as in the baseline economy.

$$\omega_t = [\omega_t^{\text{normal}}, \omega_t^{\text{crisis}}]^T \qquad \text{and} \qquad \mathbf{P}^{p,\text{normal}} = \begin{bmatrix} .99 & .01 \\ 1 - p_\omega & p_\omega \end{bmatrix}$$

Variable	No Policy	Exogenous Policy (Baseline)	Endogenous Policy, $q = 0.25$
Household Heverage	0.5990	0.6001	0.6007
Bank Leverage	0.7228	0.7228	0.7253
Household Default Rate	0.0199	0.0200	0.0201
Spread, Household Debt	1.8557	1.9447	1.9456
Household Debt / GDP	0.7013	0.7030	0.7110
Bank Debt / GDP	0.5069	0.5081	0.5156

Table A1: Stochastic steady state moments for no policy, baseline, and endogenous policy economies.

However, when $\sigma_t^b = \sigma^{b,\text{crisis}}$, the transition matrix changes and the probability of the policy being activated rises

$$\mathbf{P}^{p,\text{crisis}} = \begin{bmatrix} 1-q & q \\ 1-p_\omega & p_\omega \end{bmatrix}$$

where $q \in (0.01, 1]$. For simplicity, I assume the same $q = 0.25$ for all four policies. This means that, outside of a crisis, each policy has a 1% probability of being activated, but during a crisis this probability rises to 25%. Table A1 shows that household and bank leverage rise from the no policy to the baseline case, and then rise much more significantly from the baseline to the endogenous policy case. The endogenous policy economy features more debt, higher spreads, and a higher household default rate.

E.3 Robustness: Speed of Adjustment of Taxes

The parameter that governs the speed of adjustment of taxes ϕ_T is quantitatively important for the propagation of fiscal policy in the model and for the quantitative results. As explained in the main text, savers are unconstrained and thus internalize the effects of future taxes that follow fiscal interventions. This is one of the main reasons why their consumption is actually larger in the no policy counterfactual. Borrowers, on the other hand, face an occasionally binding constraint, which means that the extent to which they internalize future taxes depends on whether they are constrained or not, and on whether they expect to be constrained or not. The occasionally binding constraint is important to generate a time-varying (state-dependent) marginal propensity to consume, which in

Variable	Baseline	$\phi_T = 0.10$
Counterfactual % drop in Consumption	7.1762	5.4001

Table A2: Results for main counterfactual for alternative parametrizations of the tax policy rule.

turn is crucial for the quantitative effects of fiscal policy. The speed of adjustment of taxes is a key parameter, as it determines how fast taxes rise (or fall) upon policies being activated. In the limit, when $\phi_T \to \infty$, public debt is constant and taxes perfectly adjust to offset variations in spending. This reduces the net transfer to borrowers, and may greatly dampen the increase in consumption that follows some of these policies. Table A2 presents the results for the headline counterfactual number (cumulative drop in consumption as a percentage of its stochastic SS value) in the baseline case and in the case of a larger value for ϕ_T. It shows that a larger ϕ_T results in a smaller counterfactual percentage gain in consumption from activating fiscal policies.

E.4 Robustness: Monetary Policy Rule

In this section, I report the results for the baseline exercise with alternative parametrizations for the monetary policy rule. In the baseline calibration I set $\phi_\Pi = 2.5$ and $\phi_{GDP} = 0.5/4$, parameter values that are standard in the literature. Expanding on the discussion in section 5.5 of the main text, I show that making the CB more active reduces the magnitude of the crisis (given the rest of the calibration) and reduces the effectiveness of fiscal policy measures. Table A3 presents the results for the headline counterfactual number (cumulative drop in consumption as a percentage of its stochastic SS value) and for the maximum values of the fiscal multipliers for each of the fiscal policies. It shows that higher values for ϕ_Π and ϕ_{GDP} result in smaller values for the counterfactual percentage gain from activating fiscal policies as well as overall smaller multipliers for the fiscal policies. Conversely, lowering these values results in larger gains from activating fiscal policies as well as larger peak fiscal multipliers.

Variable	Baseline	$\phi_\Pi = 5$	$\phi_\Pi = 2$	$\phi_{GDP} = 0.5$	$\phi_{GDP} = 0.06$
Counterfactual % drop in Consumption	7.1762	0.5408	9.3083	3.7261	7.5771
Maximum $\mathcal{M}_{20}^{G}$	1.2575	1.0663	1.4614	0.9436	1.2079
Maximum $\mathcal{M}_{20}^{T_b}$	1.5372	1.0664	1.5774	1.4334	1.6783
Maximum $\mathcal{M}_{20}^{x_k}$	1.4937	5.0337	2.3324	1.3839	2.2957
Maximum $\mathcal{M}_{20}^{x_d}$	2.1109	0.2201	1.8334	1.2311	2.3564

Table A3: Results for main counterfactual and peak fiscal policy multipliers for alternative parametrizations of the Taylor rule.

E.5 Ex-Ante Multipliers

The main text of the paper focuses on *ex-post* fiscal multipliers: what would have the fiscal multiplier of each policy, at each point in time, given the estimated sequence of shocks that is estimated for the US economy? Alternatively, one can study *ex-ante* multipliers: what is the median (or average) fiscal multiplier of each policy, at each point in time, taking into account the current set of states in that period and the laws of motion for each exogenous variable? Ex-ante multipliers can be obtained by simulating the economy many times, starting from a given set of states (that estimated from the filtering exercise). Median multipliers, along with confidence intervals, are plotted in figure A.8. One important thing to note is that these multiplier distributions incorporate uncertainty regarding the future state of the economy, thus they account for the possibility of the crisis having been more or less persistent. This captures the risk that was associated with the financial sector interventions: the median ex-ante multiplier for bank recapitalizations is actually negative at the onset of the crisis, with a distribution that is extremely left-skewed (it could have been as low as -10). However, it quickly recovers, and the distribution illustrates that it could have been as high as 4. Similarly, credit guarantees have a much more modest median ex-ante multiplier than the ex-post value. The distribution for ex-ante multipliers for conventional policies is relatively tight, and the series for the ex-ante medians are relatively similar to the ex-post series.

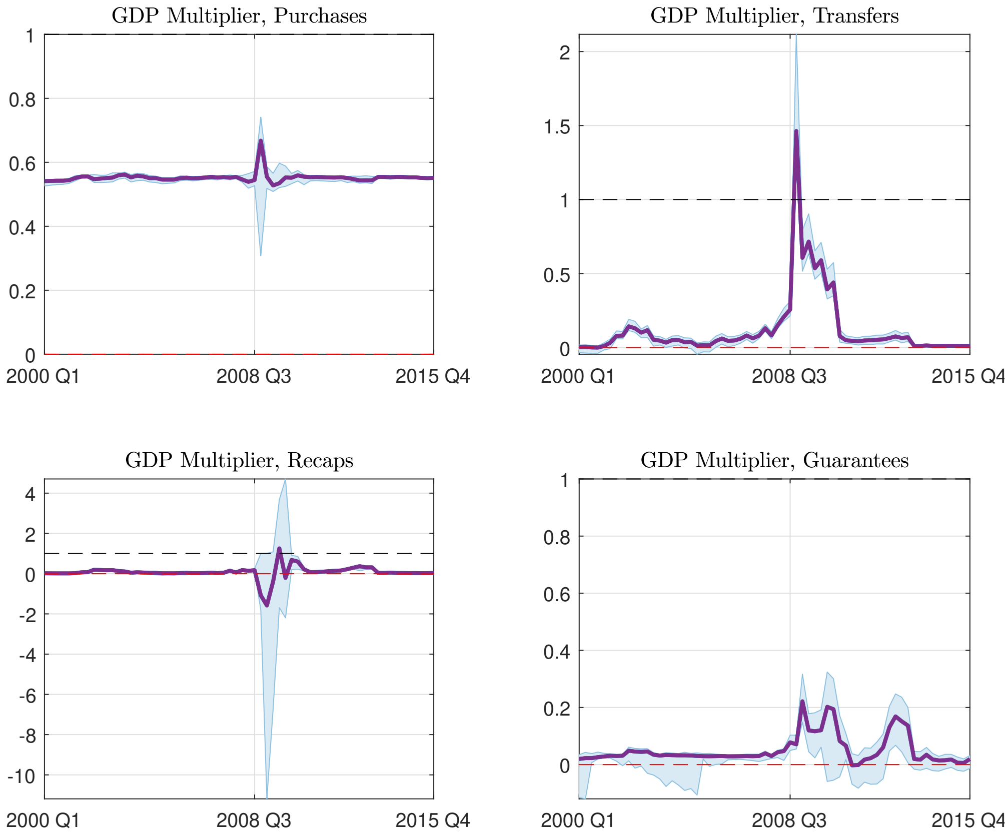


Figure A.8: Distributions for ex-ante multipliers, 20-quarter horizon, with 66% confidence intervals.

F Additional Figures

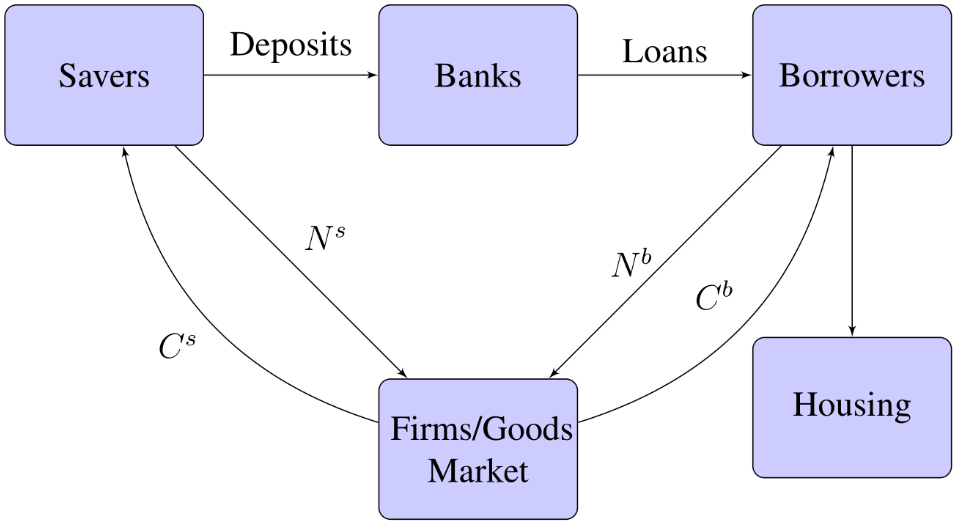


Figure A.9: Structure of the model.

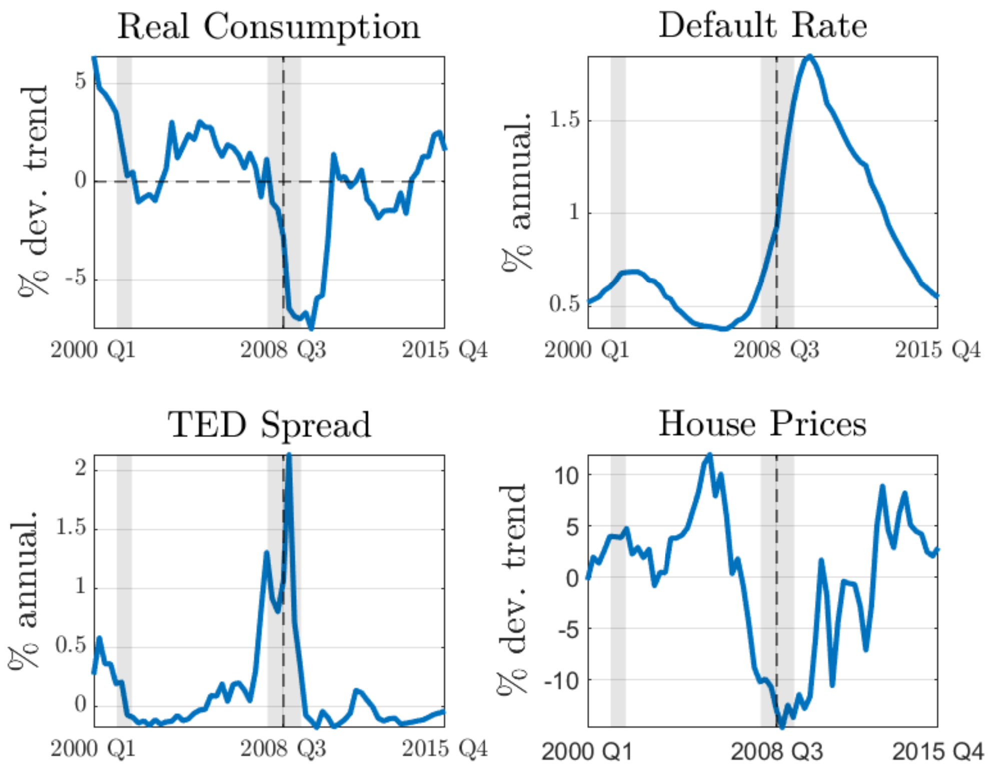


Figure A.10: Data series used for estimation (aggregate consumption and default rates) and for validation (TED spread and house prices). Sample: 2000Q1-2015Q4. Lehman Brothers failure highlighted (2008Q3). Source: FRED, Federal Reserve Bank of St. Louis.

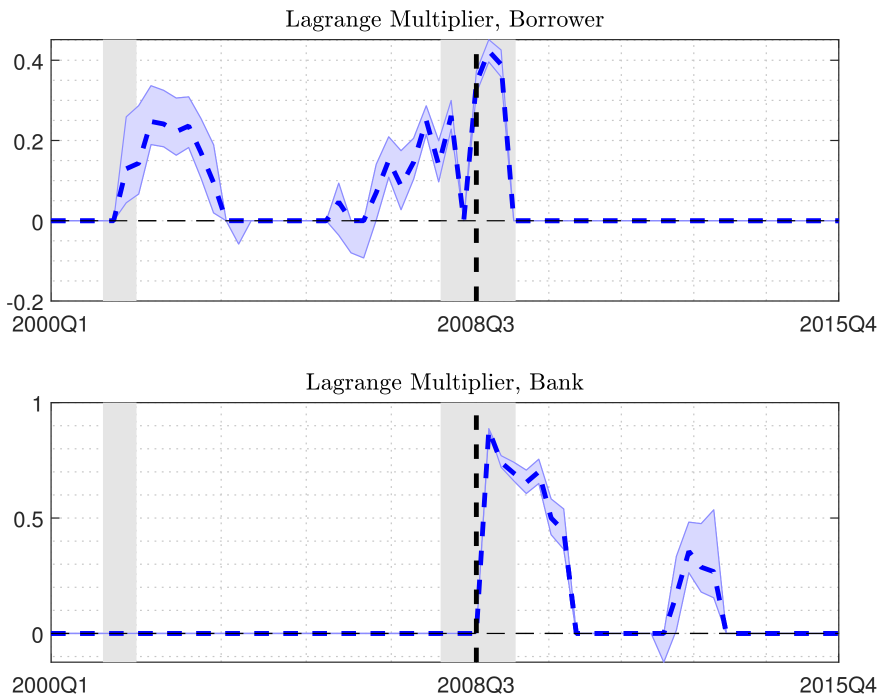


Figure A.11: Filtered series for the Lagrange multipliers.

Appendix References

Broda, C. and J. A. Parker (2014): "The Economic Stimulus Payments of 2008 and the aggregate demand for consumption," *Journal of Monetary Economics*, 68, S20–S36.

Coeurdacier, N., H. Rey, and P. Winant (2011): "The Risky Steady State," *American Economic Review*, 101, 398–401.

Cogan, J. F. and J. Taylor (2012): "What the Government Purchases Multiplier Actually Multiplied in the 2009 Stimulus Package," in *Government Policies and the Delayed Economic Recovery*, ed. by L. E. Ohanian, J. B. Taylor, and I. J. Wright, Hoover Institution, Stanford University, chap. 5.

den Haan, W. J. and A. Marcet (1990): "Solving the Stochastic Growth Model by Parameterizing Expectations," *Journal of Business & Economic Statistics*, 8, 31–34.

Dupor, W. and R. Guerrero (2017): "The Aggregate and Relative Economic Effects of Medicaid and Medicare Expansions," Tech. Rep. 2017-027A, Federal Reserve Bank of St. Louis.

GARCIA, C. AND W. ZANGWILL (1981): *Pathways to Solutions, Fixed Points, and Equilibria*, Prentice Hall.

HAMILTON, J. D. (1989): "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," *Econometrica*, 57, 357–84.

JUDD, K. (1998): *Numerical Methods in Economics*, vol. 1, The MIT Press.

JUDD, K., F. KUBLER, AND K. SCHMEDDERS (2002): "A solution method for incomplete asset markets with heterogeneous agents," Available at SSRN.

LUCAS, D. (2016): "Credit Policy as Fiscal Policy," *Brookings Papers on Economic Activity*, 52, 1–57.

PARKER, J. A., N. S. SOULELES, D. S. JOHNSON, AND R. MCCLELLAND (2013): "Consumer Spending and the Economic Stimulus Payments of 2008," *American Economic Review*, 103, 2530–53.

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