

# Fiscal Multipliers and Financial Crises

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## Abstract

What type of fiscal policy is most effective during a financial crisis? I study the macroeconomic effects of the US fiscal policy response to the Great Recession, accounting not only for standard tools such as government purchases and transfers but also for financial sector interventions such as bank recapitalizations and credit guarantees. A nonlinear quantitative model calibrated to the US allows me to study the state-dependent effects of different types of fiscal policies. I combine the model with data on the US fiscal policy response to find that the fall in aggregate consumption would have been 50% worse in the absence of that response with a cumulative loss of 9.68%. Transfers and bank recapitalizations yielded the largest fiscal multipliers at the height of the crisis, due to new transmission channels that arise from linkages between household and bank balance sheets.

JEL Codes: E4, E6, G01, G28

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# 1 Introduction

The recent 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 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 in macroeconomics. 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.

In this paper, I study the effects of these different tools in a quantitative assessment of the US discretionary fiscal policy response to the financial crisis and Great Recession. I find that these interventions were very important for stabilizing the economy: in their absence, the fall in aggregate consumption would have been 50% 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, borrower households finance housing purchases with long-term debt, subject to a loan-to-value constraint. A financial sector supplies this credit, raising short-term deposits from savers. This sector 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 fiscal tools (purchases and transfers) operate.<sup>1</sup> By raising borrower disposable income, fiscal policy also raises house prices. This reduces household leverage, relaxing borrowing constraints directly and reducing the number of defaults. In turn, banks post fewer losses and are able to lend more at lower rates, further raising current disposable income for borrowers. 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 very important to determine the effectiveness of different types of fiscal tools. This state dependence cannot be captured using standard solution techniques based on log-linearization around a steady-state. 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 (Linde and Trabandt, 2018).

I calibrate the model to the US, and use it to assess the fiscal policy response to the financial crisis of 2007-08 and the subsequent Great Recession. The calibration strategy 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 includes the Economic Stimulus Act of 2008 (ESA, the Bush tax rebates), the TARP and the ARRA of 2009 (the Obama stimulus), among others.<sup>2</sup> I map this data into the fiscal policy tools considered in the model. 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 estimates the distributions of structural shocks that allow me to study fiscal

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<sup>1</sup>Standard channels arise from the combination of monopolistic competition and nominal rigidities, as outlined in Woodford (2011). These channels are complemented by the presence of non-Ricardian agents, who have a higher marginal propensity to consume out of current income (MPC), as in Galí et al. (2007).

<sup>2</sup>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 be extended to study the latter, but that is outside of the scope of this paper.

75 policy counterfactuals.

76 I find that fiscal interventions played an important role: aggregate consumption would have  
77 fallen by twice as much in the absence of a fiscal policy response, with a total cumulative loss of  
78 almost 9.68%, or \$1.02 trillion. I decompose the contribution of the different tools and find that  
79 social transfer programs and bank recapitalizations had the largest effect on aggregate consump-  
80 tion. I argue that these large effects arise from the interaction between household and financial  
81 sector constraints. Finally, I use the estimated sequences of shocks to estimate time-varying fis-  
82 cal multipliers for different policy tools in the US. Defining the fiscal multipliers for the financial  
83 sector interventions is not trivial, and I develop an approach suited for nonlinear models that is in  
84 the spirit of [Lucas \(2016\)](#), who analyzes multipliers for federal credit policies. I find that the fis-  
85 cal multiplier for government purchases is close to 0.5 and stable during normal periods and rises  
86 during the crisis, consistent with the empirical findings of [Auerbach and Gorodnichenko \(2012\)](#) or  
87 [Ramey and Zubairy \(2016\)](#). The fiscal multipliers for transfers, bank recapitalizations, and gua-  
88 rantees, are very low (and even negative) during periods of expansion, such as the pre-crisis boom  
89 but become very high during the 2008-2009 crisis, rising above 1.

90 The effects of transfers rely on two transmission channels: the first, the direct channel, is that  
91 borrowing constraints are relaxed during expansions, which lowers the MPC for borrowers. The  
92 second, the indirect channel, requires both borrower and bank constraints to bind: by sustaining  
93 disposable income, transfers have first-order effects on house prices through the borrower sto-  
94 chastic discount factor when the borrower constraint binds. Thus transfers endogenously reduce  
95 loan-to-value and default rates, mitigating bank losses and relaxing their leverage constraint. This,  
96 in turn, allows banks to lend more and at lower rates. The strength of this second channel depends  
97 both on borrower MPC and on how tight the leverage constraint is for banks. For this reason it  
98 is particularly strong when the economy is in a recession and the financial sector is undercapitali-  
99 zed. Bank recapitalizations work in a similar way and operate mainly through this second channel,  
100 raising current lending and lowering the cost of funds, thus raising borrower disposable income.

101 **Relation to the Literature** This paper contributes to the evaluation of fiscal policy during the  
102 Great Recession, providing the first model-based comprehensive assessment of both conventional  
103 tools and financial sector interventions.<sup>3</sup> [Drautzburg and Uhlig \(2015\)](#) study conventional fiscal  
104 policy during this period in the context of a New Keynesian model; I extend their analysis by in-

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<sup>3</sup>[Blinder and Zandi \(2015\)](#) perform a similar exercise using a macroeconometric model.

cluding a financial sector. This allows me to study the impact of conventional policy through this sector, as well as non-conventional fiscal tools that are targeted at intermediaries. Since these interventions draw on the same fiscal resources as traditional tools (taxpayer dollars), it makes sense to evaluate them using the same set of criteria used to evaluate the stabilizing effects of traditional tools on the economy. [Lucas \(2016\)](#) pioneered this approach: she argues that the effective amount of stimulus provided by fiscal policy tends to be severely underestimated due to the omission of programs such as credit guarantees, particularly during severe downturns.

This work also contributes to the on-going debate about the effectiveness of the policy response to the Great Recession, especially in terms of its composition. [Mian and Sufi \(2014\)](#), for example, argue that the US government devoted too many resources to supporting the financial sector at the onset of the financial crisis while disregarding overindebted homeowners in the process of deleveraging. Several prominent policymakers have disagreed, defending the crucial role played by the financial sector in intermediating resources and ensuring that household deleveraging be orderly and controlled (i.e., [Geithner, 2015](#)). The model I develop contributes to formalizing and quantifying these arguments: I find that transfers to borrowers were very important in preventing the drop in household spending, but that financial sector support was also important and with different redistributive consequences.

Several authors have explored the state dependence of fiscal multipliers for purchases and transfers in recent research: both [Auerbach and Gorodnichenko \(2012\)](#) and [Ramey and Zubairy \(2018\)](#) empirically estimate fiscal multipliers for the US over the business cycle, finding larger multipliers during recessions. My model-based estimates for the fiscal multiplier of government spending vary within the ranges found by these studies: around 0.6 during normal times, and close to 1 during crises.<sup>4</sup>

Recent research on fiscal policy has been increasingly concerned with the impact of government transfers to households. [Oh and Reis \(2012\)](#) document that a large part of the conventional fiscal stimulus during the Great Recession was composed of social transfers (mainly Medicaid and unemployment insurance) and analyze the effectiveness of transfers and government purchases for macroeconomic stabilization in an Aiyagari-Bewley model with nominal rigidities. [Kaplan and Violante \(2014\)](#) further develop this argument, using data from the Survey of Consumer Finances

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<sup>4</sup>For other model-based treatments of the state dependence of fiscal multipliers, see [Canzoneri et al. \(2016\)](#), [Mertens and Ravn \(2014\)](#), and [Brinca et al. \(2018\)](#). In an empirical analysis, [Barnichon and Matthes \(2017\)](#) find that US government spending multipliers are larger for fiscal contractions than for expansions.

and a structural model to show that the liquidity of household asset portfolios matters for their MPC and, therefore, for the consumption response to tax rebates. Unlike these studies, I do not consider a full-blown Aiyagari-Bewley heterogeneous agents model, but I draw on their findings to motivate the introduction of a limited type of heterogeneity in my model in the tradition of [Campbell and Mankiw \(1989\)](#): I consider two types of households who differ in their preferences and access to financial assets. Savers are permanently unconstrained and act in a manner fully consistent with Ricardian equivalence, accounting for the fact that current fiscal deficits are future tax liabilities. Borrowers, on the other hand, face a borrowing constraint and are non-Ricardian. Unlike most of the literature, I do not assume that these agents are permanently constrained: in my model, their MPC varies with the state of the economy, as the borrowing constraint may or may not bind. I also improve on existing work by considering the role that transfers they play in the interaction between the household and financial sectors. In my model, transfers reduce default rates by borrowers and help keep the financial system well capitalized. Through this novel channel, this results in lower lending spreads and enables the flow of credit between different types of agents.<sup>5</sup>

My paper also 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 are preferable. I find that, for the purpose of macroeconomic stabilization, this may change with the state of the economy, in particular depending on which constraints bind and which sector has the highest level of leverage. Several papers have analyzed the impact of interventions such as bank bailouts on private incentives and their implications for moral hazard and excessive risk-taking in the financial sector: [Farhi and Tirole \(2012\)](#), [Jeanne and Korinek \(2013\)](#), and [Chari and Kehoe \(2016\)](#) all study how, in one way or another, the expectation of transfers in states of the world with a financial crisis may raise the likelihood that such a crisis materializes in the first place. While such anticipation effects exist in my model, they are not the focus of my analysis. Financial crises are exogenous events in my model, even though the state of the economy (in particular household and bank leverage) matters for how severe the crisis is. This literature tends to focus on optimal policy from an *ex-ante* perspective, while I am interested in analyzing the *ex-post*

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<sup>5</sup>Related mechanisms have been studied by [Paixao \(2018\)](#) and [Ferrante \(2018\)](#). [Gali et al. \(2007\)](#) first emphasized that the effects of fiscal policy could be amplified in borrower-saver models. See also [Mehrotra \(2018\)](#) and [Pennings \(2016\)](#) for recent studies that use this device to study the impact of transfers and how their effects depend on the distribution of MPC. [Athreya et al. \(2017\)](#) also argue that the effects of transfers depend on the distribution of the marginal propensities to work.

effects of fiscal interventions.<sup>6</sup>

**Structure** The rest of the paper is organized as follows: section 2 describes the model and defines the equilibrium. Section 3 discusses the model calibration and solution. Section 4 explains the key mechanisms in the model, emphasizing the interactions between the balance sheets of the different sectors. In section 5, I conduct the main quantitative exercise of this work, which consists of evaluating fiscal policy during the Great Recession, and 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. The model is set up in discrete and infinite time,  $t = 0, 1, 2, \dots$ . The economy is populated by five types of agents: households, who can be either borrowers or savers; financial firms (commercial banks); a corporate sector consisting of intermediate goods producers and final goods retailers; a central bank; and a fiscal authority.

The structure of the model is summarized in Figure 1: borrowers differ from savers to the extent that they derive utility from housing services and can finance housing purchases by borrowing in long-term debt contracts. Banks intermediate funds between savers and borrowers, originating long-term loans and borrowing in short-term deposits. Both borrowers and savers supply their labor to monopolistically competitive producers of intermediate goods, who in turn supply a representative retailer of final goods. Borrowers can default on their payments to the bank, and banks can default on their deposit payments to savers. The central bank sets the policy rate using a standard Taylor rule.<sup>7</sup>

There are two exogenous shocks in 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

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<sup>6</sup>Kollmann et al. (2013), Prestipino (2014) and Bianchi (2016) also analyze equity injections in the context of dynamic stochastic models. In these models, financial intermediaries allocate savings from depositors to investors/producers, unlike in my model where banks intermediate credit between households with different MPC in a way that is more similar to Cúrdia and Woodford (2010).

<sup>7</sup>The overall structure is reminiscent of the models developed by Iacoviello (2015), Landvoigt (2016), and Ferrante (2018)

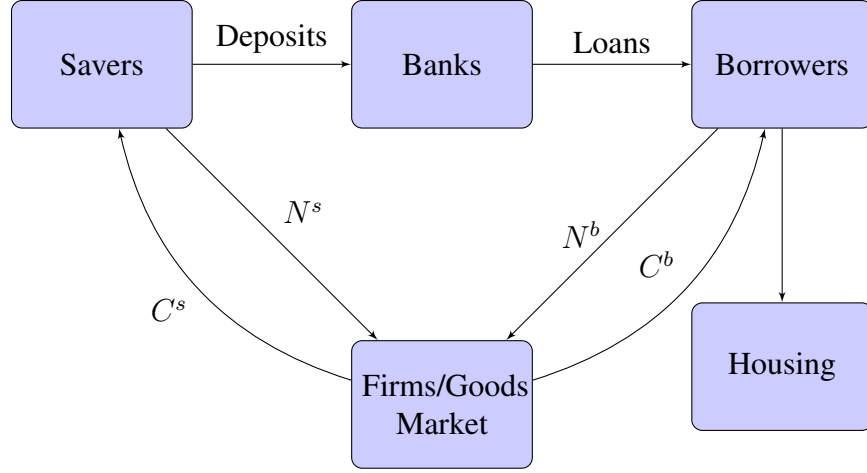


Figure 1: Structure of the model.

(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  $i = \{b, s\}$  and in measures  $\chi$  and  $1 - \chi$ , respectively. Households differ in terms of the preferences and the type of financial assets they have access to. Savers can invest in short-term 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,

$$V_t^i = u_t^i + \beta^i \mathbb{E}_t(V_{t+1}^i) \quad (1)$$

Household preferences differ in only one dimension: borrowers derive utility from houses. Instantaneous utility is defined over streams of consumption  $C_t^i$ , labor  $N_t^i$ , and housing  $h_t^i$ , and is given by

$$u_t^i = \log(C_t^i) - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} + \xi^i \log(h_t^i)$$



Logarithmic preferences over consumption implicitly set the elasticity of intertemporal substitution to 1;  $\varphi$  is the inverse of the Frisch elasticity of labor supply, and  $\xi^i$  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.<sup>8</sup>

### 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,  $\tau$  is a linear tax on labor,  $T_t$  are net lump-sum taxes/transfers from the government, and  $\Gamma_t$  are net profits and transfers from the corporate and financial sectors. Savers own all firms and banks in this economy.  $Z_t^d$  is the payoff per unit of deposits, only realized at  $t$  due to the possibility of bank failure and liquidation as explained below. Saver first-order conditions are standard and consist of asset-pricing conditions for deposits and for government debt (the Euler equation) as well as an intratemporal labor supply condition.<sup>9</sup> It is useful to define the saver's stochastic discount factor for real payoffs:

$$\Lambda_{t,t+1}^s \equiv \beta^s \frac{C_t^s}{C_{t+1}^s} \quad (2)$$

### 2.1.3 Borrowers

Borrowers derive utility from housing services and borrow in long-term debt contracts to finance house purchases.

**Debt Contracts, Default, and Foreclosures** Banks offer long-term debt contracts to borrowers: each contract has a face value of \$1 and a market price of  $Q_t^b$ . These contracts are geometrically decaying perpetuities with a coupon/decay rate of  $\gamma \in [0, 1]$ , as in [Woodford \(2001\)](#). To obtain partial default in equilibrium while keeping the model environment tractable, I assume a family

<sup>8</sup>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 fragmented.

<sup>9</sup>All equilibrium conditions, including the saver's optimality conditions, are reported in [Appendix A.1](#).

construct for the borrower following [Landvoigt \(2016\)](#).<sup>10</sup> The borrower family enters period  $t$  with an outstanding nominal debt balance  $P_{t-1}\bar{B}_{t-1}^b$  and a total stock of housing  $h_{t-1}$ .<sup>11</sup>

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  $(P_{t-1}\bar{B}_{t-1}^b, h_{t-1})$ . 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  $F_t^b[0, +\infty)$  and satisfying  $\mathbb{E}_t[\nu_t(i)] = 1, \forall t$ .

Family members who do not move (a fraction  $1 - m$ ) simply fulfill their debt payment in the current period  $\gamma \times P_{t-1}\bar{B}_{t-1}^b$ . 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  $P_{t-1}\bar{B}_{t-1}^b$ , and the market value of their house is  $P_t p_t^h \times \nu_t(i) h_{t-1}$  given the quality adjustment.<sup>12</sup> Upon default, the lender seizes the housing assets that serve as collateral; i.e., the house gets foreclosed.

Given the resale value of housing, each family member chooses to repay her maturing debt 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  $\nu$ . This indicator function is equal to 1 if this member defaults on her debt repayments, and zero otherwise. After default and repayment decisions are made, members reconvene in the borrower household, who then takes all relevant decisions for the current period (including the values of the states for the following period). End-of-period debt balances for the borrower family equal new borrowings  $L_t$  plus non-prepaid balances net of the current coupon:

$$P_t \bar{B}_t^b = P_t L_t + (1 - m)(1 - \gamma) P_{t-1} \bar{B}_{t-1}^b \quad (3)$$

**Budget and Borrowing Constraints** Once individual members have made their default decisions, they are regrouped in the borrower household, who chooses all control variables: consumption, labor supply, new borrowing, and new housing as well as the default rules for each individual

<sup>10</sup>Similar approaches are adopted by [Jeske et al. \(2013\)](#) and [Elenev et al. \(2016\)](#).

<sup>11</sup>The upper bar is the per capita variable. Since there is a mass  $\chi$  of borrowers, the aggregate level of debt is  $B_{t-1}^b = \chi \bar{B}_{t-1}^b$ .

<sup>12</sup>This housing quality shock can alternatively be interpreted as a housing depreciation shock. The important feature is that it is technological, affecting the house's exchange rate for final goods, and not a preference shock.

member.<sup>13</sup> The budget constraint written in real terms is

$$\begin{aligned} C_t^b + \frac{\bar{B}_{t-1}^b}{\Pi_t} \left[ (1-m)\gamma + m \int [1 - \iota_t(\nu)] dF_t^b \right] + p_t^h h_t^* \\ = (1-\tau)w_t N_t^b + Q_t^b L_t + p_t^h h_{t-1} m \int \nu [1 - \iota_t(\nu)] dF_t^b - T_t + T_t^b \end{aligned} \quad (4)$$

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 (3). The law of motion for the stock of housing is

$$h_t = h_t^* + (1-m)h_{t-1} \quad (5)$$

The borrower family is subject to a loan-to-value constraint on new borrowing: new debt balances contracted this period cannot exceed a fraction of the value of new housing purchases,<sup>14</sup>

$$L_t \leq \theta^{LTV} p_t^h h_t^* \quad (6)$$

**Optimality** 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 (3)-(6). 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 this threshold satisfies

$$\nu_t^* = \frac{\bar{B}_{t-1}^b}{\Pi_t p_t^h h_{t-1}} \quad (7)$$

Basically, a “moving” member of the borrower household behaves as having limited liability when it 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

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<sup>13</sup>This arrangement is thus implicitly 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.

<sup>14</sup>A constraint on borrowing at origination is a more realistic assumption than the more common constraint on the total stock of debt. In practice, households are not subject to marginal calls on their mortgages by financial institutions (i.e., demand for repayment should the value of collateral fall below the value of debt). The two types of constraints coincide for 1-period debt.

248 relevant optimality condition is the asset-pricing equation for housing, which takes the form

$$p_t^h = \frac{\frac{\xi}{h_t} C_t^b + \mathbb{E}_t \left\{ \Lambda_{t,t+1}^b p_{t+1}^h [(1-m)(1 - \lambda_{t+1}^b \theta^{LTV}) + m \Psi_{t+1}^b(\nu_{t+1}^*)] \right\}}{1 - \lambda_t^b \theta^{LTV}} \quad (8)$$

249 where  $\lambda_t^b$  is the Lagrange multiplier on the borrowing constraint (6) and  $\Lambda_{t,t+1}^b$  is the borrower's  
 250 stochastic discount factor for real payoffs, defined analogously to (2).  $\Psi_{t+1}^b(\nu_{t+1}^*)$  is a partial  
 251 expectation term for the house quality shock, defined as

$$\Psi_t^b(\nu_t^*) \equiv \int_{\nu_t^*}^{\infty} \nu dF_t^b(\nu)$$

252 Condition (8) highlights that changes in borrower consumption have a first-order effect on house  
 253 prices, both through the current utility dividend from housing services and through the stochastic  
 254 discount factor that is applied to the continuation value.

#### 255 2.1.4 Corporate Sector

256 The corporate sector consists of final goods retailers and intermediate goods producers. Final  
 257 goods retailers are perfectly competitive and employ a continuum of intermediate goods varieties  
 258 indexed by  $k \in [0, 1]$  to produce the final good using a Dixit-Stiglitz aggregator with constant  
 259 elasticity of substitution  $\varepsilon$

$$Y_t = \left[ \int_0^1 Y_t(k)^{\frac{\varepsilon}{\varepsilon-1}} dk \right]^{\frac{\varepsilon-1}{\varepsilon}}$$

260 There is a continuum of intermediate goods producers, each producing a different variety  $k$ . All  
 261 firms are owned by the savers and have access to a linear production technology in labor,

$$Y_t(k) = A_t N_t(k)$$

262 where  $A_t$  is an exogenous aggregate TFP shock. Given the constant elasticity of substitution  
 263 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 as in Rotemberg (1982), with a standard quadratic functional form of the type

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

where  $\Pi$  is the inflation target set by the central bank (so that it is free to adjust to keep up with trend inflation) and  $\eta$  is the menu cost parameter. Appendix A.2 presents the details on the firm's problem. It shows that the first-order condition for an individual price-setting firm  $k$  combined with the assumption of a symmetric equilibrium yields a standard (nonlinear) Phillips curve that relates inflation to aggregate output:

$$\eta \frac{\Pi_t}{\Pi} \left( \frac{\Pi_t}{\Pi} - 1 \right) + \varepsilon \left( \frac{\varepsilon - 1}{\varepsilon} - \frac{w_t}{A_t} \right) = \eta \mathbb{E}_t \left[ \Lambda_{t,t+1}^s \frac{Y_{t+1}}{Y_t} \frac{\Pi_{t+1}}{\Pi} \left( \frac{\Pi_{t+1}}{\Pi} - 1 \right) \right] \quad (9)$$

### 2.1.5 Financial Sector

The modeling of the financial sector broadly follows Gertler and Kiyotaki (2010), 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 (Begenau et al., 2015). 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.

There is a continuum of banks indexed by  $j \in [0, 1]$ , wholly owned by savers. 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  $Z_t^b$ . 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

$$P_t e_{j,t} = u_{j,t} Z_t^b P_{t-1} b_{j,t-1} - P_{t-1} d_{j,t-1} \quad (10)$$

Banks that are unable to fully repay their depositors default. This means that  $\exists u_{j,t}^*$  such that the

287 bank defaults if and only if  $u_{j,t} < u_{j,t}^*$ , where

$$u_{j,t}^* = \frac{d_{j,t-1}}{Z_t^b b_{j,t-1}}$$

288 The default threshold is equal to the bank's leverage divided by the aggregate return on the bank's  
 289 assets. This means that periods of high household default, when  $Z^b$  is low, may also trigger waves  
 290 of bank default, and this is more likely when bank leverage is high.

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

$$Q_t^b b_{j,t} = \theta e_{j,t} + Q_t^d d_{j,t} \quad (11)$$

295 The bank also faces a leverage constraint, which constrains the market value of its assets not to  
 296 exceed the ex-dividend market value of the bank. Let  $V_{j,t}(e_{j,t})$  denote the real market value of the  
 297 bank at the beginning of the period, before dividends are paid. The ex-dividend value of the bank  
 298 is then given by

$$\Phi_{j,t}(e_{j,t}) \equiv V_{j,t}(e_{j,t}) - (1 - \theta)e_{j,t}$$

299 The constraint imposes that this value must always exceed a fraction  $\kappa$  of the market value of the  
 300 bank's assets,

$$\Phi_{j,t}(e_{j,t}) \geq \kappa Q_t^b b_{j,t} \quad (12)$$

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

$$V_{j,t}(e_{j,t}) = \max_{b_{j,t}, d_{j,t}} \left\{ (1 - \theta)e_{j,t} + \mathbb{E}_t \left[ \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} \max \{0, V_{j,t+1}(e_{j,t+1})\} dF^d \right] \right\} \quad (13)$$

304 Banks solve (13) subject to the law of motion for earnings (10), the flow of funds constraint (11),  
 305 and the capital requirement (12). A detailed derivation of the bank's problem may be found in  
 306 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

$$\mathbb{E}_t \left\{ \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) \left[ \Psi^d(u_{j,t+1}^*) \frac{Z_{t+1}^b}{Q_t^b} - \frac{1 - F^d(u_{j,t+1}^*)}{Q_t^d} \right] \right\} = \kappa \mu_{j,t} \quad (14)$$

where  $\Psi^d(u_t^*) \equiv \int_{u_t^*}^{\infty} u dF^d(u)$  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

$$\Phi_{j,t} = \frac{\mathbb{E}_t \left\{ \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) [1 - F^d(u_{j,t+1}^*)] \right\}}{Q_t^d (1 - \mu_{j,t})} \quad (15)$$

**Aggregation and Bank Entry** Since the shocks  $u_{j,t}$  are i.i.d. across banks and time, condition (15) 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. Since all banks take proportional portfolio decisions, this also means 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, in particular, allows us to focus the analysis on a representative bank whose earnings correspond to aggregate earnings for the banking system net of defaults.

Aggregate earnings  $P_t E_t$  are comprised of earnings of surviving banks  $P_t E_t^s$  plus earnings of new banks  $P_t E_t^n$ . Earnings for surviving banks are given by

$$P_t E_t^s = P_{t-1} \theta \int_{u_t^*}^{\infty} [u_{j,t} Z_t^b b_{j,t-1} - d_{j,t-1}] dF^d(u_{j,t}) = P_{t-1} \theta \{ \Psi^d(u_t^*) Z_t^b B_{t-1}^b - [1 - F^d(u_t^*)] D_{t-1} \}$$

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

$$P_t E_t^n = \varpi P_{t-1}$$

327 and thus real aggregate bank earnings evolve as

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

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

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

335 where the value of recovered and resold houses is implicit in  $\nu_t^* = \frac{B_{t-1}^b}{\Pi_t p_t^h h_{t-1}}$ . Similarly, for bank  
 336 deposits, we define the unit return as  $Z_t^d$ , which can be written as

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

### 337 2.1.6 Housing

338 I assume that the housing market is segmented: borrowers are the only agents that derive utility  
 339 from housing services and the only agents that are allowed to hold housing assets intertemporally.  
 340 This implies that house prices are fully determined with the borrower's stochastic discount factor.  
 341 Movements in house prices are important in determining equilibrium default rates and generate  
 342 pecuniary externalities through the borrowing constraint.<sup>15</sup> Foreclosed houses that are acquired  
 343 by the banks are immediately resold back to the borrowers. For simplicity, I also assume that the  
 344 supply of housing is fixed and normalized to 1,  $h_t = 1, \forall t$ . This assumption, coupled with the fact  
 345 that  $\mathbb{E}_t(\nu) = 1 \forall t$ , means that the total, quality-adjusted supply of housing in the economy is equal

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<sup>15</sup>This assumption of market segmentation has also been used by [Garriga et al. \(2017\)](#) and [Greenwald \(2016\)](#), for example.



346 to 1 at every point in time,  $h_t \int \nu dF_t^b(\nu) = 1 \forall t$ .<sup>16</sup>

### 347 2.1.7 Labor Markets

348 I follow the literature (Debortoli and Gali, 2017) in assuming that the real wage schedule follows  
349 a rule of the type

$$w_t = \mu^w C_t^\sigma N_t^\varphi$$

350 where  $\mu^w$  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.  
351 I assume that labor is proportionally rationed between both types, so that  $N_t^b = N_t^s = N_t$ . This  
352 can be microfounded as the outcome of the problem for a wage-setting union, and is useful to  
353 rule out certain types of counterfactual behavior (such as borrower labor greatly expanding during  
354 recessions).<sup>17</sup>

### 355 2.1.8 Government

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

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

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

357 where  $\bar{GDP}, \bar{Q}$  are the steady-state values of output and the nominal interest rate. I define  $GDP_t \equiv$   
358  $C_t + G_t$ , that is, output net of resource costs. Since I depart from the standard representative agent  
359 framework, it is not obvious what optimal monetary policy should look like outside of a standard  
360 linear-quadratic framework, as pointed out by McKay and Reis (2016). While acknowledging this,  
361 I nevertheless choose the above Taylor rule for two reasons: (i) it has been extensively shown to  
362 be a good representation of Federal Reserve behavior post Volcker, and (ii) it allows me to remain  
363 as close to the existing literature as possible.

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<sup>16</sup>This normalization is chosen to simplify algebra and the derivation of the aggregate resource constraints but is easily relaxed — the model can be easily extended to handle aggregate shocks to the average quality of housing.

<sup>17</sup>Qualitatively, most of the subsequent results are robust to relaxing this assumption.

**Zero Lower Bound and Unconventional Monetary Policy (UMP)** Some authors have argued that a “shadow” measure of the policy rate that can take negative values can proxy for the macroeconomic effects of unconventional monetary policy (Wu and Xia, 2016). I follow this approach, meaning that the current model features neither a zero lower bound on the policy rate nor an explicit modeling of UMP, such as asset purchases by the central bank. In the quantitative exercise that follows, I show that the zero lower bound (ZLB) is not a necessary condition to generate state dependence of fiscal multipliers, particularly during periods of financial distress.<sup>18</sup> 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.<sup>19</sup>

**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

$$P_{t-1}B_{t-1}^g + P_t G_t + T_t^b + \sum_{\omega \in \Omega} \text{Net Costs}_\omega = \tau P_t Y_t [1 - d(\Pi_t)] + P_t T_t + Q_t P_t B_t^g \quad (16)$$

On the left-hand side we have expenditures: maturing debt, government purchases of the final goods, and net costs of extraordinary fiscal measures  $\omega \in \Omega$ . On the right-hand side we have sources of funds: income taxes, lump-sum taxes, and bond issuances. Income taxes are levied on corporate profits and labor income, which can be shown to be 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  $\tau$  as well as 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 steady-state level according to a simple fiscal rule of the form

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

<sup>18</sup>For a thorough analysis of the behavior of fiscal multipliers at the ZLB, see Christiano et al. (2011). For quantitative analyses of the ZLB that use nonlinear solution methods, see Aruoba et al. (2018) and Gust et al. (2017).

<sup>19</sup>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.

where  $\bar{B}^g$  is the steady-state level of public debt and  $\phi_T$  is the speed of adjustment: as discussed later in the calibration section, this parameter will be set to a small number so that large changes in fiscal outlays or revenues are mostly reflected in movements of public debt in the short-run.

**Modeling Financial Interventions** While government purchases and transfers to borrowers are standard in macroeconomic models, including equity injections and credit guarantees is less common. One feature that is important to capture is that both of 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 is able to fully recover its investments, or be very expensive in the other states where the financial sector is distressed and unable to repay government commitments. Assessing the effectiveness and cost-benefits of these fiscal policies should reflect these *ex-ante* uncertain costs.

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  $x_t^k \geq 0$  denote the government equity injection at  $t$ , as a percentage of equity. This percentage entitles the government to a stream of dividends equal to a fraction  $\theta^k$  of the bank's equity, and these dividends are paid before common stock. Importantly, these are still equity claims and the government loses its investment if the bank fails; in other words, the government acquires a claim that is junior to deposits. At the time of the subsidy, the equity claim appears in the bank's budget constraint as a subsidy to current book equity

$$Q_t^b B_t^b = (1 + x_t^k) E_t + Q_t^d D_t$$

with a current cost equal to  $x_t^k \theta E_t$  for the government. We let  $s_t^k$  denote the share of equity in the banking system that is currently owned by the government. The law of motion for this state variable is

$$s_t^k = \frac{\theta^k [1 - F^d(u_t^*)] s_{t-1}^k + x_t^k}{1 + x_t^k}$$

Note that, absent new injections, the claim decays at rate  $\theta^k$  — potentially faster if these recapitalized banks fail. From the point of view of the bank, while this intervention can help relax constraints in the short-run, it becomes expensive in the long-run as it reduces earnings that can be invested and/or paid out to equity holders. Due to the preferred dividend payments, the law of

407 motion for equity in the banking system becomes

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

408 Credit guarantees, on the other hand, are modeled similarly to deposit insurance: many of the  
 409 extraordinary guarantee programs deployed by the Treasury and the Federal Deposit Insurance  
 410 Corporation (FDIC) during this period were guarantees over non-deposit debt issued by financial  
 411 institutions. Let  $s_t^d \in [0, 1]$  be the fraction of bank debt that is guaranteed at  $t + 1$ : for the guarantee  
 412 to be effective, it must be announced a period before. The law of motion for this variable is

$$s_t^d = \theta^d[1 - F^d(u_t^*)]s_{t-1}^d + x_t^d$$

413 where  $\theta^d$  is the rate of decay of the guarantee and  $x_t^d \in [0, \theta^d[1 - F^d(u_t^*)]s_{t-1}^d]$  are new guarantees  
 414 announced this period. At each point in time, the government guarantee entitles the depositor to  
 415 a guaranteed return equal to a fraction  $s_t^d$  of the investment at  $t + 1$ . The effective return for the  
 416 depositor then becomes

$$Z_{t+1}^d = s_t^d + (1 - s_t^d) \left[ 1 - F^d(u_{t+1}^*) + (1 - \lambda^d) \frac{1 - \Psi^d(u_{t+1}^*)}{u_{t+1}^*} \right]$$

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

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

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

## 2.2 Equilibrium

Equilibrium is defined in the standard way: it 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. A full list of the model's equilibrium conditions is provided in Appendix A.1.

For reference, the aggregate resource constraint is given by

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

where  $Y_t \equiv A_t N_t$  is gross output,  $C_t \equiv \chi C_t^b + (1 - \chi) C_t^s$  is aggregate consumption, and  $N_t = N_t^b = N_t^s$  are aggregate hours. Throughout, I focus on the fiscal multiplier of fiscal policies over GDP, which I define as total consumption by the private and public sectors,<sup>20</sup>

$$GDP_t = C_t + G_t$$

## 3 Model Calibration and Solution

Before presenting the main quantitative experiment, I discuss the calibration and the solution method.

### 3.1 Calibration

The period in the model is a quarter. Most parameters are chosen so that the model's stochastic steady-state matches moments of the US economy and financial system in the early 2000s, prior to the 2007 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 steady-state. The inverse Frisch elasticity of labor supply is set to be  $\varphi = 1$ , which is an average value in macroeconomic models in the absence of

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<sup>20</sup>Menu costs are very small, and including them or not does not affect the results.

any sort of labor market frictions or wage rigidities. The elasticity of substitution across varieties is set at  $\varepsilon = 6$ , implying an average markup of 20% at the steady-state. To choose the Rotemberg menu cost parameter, I set  $\eta$  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%. This corresponds to a “Calvo parameter” of 0.80, consistent with recent estimates in the literature. This procedure yields  $\eta = 98.06$ . I assume that the productivity 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 central bank pursues an annualized inflation target of 2%. For fiscal policy flows, I assume standard targets as percentages of steady-state output. I set  $\bar{G}$  to be 20% of steady-state GDP, which is the US average. The value of  $\bar{B}^g$ , the steady-state level of public debt, matters for determining the tax rate, as  $\bar{\tau}$  emerges as the rate that balances the government’s budget in steady-state. I set  $\bar{B}^g$  to be equal to 60% of annual GDP. At the steady-state, 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 during and after 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 loan-to-value (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  $\xi$  is jointly chosen to generate a ratio of household debt to GDP of 70% at the stochastic steady-

456 state, the value in the early 2000s.<sup>21</sup> The coupon rate  $\gamma = 0.0188$  is chosen to match an effective  
 457 mortgage duration of 4 years with prepayment taken into account. Similarly, it implies a maturity  
 458 mismatch for banks close to what has been documented in the data (English et al., 2018).

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 parameter,  $\sigma_t^b$ . The beta assumption implies that we have closed-form expressions for the distribution function and partial expectations that appear in the equilibrium conditions:

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

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

459 I assume that  $\sigma_t^b$  follows a two-state Markov chain, with a high- and a low-risk state,  $\sigma_t^b \in$   
 460  $\{\sigma^{b,\text{crisis}}, \sigma^{b,\text{normal}}\}$ . The transition probability matrix is

$$\mathbf{P}^b = \begin{bmatrix} 0.85 & 0.15 \\ 0.01 & 0.99 \end{bmatrix}$$

461 This means that crises are infrequent but relatively persistent. The economy has an unconditional  
 462 probability of 6.25% of being in a high risk state. To choose the values of the states, I target a  
 463 steady-state default rate of 0.5%. This yields  $\sigma^{b,\text{normal}} = 2.9329$ . I set  $\sigma^{b,\text{crisis}}$  to 35% of that value,  
 464 which generates a default rate of 1.5%, three times larger. These probabilities also imply that the  
 465 economy spends, on average, one year and a half in a financial crisis, consistent with the estimates  
 466 by Jordà et al. (2016). Liquidation losses from mortgages are assumed to be equal to  $\lambda^b = 0.30$   
 467 in the low-risk state, and twice as large  $\lambda_h^b = 0.60$  in the high-risk state, which is in line with  
 468 the evidence on loss-given-default rates for US bank secured loan portfolios in Ross and Shibut  
 469 (2015).

470 **Fraction of Borrowers and Discount Factor** Two crucial parameters are the fraction of borro-  
 471 wers  $\chi$  and their discount factor  $\beta^b$ , which I pick to ensure that the model is able to replicate the es-

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<sup>21</sup>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.

estimates of [Parker et al. \(2013\)](#) of the impact of the 2008 Bush tax rebate on aggregate consumption. I choose  $\chi, \beta^b$  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, annualized values in the middle of the range of the authors' estimates. Setting  $\chi = 0.47, \beta^b = 0.9934$  achieves the desired effect. The value for  $\chi$  is broadly consistent with the fraction of borrowers estimated and/or calibrated by other authors based on different datasets and targets. Using 2001 Survey of Consumer Finances (SCF) data, [Kaplan and Violante \(2014\)](#) estimate that between 17.5% and 35% of households are hand-to-mouth in the US. While this number is lower than mine, borrowers in the model will not behave as hand-to-mouth when their borrowing constraint is not binding. [Broda and Parker \(2014\)](#) estimate that around 40% of households in the US are liquidity constrained, based on Nielsen survey data. Finally, [Elenev et al. \(2016\)](#) use several waves of the SCF to estimate the fraction of the population with negative fixed income positions and arrive at 47%, a number very close to mine. The value for  $\beta^b$  is very close to that of  $\beta^s$  (the saver discount factor), and ensures that borrowers are unconstrained at the stochastic steady state.

**Banking** The retained earnings parameter  $\theta = 0.80$  and the transfer to starting banks  $\varpi = 0.018$  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 steady-state. These values ensure that the bank constraint does not bind at the steady-state. The distribution for bank idiosyncratic shocks is a generalized beta with support  $[\underline{u}, \bar{u}]$  and given by

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

I set  $\sigma^d = 1, \underline{u} = 0.91, \bar{u} = 1.09$ . This ensures that the mean asset quality shock is equal to 1, and that the probability of bank default is zero at the deterministic steady-state. Along with  $\lambda^d = 0.10$ , the choice of this distribution ensures that the spread between deposits and government bonds is close to 0.12% annualized, the level of the TED spread in the pre-crisis period, and that it rises to close to 2.00% annualized at the peak of the crisis.<sup>22</sup> The leverage constraint parameter is chosen to match a leverage ratio of around 10 for large US commercial banks,  $\kappa = 0.1$ .

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<sup>22</sup>The TED Spread is a commonly used measure of cost of funding for banks in the interbank market, and is defined as the difference between the 3-month LIBOR in US dollars and the 3-month Treasury bill.



Parameter	Description	Value	Target
<i>Standard Parameters</i>			
$\beta^s$	Discount factor saver	0.9951	Annualized real interest rate of 2%
$\varphi$	Frisch elasticity	1	Standard
$\varepsilon$	Micro elasticity of substitution across varieties	6	20% markup in SS
$\eta$	Rotemberg Menu Cost	98.06	Prices adjusted once every five quarters
<i>Policy Parameters</i>			
$\bar{G}$	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
$\bar{\Pi}$	Trend Inflation	$1.02^{0.25}$	2% for the US
$\phi_{\Pi}$	Taylor rule: Inflation	2.5	Standard, inflation volatility
$\phi_Y$	Taylor rule: Output	0.5/4	Standard
$\phi_{\tau}$	Fiscal Rule	0.01	<a href="#">Leeper et al. (2010)</a>
<i>Borrower Parameters</i>			
$\chi$	Fraction of borrowers	0.47	Response of consumption to ESA'08 in <a href="#">Parker et al. (2013)</a>
$\beta^b$	Discount factor borrower	0.9934	Response of consumption to ESA'08 in <a href="#">Parker et al. (2013)</a>
$\theta^{LTV}$	Maximum LTV at origination	0.85	<a href="#">Greenwald (2016)</a>
$m$	Fraction of movers	0.0537	Aggregate LTV of 60%
$\xi$	Housing preference	0.1419	Debt to GDP of 70%
$\sigma^b$	House quality distr.	2.9329	Annual default rate of 0.5%
$\lambda^b$	Loss given default	0.3	FDIC data
$\gamma$	Maturity of debt	0.0188	Effective mortgage maturity 4 yrs
<i>Banking Parameters</i>			
$\theta$	Retained earnings	0.8	Net payout rate of 2.5% ( <a href="#">Baron, 2020</a> )
$\kappa$	Leverage constraint	0.1	Book leverage of 10
$\varpi$	Transfer to new banks	0.018	Annual lending spread of 2%
$\lambda^d$	Liquidation costs	0.10	Annual TED spread of 0.12%
<i>Shock Parameters</i>			
$\rho_a$	Persistence of TFP	0.9	Pre-crisis persistence of detrended consumption
$\sigma_a$	SD of TFP Innovations	0.005	Pre-crisis volatility of detrended consumption
$\sigma^{b,risky}$	House quality during crises	1.027	Annual default rate of 2% during crises
$\lambda^{b,risky}$	Loss given default during crises	0.60	FDIC data
$\Pr(\text{crisis}_t   \text{crisis}_{t-1})$	Crisis persistence	0.85	<a href="#">Jordà et al. (2016)</a>

Table 1: Summary of the calibration.

## 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 steady-state 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 ([Judd et al., 2002](#)) with multilinear interpolation.

The occasionally binding constraints for the banks and the borrowers pose technical challenges

ges. For this reason, I opt to use multilinear interpolation as opposed to global shape-preserving methods (such as higher-order splines or Chebyshev polynomials). The reason is that multilinear interpolation is more flexible at dealing with the strong nonlinearities that occur in the points of the state space where constraints start (and stop) binding.<sup>23</sup> 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, the full model features 11 state variables:

$$\mathcal{S}_t = (D_{t-1}, B_{t-1}^b, B_{t-1}^g, A_t, \sigma_t^b, G_t, T_t^b, x_t^k, s_{t-1}^k, x_t^d, s_{t-1}^d)$$

These states are: bank deposits, household debt, government debt, TFP, risk shock, government spending, transfers, equity injection, stock of government-owned bank equity, new credit guarantees, stock of guaranteed credit.

### 3.3 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 2, and which are crucial for some of the results. At the stochastic steady state, 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 to combine a nonlinear model and macroeconomic

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<sup>23</sup>The key disadvantage of multilinear interpolation with respect to these other methods is that it is typically worse at extrapolation. I address this concern by choosing grids for the endogenous states that minimize extrapolation.

data to estimate structural shocks and use those shocks to conduct policy counterfactuals.<sup>24</sup>

## 4 Financial Crisis

A crisis in the model is a period of high credit risk, when  $\sigma_t^b = \sigma^{b, \text{crisis}}$ . 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  $\nu_t^*$ . 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. As the current payoff on debt securities falls, banks may start defaulting, which further erodes bank capital by decreasing the price of deposits  $Q_t^d$ .

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 new 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 only further 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 2 plots the behavior of the model around financial crises. I simulate the model for a long number of periods and extract all sequences of periods where the economy enters a crisis. I then further split this sample of crises into two: crisis periods where the economy enters with low household and bank leverage and crises that start when the economy has high household and bank leverage.<sup>25</sup> The median path for low-leverage crises is shown in blue circles, while the median

<sup>24</sup>See [Jermann and Quadrini \(2012\)](#) for another quantitative application of a macroeconomic model to estimate financial shocks.

<sup>25</sup>Bank leverage is defined as  $\frac{D_{t-1}}{B_{t-1}^b}$ , while household leverage is defined as  $\frac{B_{t-1}^b}{p_t^h}$ . Crises with low- (high-) leverage

path for high-leverage crises is shown in orange 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 stochastic discount factor, 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 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

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are such that both household and bank leverage are below their 5th percentiles (above their 95th percentiles) when the crisis event is triggered.

use a particle filter to estimate the sequences of structural shocks that allow the model to replicate the observed data on aggregate consumption and a measure of credit spreads in the data. Importantly, these shocks are estimated by accounting for the model's endogenous responses to policy and so are truly invariant to fiscal policy. I use these estimated shock distributions and the model to conduct counterfactual experiments. First, I answer the following question: what would the Great Recession have looked like in the absence of a fiscal policy response? Second, I perform a decomposition by turning off one policy at a time. This allows us to measure the contribution of each policy tool towards macroeconomic stabilization. Finally, I estimate a time series of state-dependent fiscal multipliers for each fiscal policy tool. These multipliers are informative regarding what combinations of policies are more effective at different points in time.

## 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 observed data on consumption and spreads?

### 5.1.1 Standard Data Series

As observables, I use aggregate consumption and default rates on bank loans. To validate the estimation exercise, I also compare the model-implied paths of bank credit spreads and house prices to the data.

**Consumption** 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 is the data counterpart of  $C_t = \chi C_t^b + (1 - \chi)C_t^s$ . I use quarterly real personal consumption expenditures (PCE) from the Federal Reserve Bank of St. Louis FRED database (series code: PCECC96). I detrend this series using the approach proposed

613 by [Hamilton \(Forthcoming\)](#), which involves estimating the following OLS regression

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

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

**Default Rates** 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

$$\text{default}_t = m \times F_t^b$$

615 This series is chosen as an observable as it is relatively low and stable outside of financial crises.  
 616 When the financial shock hits, the default rate can be subject to large jumps. For that reason, it  
 617 contains useful information to identify the risk shock  $\sigma_t^b$ . I take a series on delinquency rates on  
 618 bank loans from FRED (series code: DRALACBS).

**Credit Spreads** 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,

$$\text{spread}_t^d = \log Q_t - \log Q_t^d$$

619 Outside of financial crises, the credit risk of deposits is very low and their price mostly tracks the  
 620 risk-free rate. When the financial shock hits, however, a wave of mortgage defaults can trigger  
 621 large jumps in the deposit spread. The series is taken from FRED (series code: TEDRATE) and  
 622 consists of the spread between the 3-month LIBOR and the yield on the 3-month Treasury bill. It  
 623 is a common measure of the cost of wholesale funding for large banks.

624 **House Prices** House prices are detrended using the same method as aggregate consumption. I  
 625 take the an all-transactions house price index for the United States (FRED series code: USSTHPI),  
 626 estimate the following OLS regression

$$\log p_{t+8}^h = \alpha + \sum_{i=0}^4 \beta_i \log p_{t-i}^h + \epsilon_t^p$$

and obtain detrended house prices as  $\hat{\epsilon}_t^p$ .

The data series for detrended consumption, default rates, TED Spread, and detrended house prices are plotted in Figure 3. The top two data series are used as observables to estimate the shocks, while the bottom two are used to validate the model-based estimates for the shocks.

### 5.1.2 Fiscal Policies

While the previous data series are standard, the mapping of observed fiscal measures onto the four policies considered in the model requires some further work. I compile a list of discretionary fiscal policy measures undertaken by the US government and its agencies during the Great Recession and map each of these measures into one of the model's policies. The general classification is based on the following criteria:

1.  $G_t$ : policies that consist of direct purchases of goods and services by the government, also including goods that correspond to transfers in kind.
2.  $T_t^b$ : 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.
3.  $x_t^k$ : equity injections and transfers to the financial sector, even indirect ones.
4.  $x_t^d$ : credit and/or 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, the Obama stimulus). Additionally, I consider policies enacted by independent government agencies and corporations for which the US Treasury is ultimately liable, such as the FDIC.<sup>26</sup> I describe the data collection procedure in more detail in Appendix D, and Table 2 provides a summary of the policies considered.

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<sup>26</sup>The Federal Reserve also engaged in extensive quasi-fiscal policies during this period, the analysis of which is beyond the scope of this paper.

Instrument	Description	Policies	Sources
$G$	Govt. Purchases	<u>ARRA</u> : consumption expenditures, gross investment, transfers and grants to state and local governments including Medicaid and Education.	BEA
$T^b$	Transfers	<u>ESA</u> : tax rebates. <u>HERA</u> : home buying tax credits. <u>ARRA</u> : losses in current tax receipts (incl. Making Work Pay), current transfer payments (incl. unemployment extension), Cash for Clunkers, HOPE, Neighborhood Stabilization Program. <u>TARP</u> : Making Home Affordable (incl. HAMP), transfers to Federal Housing Agency, Hardest Hit Fund.	BEA, US Treasury
$x^k$	Equity Injections	<u>TARP</u> : 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
$x^d$	Guarantees	<u>TARP</u> : Asset Guarantee Program, Term Asset-Backed Securities Loan Facility, Small Business Credit Liquidity Initiative, Treasury MMF Guarantees. <u>FDIC</u> : Temporary Liquidity Guarantee Program.	FDIC, Fed, US Treasury

Table 2: Summary of fiscal policies considered. 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 the data.

**Mapping Fiscal Policy Data to the Model** Figure 4 plots the resulting data series, normalized by US GDP in the first quarter of 2007 (annualized). The vertical dashed line corresponds to the third quarter of 2008, the quarter of the failure of Lehman Brothers. The bulk of traditional fiscal policy consisted of transfers, which exceeded 2% of GDP immediately before Lehman (through the ESA tax rebates), as well as in the beginning of 2009 (due to the ARRA programs). The magnitude of fiscal interventions in the financial sector, through equity injections and asset guarantees, exceeded that of traditional fiscal policy. Equity injections reached 8% of GDP in the last quarter of 2008, as the Capital Purchase Program (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 steady-state) 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.<sup>27</sup>

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.<sup>28</sup> For the purpose of describing the effects of fiscal policy on the economy, I model discretionary policies as low-probability, transitory shocks. Denoting each policy instrument by  $\omega_t \in \{G_t, T_t^b, x_t^k, x_t^d\} \equiv \Omega_t$ , I assume the following vector of states and transition matrix:

$$\omega_t = [\omega_t^{\text{normal}}, \omega_t^{\text{crisis}}]^T \quad \text{and} \quad \mathbf{P}^p = \begin{bmatrix} .995 & .005 \\ 1 - p_\omega & p_\omega \end{bmatrix} \quad (17)$$

That is, each policy instrument follows a two-state Markov process, with the first state being a “normal” value and the second a “crisis” one. The normal value is equal to a constant value of 20% of steady-state GDP for government spending and zero for all other instruments. The crisis value 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 and a Hamilton filter 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 estimation procedure involves the estimation of the parameters of a hidden Markov model and follows [Hamilton \(1989\)](#).<sup>29</sup> The resulting estimates are in Table 3. Figure A.6 in the appendix plots the time series for each policy along with the discretized

<sup>27</sup>For equity injections, I assume that the observed data series measure  $y_t^k = \frac{x_t^k \theta \bar{E}}{\bar{Y}}$ , where variables with bars are stochastic steady-state values, and obtain  $x_t^k$  by inverting that expression. Similarly, for credit guarantees, I assume that the measured series is  $y_t^d = \frac{s_t^d \bar{D}}{\bar{Y}}$  and compute  $x_t^d$  after estimating  $s_t^d$ .

<sup>28</sup>I assume that fiscal policies are purely exogenous shocks and do not follow fiscal rules 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. I have solved a version of the model where the policy rules depend on the current state of the economy, and fiscal interventions are more likely during financial crises. The quantitative results are similar and are available upon request.

<sup>29</sup>A detailed description of the procedure can be found in Appendix E.

	$G_t/Y$	$T_t^b/Y$	$x_t^k$	$x_t^d$
$p^\omega$	0.80	0.50	0.50	0.50
$\omega^{\text{crisis}}$	0.80%	1.60%	19.60%	12.5%

Table 3: Maximum likelihood estimates for fiscal policy shock processes

counterparts. Appendix C analyzes the state-dependent effects of the economy in response to different policy shocks of this type.

Finally, I use the estimated/measured series  $(x_t^k, s_t^k)$  as well as  $(x_t^d, s_t^d)$  to estimate the persistence of the equity purchase and credit guarantee stocks. This yields  $\theta^k = 0.945$  and  $\theta^d = 0.913$ .

### 5.1.3 Measuring the Structural Shocks

Armed with the 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  $\{\Omega_t\}_{t=0}^T$ .<sup>30</sup>

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. Figure 5 plots the median of the filtered densities for the shocks along with 5% confidence bands 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

<sup>30</sup>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 the filter 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.

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 defaults takes place around the financial crisis, triggering the credit risk shock. All other variation, which includes all fluctuations in consumption before and after the Great Recession, must therefore be absorbed by movements in TFP.

Figure 6 plots 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.

Figure 7 plots 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.<sup>31</sup>

## 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  $\{Y_t\}_{t=0}^T = Y^T = f(\{\mathcal{Z}_t, \Omega_t\}_{t=0}^T, X_0)$ . Since the particle filter retrieves estimates for  $(\{\mathcal{Z}\}_{t=0}^T, X_0)$ , we can evaluate the counterfactual path of endogenous variables  $Y^{T,CF}$  by setting  $\Omega_t = \Omega^{\text{normal}}, \forall t \geq 0$ .

Figure 8 plots the baseline path for consumption (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 the aggregate consumption would had fallen by almost twice as much in the absence of fiscal policy during the year 2009. That is, instead of

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<sup>31</sup>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., 2017).

falling to 6% below trend, it would have fallen to over 10%. The cumulative loss for this period (2007Q1 - 2013Q4) of no fiscal policy response is 9.68%, or 1.023 trillion dollars of aggregate consumption.<sup>32</sup> 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. For that reason, the recovery would have been slightly faster.

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.

Figure 9 plots the difference between the counterfactual and the baseline series as a percentage of the variable's stochastic steady-state. A negative value for this difference means that the variable would have taken a lower value in the absence of fiscal policy. The first panel shows clearly the stabilizing effects of the three main tools of fiscal policy: the ESA, TARP, and ARRA. The initial trough, before Lehman, corresponds to the stimulus under the ESA via the early-2008 Bush tax rebates. The fall right after Lehman is the no-bank-bailout counterfactual and, finally, the larger fall in mid-2009 corresponds to the transfer programs under the ARRA and the government purchases program. The second panel shows that TARP was essential to contain spreads and the ARRA also played a minor role in 2009. Finally, the lower panels show that the ESA and the ARRA essentially acted as transfers from savers to borrowers, while TARP also played a role in boosting saver consumption.

### 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. Figure 10 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

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<sup>32</sup>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 in 2007Q1. This is the full integral, also accounting for when the counterfactual rises above the baseline.

guarantees 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 one, 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  $\mathcal{M}^\omega(\mathbb{S}_t)$ , where  $\mathbb{S}_t \equiv (D_{t-1}, B_{t-1}^b, B_{t-1}^g, A_t, \sigma_t^b, \Omega_t)$ . Throughout, I focus on long-term discounted multipliers as defined in [Mountford and Uhlig \(2009\)](#):

$$\mathcal{M}_T^\omega(\mathbb{S}_t) = \frac{\sum_{t=1}^T \prod_{j=1}^t Q_j (\text{GDP}_t^{\text{Stimulus}} - \text{GDP}_t^{\text{No Stimulus}})}{\sum_{t=1}^T \prod_{j=1}^t Q_j (\text{Spending}_t^{\text{Stimulus}} - \text{Spending}_t^{\text{No Stimulus}})} \quad (18)$$

where Spending is defined as the left-hand side of the government budget constraint in (16). 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. This definition is similar to that of “integral multiplier” in [Ramey and Zubairy \(2018\)](#).<sup>33</sup> 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.<sup>34</sup>

<sup>33</sup>When  $T = 0$ , this is also known as the impact multiplier. The impact multiplier is an imperfect measure, as it potentially ignores future negative effects from fiscal financing, thus providing an incomplete view of the effects of a given dollar of fiscal spending on economic activity.

<sup>34</sup>It is not obvious which interest rate should be used to discount future periods in this context — if whether the interest rate given policy or the rate in the absence of policy. I choose the former and always evaluate multipliers using the path of interest rates given that the policy has been enacted.

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 combination 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 11 plots fiscal multipliers for each policy tool over time, with  $T$  set to 20 quarters. These multipliers are computed by activating each policy at a time for one period, assuming that no other policies are active. 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, establishing that the state of the economy is crucial for the effectiveness of the fiscal policy response.<sup>35</sup> 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. It rises considerably, above 2, during the financial crisis, which is consistent with the large role of transfers for stabilization. Bank recapitalizations also have fiscal multipliers that are typically low but rise considerably during the crisis, over 1.5. 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 very large multiplier, over 4. These facts provide further evidence on the stabilizing role of these three fiscal policy tools during the financial crisis.

**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 have very limited effects at other points in time. This arises from 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 ef-

<sup>35</sup>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.

fect on the borrower’s stochastic discount factor. Through consumption and the stochastic discount factor, 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 direct through equity injections, or indirect through credit guarantees — work in a similar way, but attack a different element of the cycle described above: by relaxing the bank’s constraint, 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.<sup>36</sup>

## 6 Conclusion

This paper develops a model of fiscal policy that allows for a comprehensive assessment of the policy response to the recent 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 main 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 less-conventional fiscal policy tools that affect the financial sector directly. In particular, I show how the interaction between borrower collateral and default and the financial system’s pricing of debt securities augment traditional Keynesian effects of fiscal policy.

The nonlinear solution of the model allows us to think about how the effects of different fiscal policies vary with the state of the economy. In a quantitative application of the model to the US, I show that these state-dependent effects are extremely important: interventions such as social transfers and bank recapitalizations can generate very low (and even negative) fiscal multipliers when the economy is in an expansion but very high positive ones when financial intermediation is

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<sup>36</sup>The estimated paths for the Lagrange multipliers are shown in the appendix.

constrained and aggregate demand is depressed. Using the model as a measurement device, I estimate distributions for policy-invariant structural shocks, which allows me to conduct counterfactual exercises. I find that transfers and bank recapitalizations were crucial to sustaining aggregate consumption. While the aggregate effects of bank recapitalizations are smaller, they seem to be closer to a Pareto improvement to the extent that they benefit both savers (who own the banks) and borrowers (who benefit from more borrowing and lower costs of borrowing).

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. Another dimension along which the model can be extended concerns a more detailed description of public finances and the explicit modeling of fiscal sustainability. Extended along this dimension, and in an open-economy setting, the model could be used to study the experiences of Ireland or Spain, two eurozone countries that experienced a sovereign debt crisis that was either caused or aggravated by large fiscal interventions in the financial system ([Martin and Philippon, 2017](#)). These are interesting avenues for future research.



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## 997 **A Model Appendix**

### 998 **A.1 Full List of Model Conditions**

Savers,

$$Q_t = \mathbb{E}_t \left( \frac{\Lambda_{t+1}^s}{\Pi_{t+1}} \right) \quad (1)$$

$$Q_t^d = \mathbb{E}_t \left( \frac{\Lambda_{t+1}^s}{\Pi_{t+1}} Z_{t+1}^d \right) \quad (2)$$

$$\Lambda_{t+1}^s = \beta^s \frac{C_t^s}{C_{t+1}^s} \quad (3)$$

Banks,

$$\Pi_t E_t = [1 - (1 - \theta^g) s_{t-1}^k] \theta \{ \Psi^d(u_t^*) Z_t^b B_{t-1}^b - [1 - F^d(u_t^*)] D_{t-1} \} + \varpi \quad (4)$$

$$Q_t^b B_t^b = (1 + x_t^k) E_t + Q_t^d D_t \quad (5)$$

$$\kappa Q_t^b B_t^b \leq \Phi_t E_t \perp \mu_t \geq 0 \quad (6)$$

$$\Lambda_{t+1}^k = \frac{\Lambda_{t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{t+1}) [1 - (1 - \theta^g) s_t^k] \quad (7)$$

$$\mu_t \kappa = \mathbb{E}_t \left\{ \Lambda_{t+1}^k \left[ \frac{\Psi^d(u_{t+1}^*) Z_{t+1}^b}{Q_t^b} - \frac{1 - F^d(u_{t+1}^*)}{Q_t^d} \right] \right\} \quad (8)$$

$$\Phi_t = (1 + x_t^k) \frac{\mathbb{E}_t \{ \Lambda_{t+1}^k [1 - F^d(u_{t+1}^*)] \}}{Q_t^d (1 - \mu_t)} \quad (9)$$

$$u_t^* = \frac{D_{t-1}}{Z_t^b B_{t-1}^b} \quad (10)$$

Borrowers,

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

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

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

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

$$(1-\tau)w_t N_t + \frac{Q_t^b B_t^b}{\chi} + \frac{T_t^b}{\chi} = C_t^b + \frac{B_{t-1}^b}{\chi \Pi_t} \left\{ m[1 - F_t^b(\nu_t^*)] + (1-m)[(1-\gamma)Q_t^b + \gamma] \right\} + m p_t^h [1 - \Psi_t^b(\nu_t^*)] + T_t^b \quad (15)$$

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

Asset payoffs,

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

$$Z_t^d = s_{t-1}^d + (1-s_{t-1}^d) \left[ 1 - F_t^d(u_t^*) + (1-\lambda_t^d) \frac{1 - \Psi_t^d(u_t^*)}{u_t^*} \right] \quad (18)$$

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

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

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

$$Y_t = A_t N_t \quad (21)$$

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



Monetary and fiscal policy,

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

$$GDP_t = C_t + G_t \quad (24)$$

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

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

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

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

Cumulative distribution functions and partial expectations for risk shocks,

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

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

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

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

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

1000 Given the aggregate state  $\mathbb{S}_t$  and the production function  $Y_t(i) = A_t N_t(i)$ , the firm's recursive  
1001 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

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

1002 In a symmetric equilibrium, all firms choose the same price  $P_t(i) = P_t$ . Thus the above condition  
1003 becomes the New Keynesian Phillips curve,

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

### 1004 **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

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

1005 We now guess, to later verify, that the bank's franchise value is linear in current earnings,

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

1006 Under this assumption, we can reformulate the bank's problem as

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

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

$$\begin{aligned} \Phi_{j,t} \theta e_{j,t} = \max_{b_{j,t}} \mathbb{E}_t \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) \left[ \left( u \frac{Z_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right) Q_t^b b_{j,t}^b + \frac{\theta e_{j,t}}{Q_t^d} \right] dF^d(u) \\ + \mu_{j,t} [\Phi_{j,t} \theta e_{j,t} - \kappa Q_t^b b_{j,t}^b] \end{aligned}$$

1007 The first-order condition with respect to  $b_{j,t}$  is then

$$\mathbb{E}_t \int_{u_{j,t+1}^*}^{\infty} \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) \left( u \frac{Z_{t+1}^b}{Q_t^b} - \frac{1}{Q_t^d} \right) dF^d(u) = \mu_{j,t} \kappa$$

1008 Applying the envelope theorem and rewriting the Lagrangian then yields

$$\Phi_{j,t} = \frac{\mathbb{E}_t \left\{ \frac{\Lambda_{t,t+1}^s}{\Pi_{t+1}} (1 - \theta + \theta \Phi_{j,t+1}) [1 - F^d(u_{j,t+1}^*)] \right\}}{Q_t^d (1 - \mu_{j,t})}$$

1009 thus confirming our conjecture that the value was linear in earnings.

## 1010 A.4 Technology Shock

1011 To understand the model's dynamics, it is instructive to look at the response of the economy's vari-  
1012 ables to a standard technology shock. Figure A.1 plots generalized impulse response functions  
1013 (GIRF) of macroeconomic and financial variables to a one-standard-deviation TFP shock. Varia-  
1014 bles are expressed in percentage deviations from their stochastic steady-state value, which is also  
1015 used as the starting point for the impulse.<sup>37</sup> Details on how these GIRF are computed can be found  
1016 in Appendix B.4.

1017 GDP responds positively to a TFP shock, as normal in this class of models. Importantly, since  
1018 borrowers have a higher MPC and labor incomes rises, their consumption increases relatively more  
1019 in response to a TFP shocks. As the final panel illustrates, this effect is complemented by lower  
1020 spreads on their borrowing. Bank funding spreads fall on impact for two main reasons: first, as

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<sup>37</sup>I use the term “stochastic steady-state” in the sense of the risky steady-state 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 steady-state to the extent that it features precautionary behavior by the agents.

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 central bank 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.

## 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  $\epsilon_t$ , 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

$$\mathcal{S}_t \equiv (\mathbb{S}_{t-1}, \epsilon_t) = (D_{t-1}, B_{t-1}^b, B_{t-1}^g, A_t, \sigma_t^b, \Omega_t)$$

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 stati-

1046 cally without solving a nonlinear equation. Based on these criteria, I pick the following variables  
1047 as the policies to solve for

$$\mathcal{X}_t = (C_t^s, Q_t^b, p_t^h, \Pi_t, C_t^b, Q_t^d, \lambda_t^b, \mu_t)$$

1048 I adopt some ideas from parametrized expectations algorithms: for a given  $\mathcal{S}_t$ , I can describe the  
1049 model's equilibrium as a set of nonlinear equations of the type

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

1050 The idea is to construct a grid over the states and innovation  $\mathcal{S}_t$ , fix the expectations terms  $\mathbb{E}_t h(\cdot)$   
1051 at each of these points, and solve a simpler system of nonlinear equations for  $\mathcal{X}_t$ . Since the system  
1052 is relatively simple (as I am fixing the value of the expectations terms for each grid point), it is  
1053 possible to compute the Jacobian analytically, which greatly improves the speed and precision of  
1054 the algorithm.

1055 The algorithm then proceeds as follows:

- 1056 1. Generate a discrete grid for the state variables,  $\{g_i\}_{i=1}^N = \mathbb{G} = G_D \times G_{B_b} \times G_{B_g} \times G_A \times$   
1057  $G_\sigma \times G_\Omega$ .
- 1058 2. Approximate  $\mathcal{X}_t, \mathbb{E}_t h(\cdot)$  over  $\mathbb{G}$  by choosing an initial guess and a functional space to define  
1059 the approximant. As the initial guess, I use the model's non-stochastic steady-state. This  
1060 means that I can guess a value for each variable  $X_t \in \mathcal{X}_t$  and each expectation term  $\mathbb{E}_t h(\cdot)$   
1061 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  
1062 approximant, I use piecewise linear functions (multilinear interpolation). This approximant  
1063 allows me to evaluate  $X^0, H^0$  outside of the grid points at any combination of values for the  
1064 states.
- 1065 3. Given these initial guesses for the policies  $\mathcal{X}^0$  and expectation terms, solve the model by  
1066 using time iteration. Set  $\mathcal{X}^\tau = \mathcal{X}^0$ , and  $H^\tau = H^0$ .
  - 1067 (a) For each point in the grid,  $g_i$ , solve a system of residual equations for the value of the  
1068 policies at that grid point. Given our guesses for the expectation terms, this is a set of

nonlinear equations of the type

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

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  $\lambda$  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  $\rho_i^X$  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 this type of methods can be particularly challenging since very few convergence results exist (unlike, for example, value function iteration).

**Occasionally Binding Constraints** To 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

1092 of equations can be applied. As a concrete example, take the bank's leverage constraint and the  
 1093 associated Lagrange multiplier  $\mu_t \geq 0$ . I define an auxiliary variable  $\mu_t^{\text{aux}} \in \mathbb{R}$  such that

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

1094 and the inequality to which the complementarity condition  $\mu_t \geq 0$  is associated reads

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

1095 Notice then that whenever  $\mu_t^{\text{aux}} \geq 0$ , the inequality holds as an equality and  $\mu_t \geq 0$ . On the other  
 1096 hand, when we have that  $\mu_t^{\text{aux}} < 0$ , this variable becomes the residual for the inequality, which  
 1097 implies that  $\Phi_t \theta E_t > \kappa Q_t^b B_t$  and  $\mu_t = 0$ . Defining this auxiliary variable as the square of a max  
 1098 operator ensures that the system is differentiable with respect to this variable, which is helpful  
 1099 when using Newton-based methods to solve the nonlinear system of equilibrium conditions.

1100 **Grid Construction** Grid boundaries for endogenous states are chosen to minimize extrapolation,  
 1101 which is important given the use of linear extrapolation. I use linear grids for all endogenous vari-  
 1102 ables. In principle, it is helpful to make grids denser in regions of the state space where constraints  
 1103 start/stop binding. That is not easy in this model: given the large number of states, these regions  
 1104 can be ill behaved. Given that bank and household debt are very positively correlated, using rec-  
 1105 tangular grids is computationally costly, since it involves solving the model for many points that  
 1106 will never be visited during stochastic simulations. One approach to dealing with this issue is to  
 1107 use grid rotations based on singular value decompositions. Since my grid is constructed manually,  
 1108 I instead opt for redefining the state variables. In particular, I use  $\text{lev}_{t-1} = \frac{D_{t-1}}{B_{t-1}^b}$  instead of  $D_{t-1}$  as  
 1109 a state.

## 1110 B.2 Accuracy Checks

1111 Even though the model solution is exact at the specified grid points, the simulated economy may  
 1112 travel to regions of the state space that do not correspond to any grid point; at these points, the  
 1113 equilibrium conditions are not guaranteed to hold exactly. To check accuracy of the model solution,  
 1114 I follow the standard procedure in the literature and evaluate the residuals at these points. To do so,  
 1115 I first simulate the model economy for 5,000 periods. Then, I evaluate the residual equations used

1116 to solve the model at each of the points of the state space that were “visited” in that simulation.  
 1117 Histograms with the decimal log of the absolute value of the residuals are shown in figure A.2 for  
 1118 each residual equation. Most equations present average errors of order -3, which are standard in  
 1119 the literature.

### 1120 **B.3 Particle Filter**

1121 In this section, I describe the particle filter used to extract the sequences of structural shocks from  
 1122 the data.

**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 is comprised of two blocks: a state transition function  $f$  and an observation function  $g$

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

1123 where  $\gamma$  is a vector of structural parameters,  $x_t$  is a vector of state variables,  $y_t$  is a vector of ob-  
 1124 servable variables,  $\epsilon_t$  are structural shocks, and  $\eta_t$  are measurement errors. The structural shocks  
 1125 follow some distribution with density function  $m$ , and measurement errors are assumed to be ad-  
 1126 ditive and Gaussian,

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

For the current model, we consider

$$\begin{aligned}x_t &= (\text{lev}_t, B_t^b, B_t^g, A_t, \sigma_t^b, \Omega_t) \\ y_t &= (C_t, \text{spread}_t, \Omega_t)\end{aligned}$$

1127 The structural shocks are the innovations to  $(A_t, \sigma_t^b, \Omega_t)$ , and all variables are observed with some  
 1128 measurement error that is Gaussian and uncorrelated across variables. For the endogenous obser-  
 1129 vables,  $(C_t, \text{spread}_t)$ , I set the standard deviation of the measurement error equal to 10% of the  
 1130 standard deviation of the data series. For the policies,  $\Omega_t$ , I set the standard deviation of the me-  
 1131asurement error to be 1% of the standard deviation of the data series. In other words, the policy



impulses are observed almost perfectly.

**Likelihood Function** Given a sample of observables  $y^T = \{y_t\}_{t=0}^T$ , we can apply the typical factorization and write the likelihood given parameters  $\gamma$  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

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

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  $\phi$  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.

**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  $\epsilon_t^i$  and computing

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

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

$$\pi_t^i = \frac{p(y_t|x_{t|t-1}^i; \gamma)p(x_t|x_{t|t-1}^i; \gamma)}{h(x_t|y^t, x_{t-1}^i)}$$

Noting that

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

we can compute each particle weight as

$$\pi_t^i = \frac{p(y_t|x_{t|t-1}^i; \gamma)}{\sum_{i=1}^N p(y_t|x_{t|t-1}^i; \gamma)}$$

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

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

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

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

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

**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  $\{x_0^i\}_{i=1}^N$  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, i.e., the deterministic steady-state. 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 generalized impulse response functions (GIRF) 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  $\epsilon_t$ . First, I simulate the model for a large number of periods without any shocks in order to obtain its stochastic steady-state, 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 steady-state. 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

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

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 stochastic discount factor: 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 banks, which in turn lower mortgage spreads. All of this feeds back into borrower consumption, leading to a positive effect on GDP.

**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 themselves (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.

**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 steady-state, 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.<sup>38</sup> Credit guarantees operate by affecting the return on deposits 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 steady-state. The reason is that the guarantee in this experiment is transitory, while credit risk is not: by sustaining credit, this policy effectively prevents deleveraging.

**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 with the guarantees, 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

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<sup>38</sup>This is consistent with the observation in the data that, in the years preceding the financial crisis, CDS spreads were not zero even though no bank failures were observed.

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 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 for 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 (18), 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

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

A more sophisticated calculation would take into account the value of debt that would be issued by the 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

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).<sup>39</sup> 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 (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

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<sup>39</sup>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.



1329 nominally allocated \$106 billion, with the Department of Treasury disbursing \$79 billion in the  
1330 second quarter of 2008 and an additional \$15 billion in the third quarter.

1331 HERA, enacted in 2008, included a series of programs aimed at supporting homeowners who  
1332 were struggling to meet their mortgage payments. For simplicity, and given that these programs  
1333 involve implicit transfers of wealth to borrowers (who are also the homeowners in the model), I  
1334 classify them as transfers. Using data collected from the website of the US Treasury and from  
1335 pieces of legislation, I include as transfers amounts disbursed under two major programs: HOPE  
1336 (a program that eased refinancing for distressed homeowners), and the Neighborhood Stabilization  
1337 Program, which involved grants to state agencies to assist in the acquisition, rehabilitation, and  
1338 resale of foreclosed homes.

1339 TARP also included a host of similar programs aimed at helping homeowners in need. Many of  
1340 these programs involved government-sponsored debt restructuring through incentive payments to  
1341 mortgage lenders. I collect data on amounts allocated and effectively disbursed under TARP pro-  
1342 grams from the website of the US Treasury. Three major TARP programs are classified as transfers:  
1343 Making Home Affordable (MHA), Federal Housing Agency Refinance Program (FHA-RP), and  
1344 the Hardest Hit Fund (HHF). The MHA, through its main pillar, the Home Affordable Modification  
1345 Program (HAMP), provided mortgage lenders with incentive payments to restructure or refinance  
1346 mortgages, and/or give temporary forbearance so as to avoid foreclosure. The MHA was allocated  
1347 \$30 billion, of which about half was actually disbursed. The FHA-RP was targeted at homeowners  
1348 who were current on their payments, but underwater. The FHA would help these homeowners  
1349 to refinance their mortgages with new ones that were adjusted for lower house values. While the  
1350 FHA-RP was allocated over \$1 billion, less than \$60 million had actually been disbursed by 2016.  
1351 Finally, the HHF consisted of extra funds made available by the Treasury to the state housing agen-  
1352 cies in those states that were hardest hit by unemployment. They were mostly channeled towards  
1353 foreclosure prevention, and many of the policy tools and effects thus overlap with those of HAMP.  
1354 The HHF was allocated \$9.6 billion, of which \$6.5 billion were actually disbursed.

1355 **Equity Injections and Transfers to the Financial Sector** Equity injections in financial instituti-  
1356 ons were arguably the most visible face of TARP. They were conducted through several programs,  
1357 most notably through the CPP, which involved the purchase of preferred stock and warrants of  
1358 commercial and investment banks and led to total disbursements of \$245 billion. A similar but  
1359 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 systemic (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), Auto Supplier Support Program (ASSP), Treasury MBS purchases, and Small Business Lending Fund (SBLF). The PPIP allowed the Treasury to invest in certain distressed securities along with private investors, thus prompting those assets' valuations in hope of jumpstarting certain asset markets. The AIFP and ASSP involved credit guarantees and equity injections in 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 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.<sup>40</sup>; 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.

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<sup>40</sup>A \$7.5 billion asset guarantee was also negotiated with Bank of America, but never implemented.

## E Discretization of Fiscal Policy Series

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

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

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  $\sigma$ , 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

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

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

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

1406 The first term is easy to evaluate for any  $j$ , since it comes from the measurement-error equation.  
 1407 The second term is trickier, for which the filter is helpful. Let  $\xi_{t|t}$  be a  $N \times 1$  vector of conditional  
 1408 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  
 1409 have that

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

1410 and the filtering step is given by

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

1411 where  $\odot$  is the Hadamard product (element-wise multiplication). Given an initial condition  $\xi_{0|0}$ ,  
 1412 this filtering procedure allows us to easily construct the likelihood function. The likelihood function  
 1413 can then be maximized with respect to the parameters using standard procedures.

1414 As the initial condition, I set  $\xi_{0|0} = [1, 0]^T$ , since the first period of the sample is 2000Q1,  
 1415 when no discretionary policy was in place. To estimate the sequence of states  $\{x_t\}_{t=0}^T$ , I use the  
 1416 backward sampler that works as follows: draw  $x_T$  from  $\xi_{T|T}$ . Given  $x_T = k$ , compute

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

1417 Sample  $x_{T-1}$  using  $\xi_{T-1|T}$ . Then, repeat the process and iterate backwards until  $x_1$ . The discretized  
 1418 series along with the original series are plotted in figure [A.6](#).

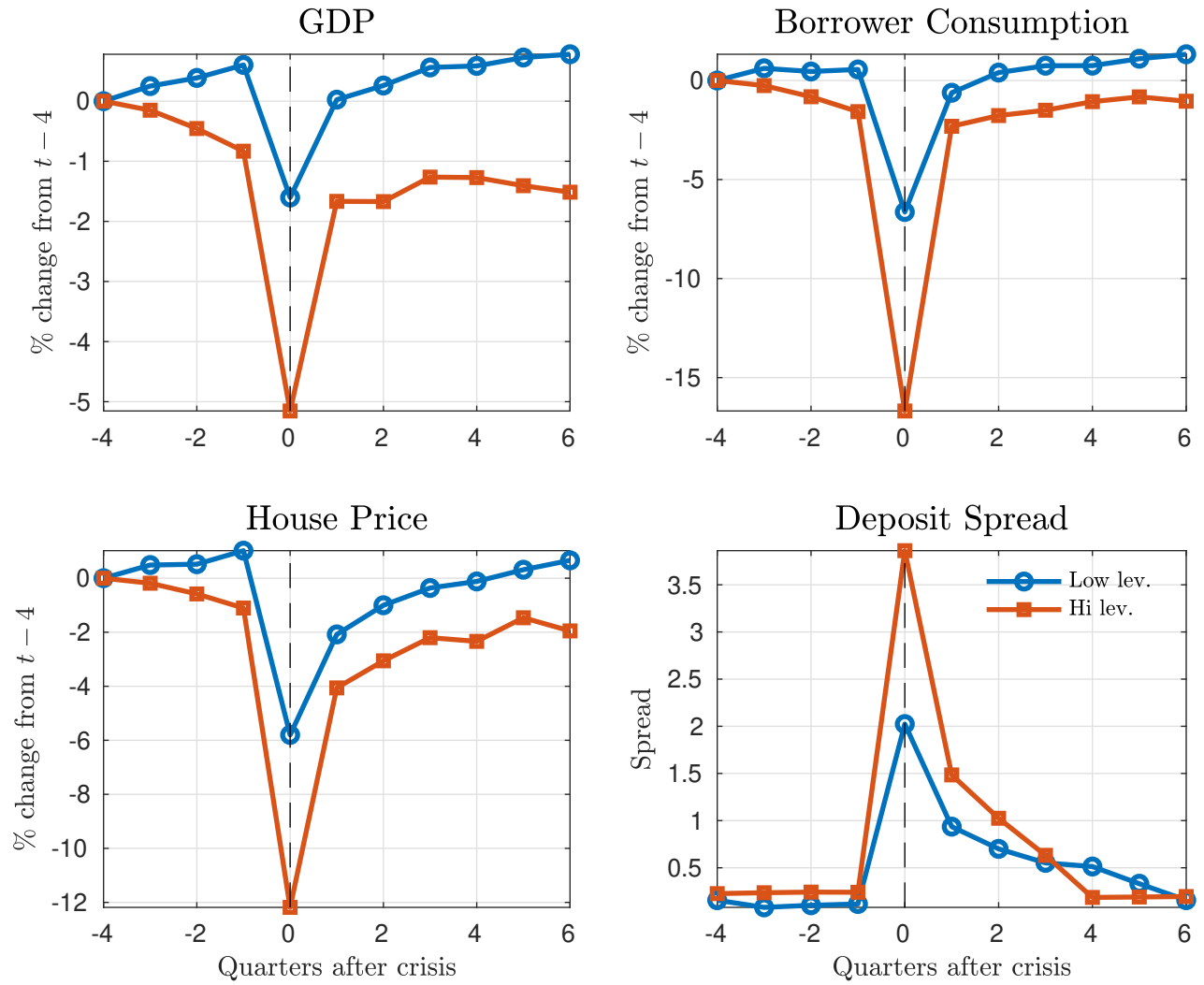


Figure 2: Typical financial crisis in low- and high-leverage states. The vertical axis measures variables in % deviations from their values at  $t-4$ , where  $t$  is the crisis shock period. Blue (circles) represents an economy with low starting leverage. Red (squares) represents an economy with high starting leverage.

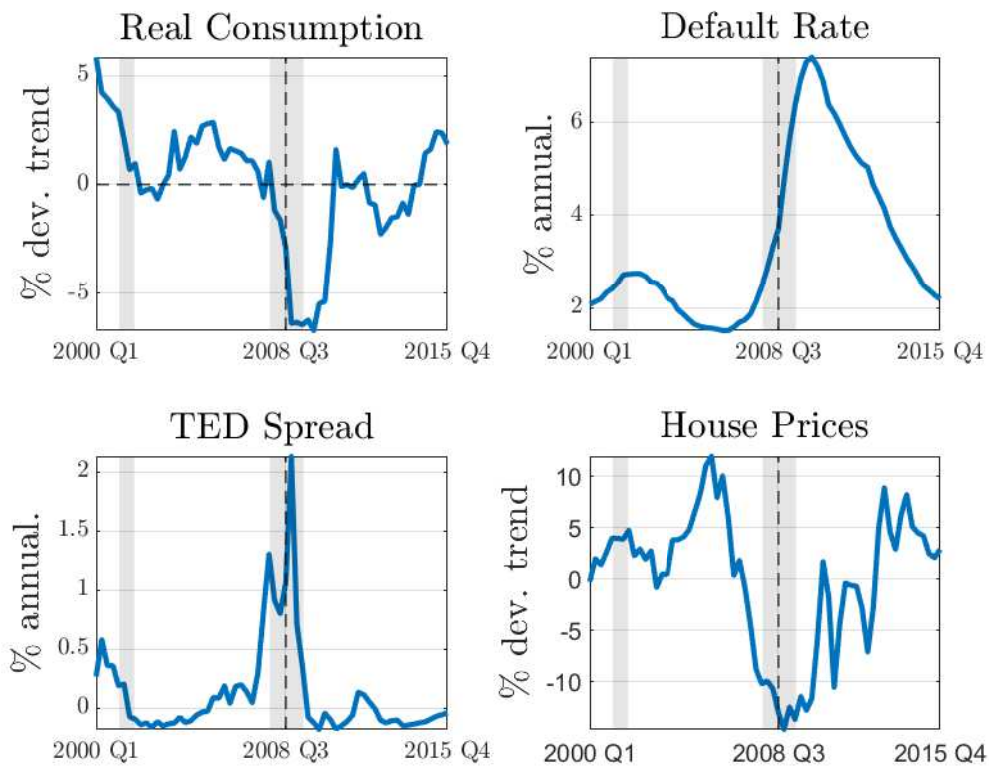


Figure 3: Data series used for estimation (aggregate consumption and default rates) and for validations (TED spread and house prices). Sample: 2000Q1-2015Q4. Lehman Brothers failure highlighted (2008Q3). Source: FRED, Federal Reserve Bank of St. Louis.

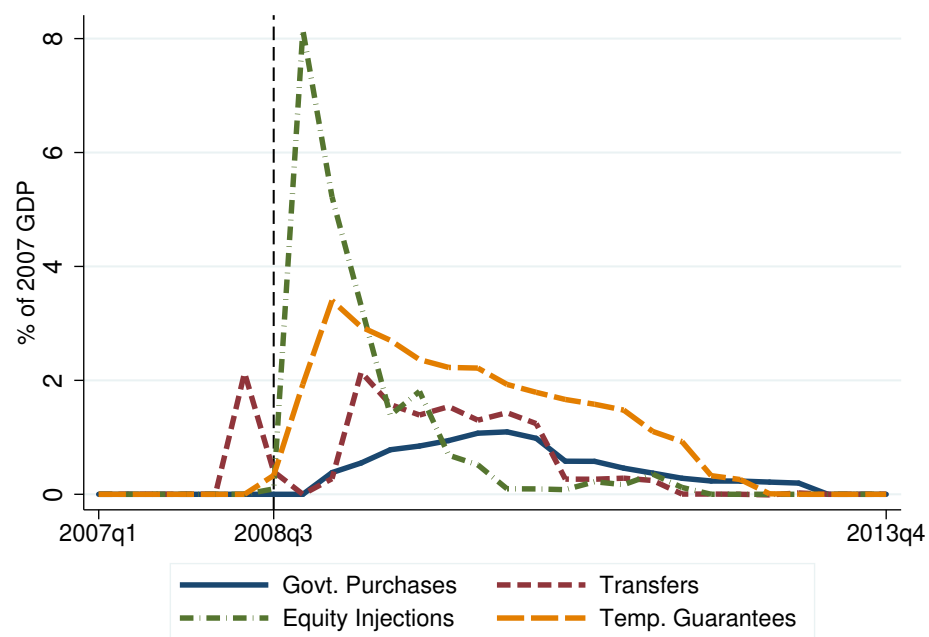


Figure 4: Discretionary fiscal policy measures enacted during the Great Recession, normalized by 2007Q1 GDP. Sources: BEA, US Treasury, FDIC, own calculations. Note: plotted here are the series for  $G, T^b, x^k, s^d$ . That is, the stock of credit guarantees as opposed to the fiscal shock.

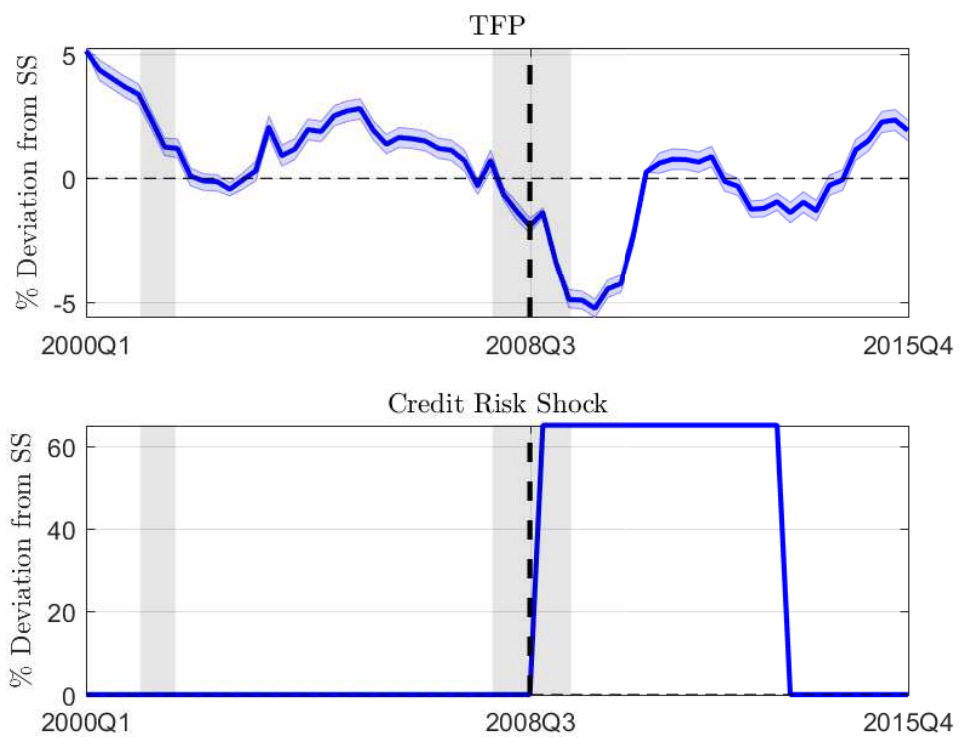


Figure 5: Filtered series for the medians of the structural shocks.

Figure 6: Estimated paths for observables vs. data.

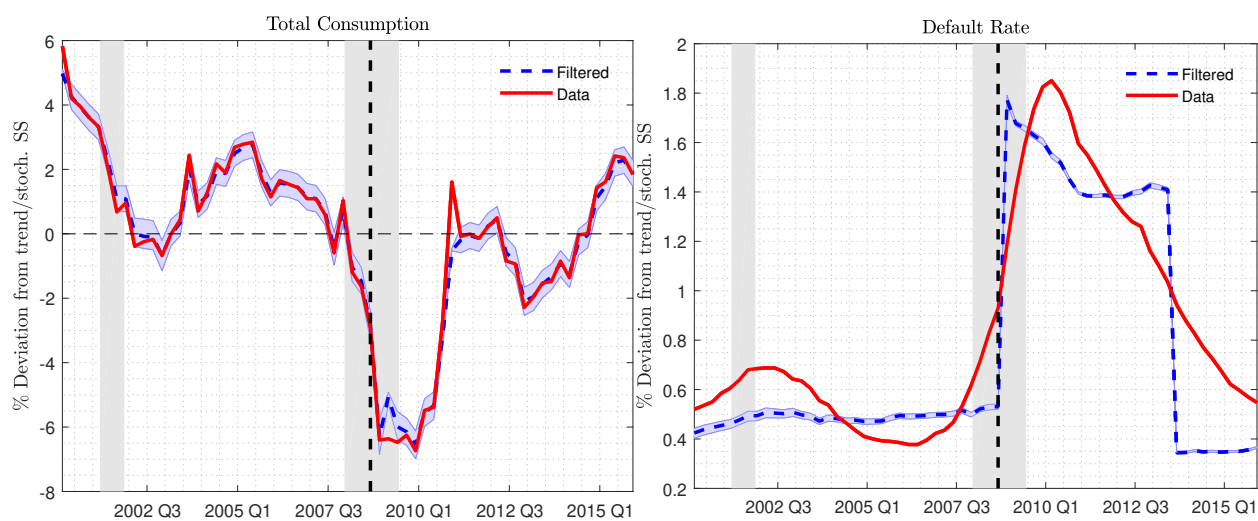
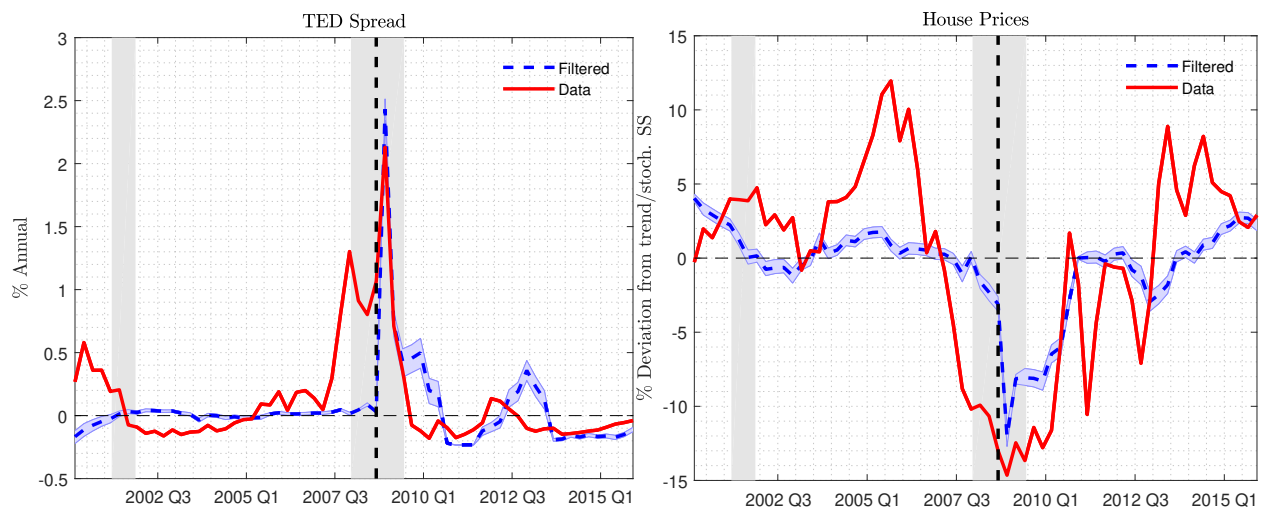




Figure 7: Estimated paths for other series vs. data.



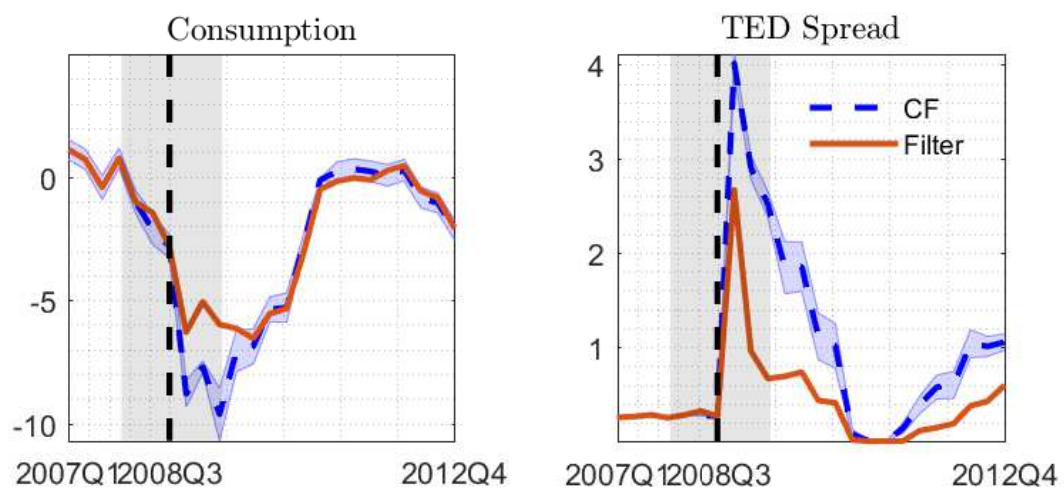


Figure 8: Baseline sequences (solid orange) vs. no fiscal policy counterfactuals (dashed blue).

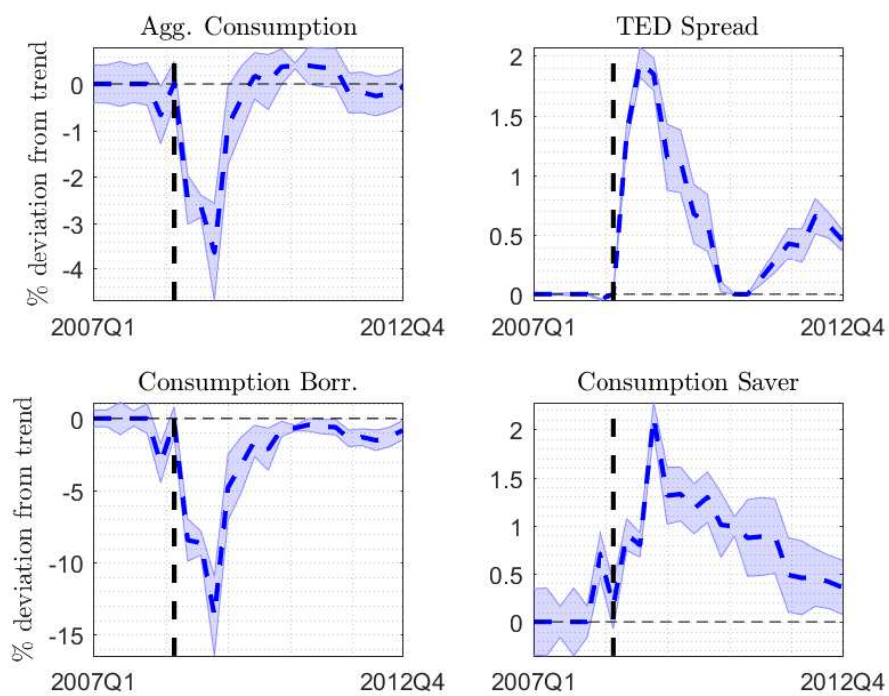


Figure 9: Difference between baseline and no policy counterfactual sequences as a percentage of the steady-state for each variable. Negative (positive) values means that the counterfactual is lower (larger) than the baseline series.

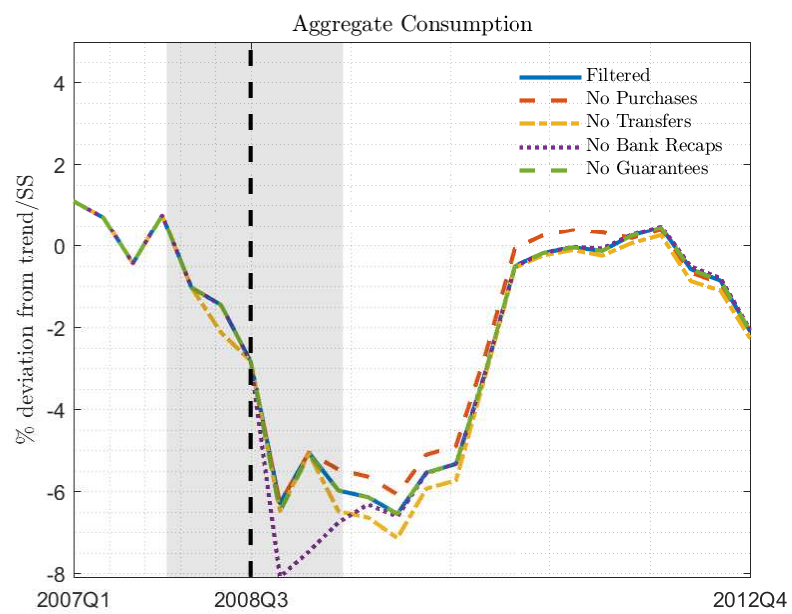


Figure 10: Counterfactual decomposition for the path of aggregate consumption.

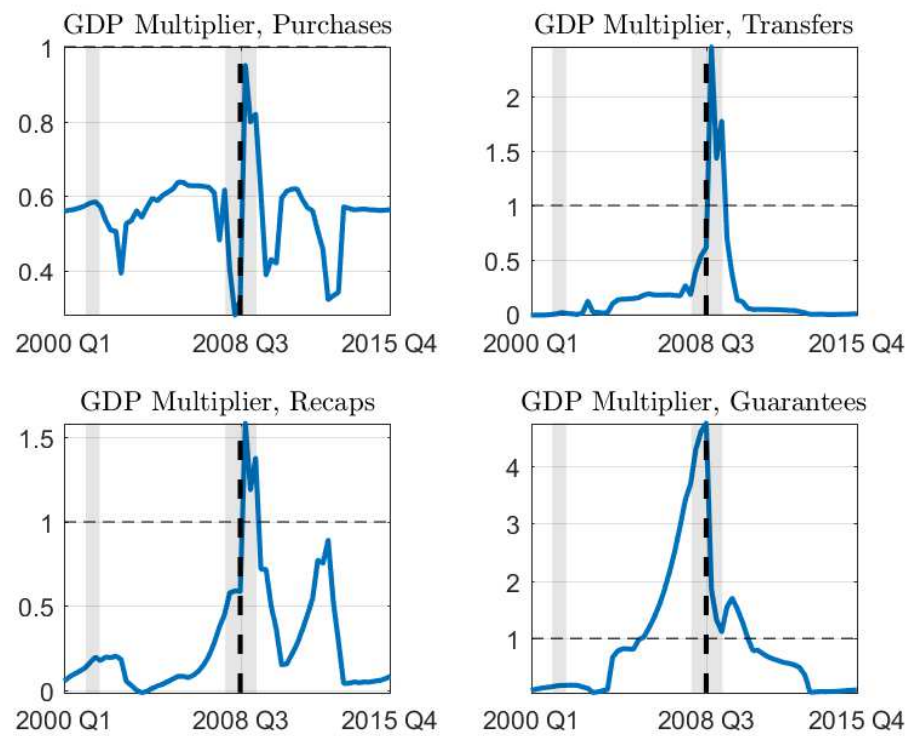


Figure 11: Estimated time series for fiscal multipliers, 20-quarter horizon.

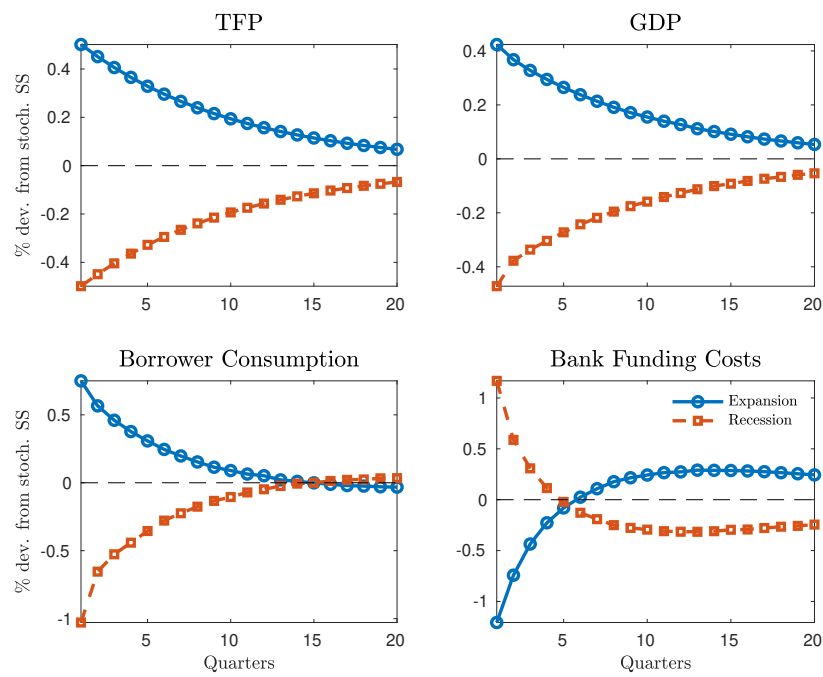


Figure A.1: Generalized impulse response functions to TFP shock.

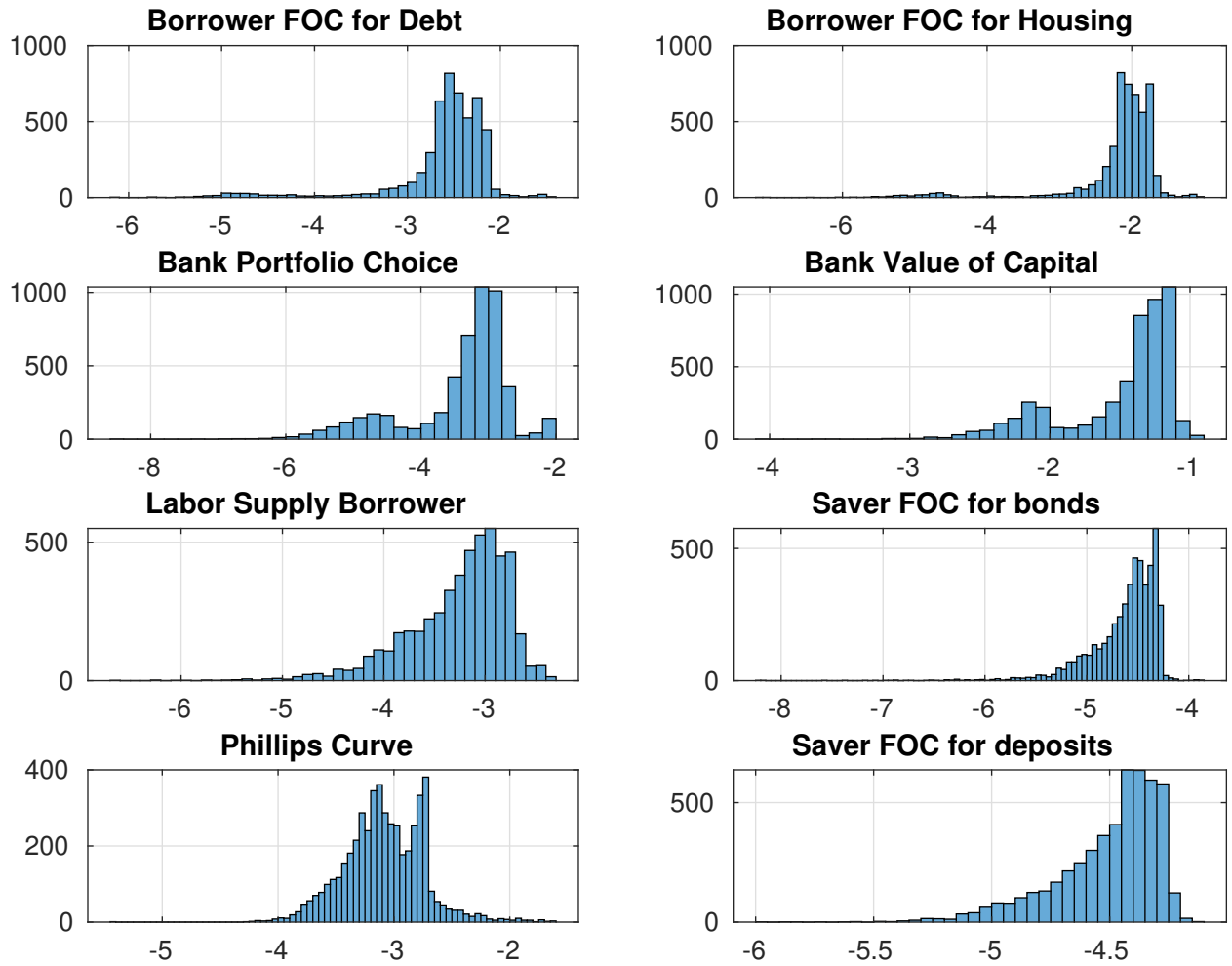


Figure A.2: Residual equation errors for a 5,000 period simulation, in decimal log basis.

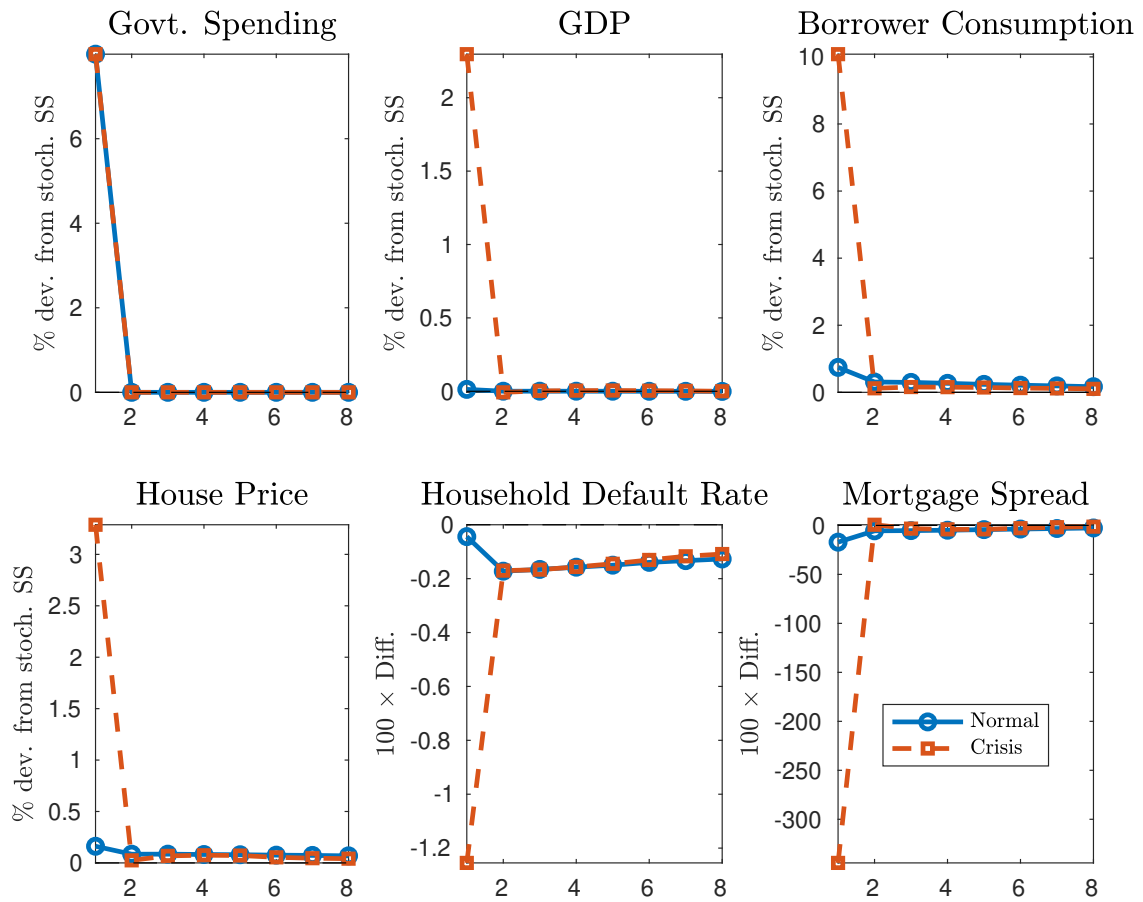


Figure A.3: GIRF of transfers, crisis and non-crisis.



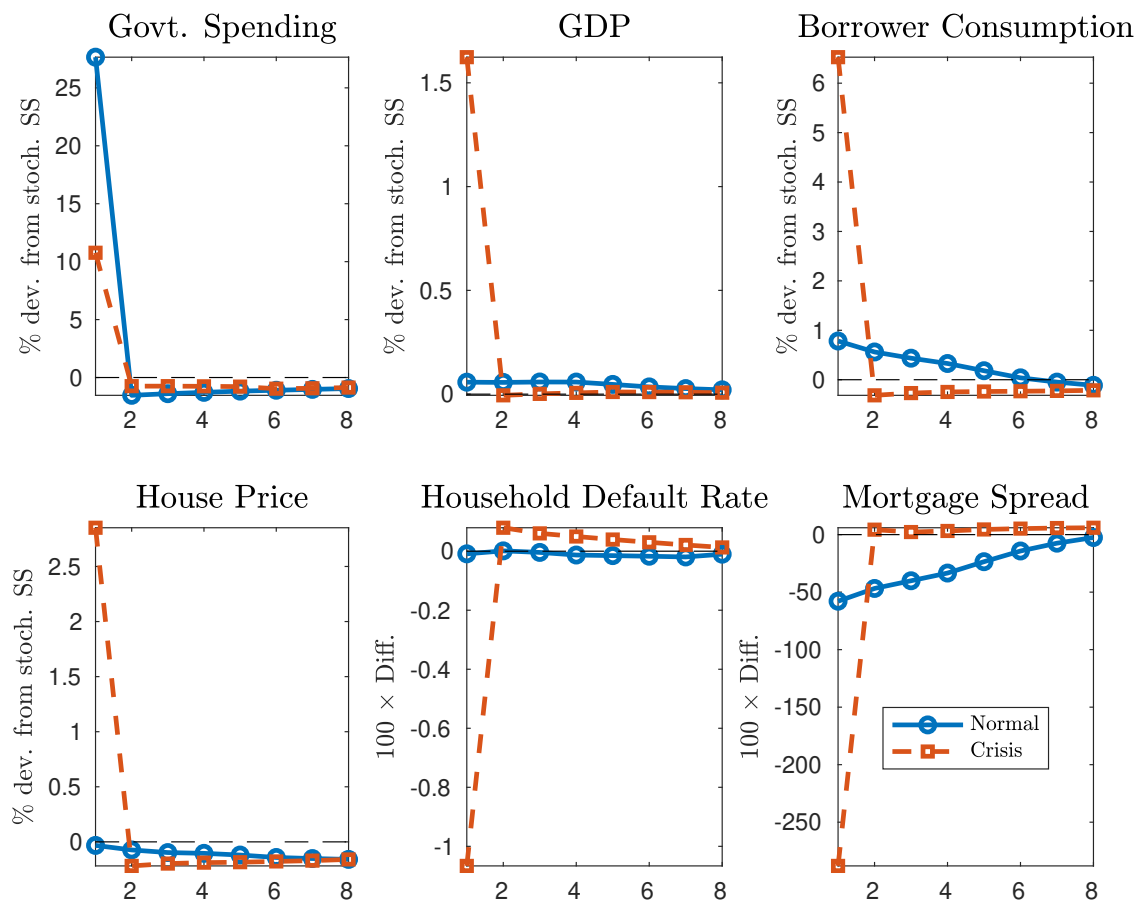


Figure A.4: GIRF of bank recapitalizations, crisis and non-crisis.

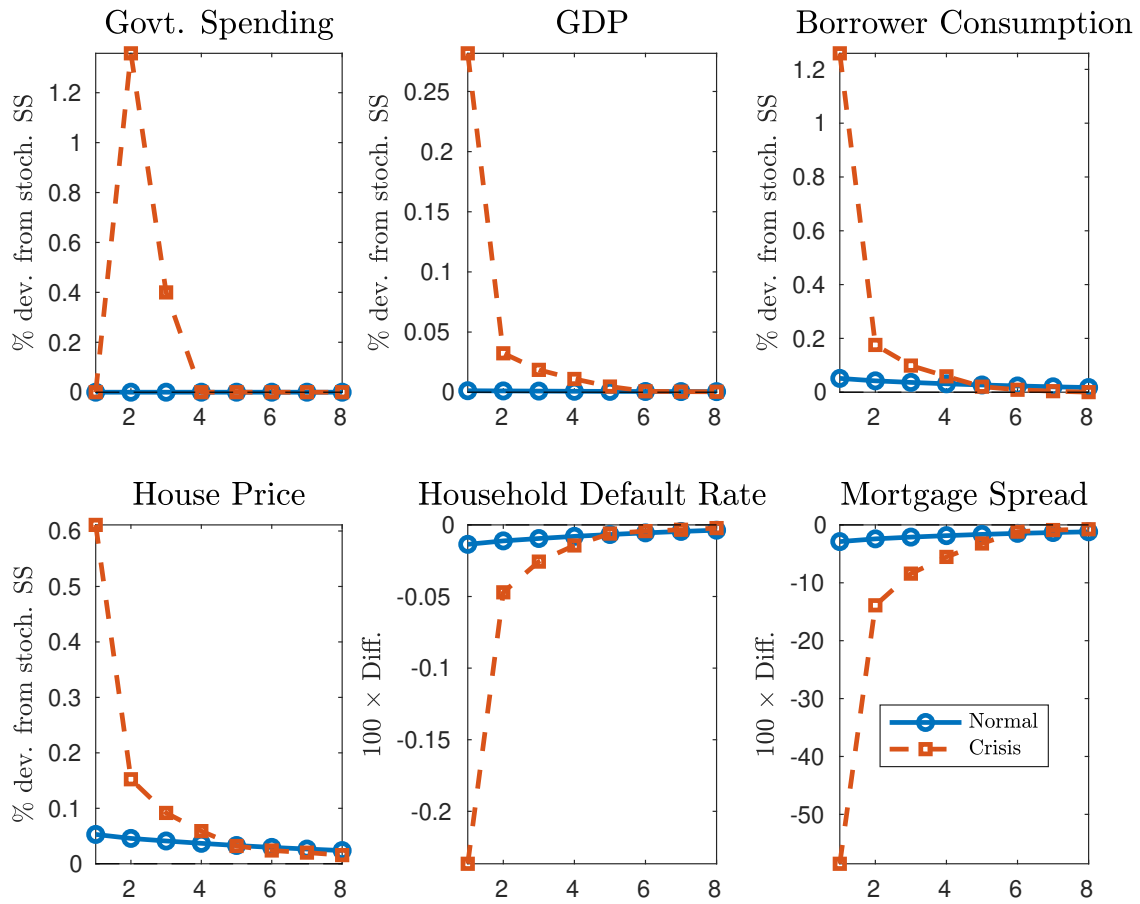


Figure A.5: GIRF of credit guarantees, crisis and non-crisis.

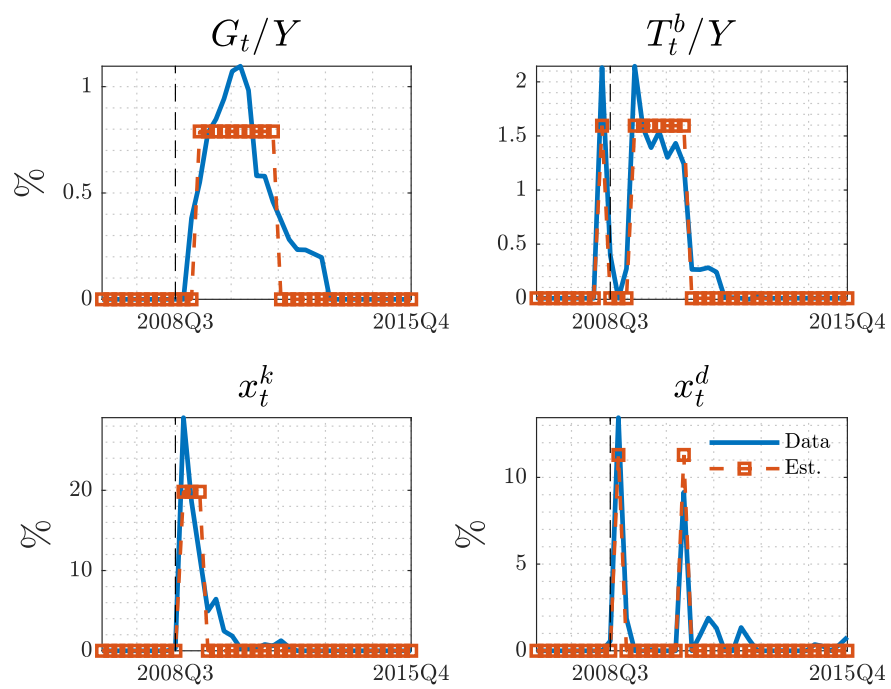


Figure A.6: Implied series for discretionary fiscal policy in the model (solid blue) and discretized series (orange squares).