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Great Recession, Slow Recovery and Muted Fiscal Policies in the US

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Abstract

This paper reconsiders the role of macroeconomic shocks and policies in determining the Great Recession and the subsequent recovery in the US. The Great Recession was mainly caused by a large demand shock and by the ZLB on the interest rate policy. In contrast with previous findings, the subsequent jobless recovery is explained by the ZLB effect. We estimate a fraction of non-Ricardian households which is close to 50%, and obtain comparatively large fiscal multipliers. However we cannot detect a significant contribution of fiscal policies in stabilizing the US economy. For instance, the 2007-2009 large increase in expenditure-to-GDP ratios was apparently determined by the adverse non-policy shocks that caused the recession.

Keywords: DSGE, Limited Asset Market Participation, Bayesian Estimation, US Economy, Business Cycle, Monetary Policy, Fiscal Policy

JEL codes: C11, C13, C32, E21, E32, E37

1 Introduction

The Great Recession that began in the fourth quarter of 2007 and lasted until the last quarter of 2009 was the most severe and long-lasting in US postwar history. The ensuing slow-growth recovery and low inflation environment was heralded as a "new normal" for the years to come (Rogoff, 2009; Summers, 2013).

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A number of contributions has identified this Great Recession as the end of the Great Moderation, i.e. the stable macroeconomic environment that characterized the US economy during the last 20 years of the 20th century (Canarella et al., 2008; Keating and Valcarcel, 2012; Ng and Wright, 2013). Econometric analyses based on dynamic factor models (Stock and Watson, 2012) tend to support the view that the macro shocks associated to the financial crisis were larger versions of shocks typically identified during the Great moderation, whose impact was exacerbated when the Fed's interest rate instrument hit the zero lower bound (ZLB). Gadea Rivas et al. (2014) and Bagliano and Morana (2015) see the Great Recession as a phase of instability within an ongoing Great Moderation, characterized by low volatility in output and inflation and by large swings in asset prices and risk premia.

In this paper we look at the Great Recession and at the subsequent recovery through the lenses of a New Keynesian DSGE model. Our contribution is twofold. On the one hand, we implement a comparative analysis between the Great Recession and the two mild recessions that occurred during the Great Moderation. On the other hand, we identify the role of fiscal policies that these authors completely neglect. For our purposes this is important because US government expenditures increased by 4.4% of GDP between 2007 and 2009.

A vast literature, based on DSGE models, has analyzed the role of shocks and monetary policy in determining the US business cycle, starting from the seminal work of Smets and Wouters (2005, 2007; SW henceforth). Empirical evidence on fiscal policies is instead limited. One notable exception is Leeper et al. (2010). Unfortunately, their analysis is implemented in the framework of a standard neoclassical growth model that includes investment adjustment costs, variable capacity utilization and consumption habits formation, but utterly neglects price and nominal wage rigidities, which are crucial to understand business cycle dynamics and the role of monetary policy.

Our work is akin to the relatively few DSGE models that incorporate the analysis of fiscal policies in the Eurozone and extend the SW framework by introducing Limited Asset Market Participation (LAMP). The LAMP hypothesis draws a distinction between a fraction of households who are asset holders and smooth their consumption over the business cycle, and the remaining

share of Non-Ricardian households who do not participate in financial markets and entirely consume their current disposable income in each period (Coenen and Straub, 2005; Forni, Monteforte and Sessa, 2009; Coenen, Straub and Trabandt, 2012, 2013, CST henceforth). This allows to incorporate the possibility that public consumption and transfers shocks stimulate private consumption (Galí et al., 2007; Oh and Reis, 2011). In addition, our policy framework incorporates the possibility that consumption and labor-income taxes be used for stabilization purposes.

Our results in a nutshell. Our estimated structural parameters are broadly in line with the findings in SW (2005, 2007), but we also estimate a fraction of Non-Ricardian households which is close to 50%. Demand shocks, i.e. risk premium and investment-specific shocks, played a relatively limited role during the Great Moderation, but they are quite important to explain the Great Recession. The ZLB greatly constrained monetary policy and is of particular importance to understand the post-2010 "jobless recovery", in sharp contrast with Stock and Watson (2012), who emphasize the slow down in trend labor force growth, and with Bagliano and Morana (2015), who point at productivity and financial shocks. Our analysis of fiscal policies emphasizes the difficulty in identifying a systematic countercyclical stance for tax and expenditure tools throughout the sample period. Similarly, discretionary fiscal policies, i.e. fiscal shocks, played a limited role during the Great Recession: the large increase in the public expenditures to GDP ratio was almost entirely determined by the adverse shocks that hit the economy during the crisis. In this regard, we see the use of fiscal policies since the onset of the crisis as a missed opportunity. In fact, the large fraction of Non-Ricardian households produces fiscal multipliers that are substantially greater than in previous studies.

Some empirical DSGE models account for the Great Recession and the subsequent recovery. Del Negro et al. (2013) focus on identifying the shocks that caused the recession and on the contribution of monetary policy. Galì et al. (2012) look at the post 2010 jobless recovery. These papers maintain the assumption of frictionless financial markets and neglect the role of fiscal policies. Recent policy-oriented work (Ball et al. 2014) highlights the persistent contractionary effects of slumps such as the Great Recession, and emphasizes the role of traditional Keynesian

demand policies. Our contribution provides full support for this view, and paves the way for the design of a new, less timid framework for the conduct of fiscal stabilization policies.

The remainder of the paper is organized as follows. Section 2 describes the model, Section 3 discuses the details of the estimation method, Section 4 presents the results, and Section 5 concludes.

2 The model[1]

There is a continuum $i \in [0,1]$ of households. To incorporate the LAMP hypothesis we assume that a fraction $1-\theta$ of households (Ricardian households, $i = o$) own firms, trade government bonds, accumulate physical capital and rent capital services to firms. The remaining θ households (Non-Ricardian or LAMP households, $i = rt$) do not have access to financial markets and entirely consume their disposable income. Preferences are assumed identical across households

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\sigma} \left(\frac{c_t^i}{(c_{t-1})^b} \right)^{1-\sigma} \exp\left(\frac{(\sigma-1)}{1+\phi_l} (h_t)^{1+\phi_l} \right) \right\} \tag{1}$$

where $c_t^i = \frac{C_t^i}{z_t}$ and $c_t = \frac{C_t}{z_t}$ are individual and total real consumption levels normalized by a labour-augmenting non-stationary technology shifter z_t. The presence of z_t in (1) guarantees that the model has a balanced growth path when productivity is non stationary.[2] In contrast with Leeper et al. (2010) and CST (2012, 2013) we abstract from non-separability (complementarity) between private and public goods consumption and stick to the utility function used in SW (2005, 2007), characterized by non separability between consumption and labor effort.

There are several arguments that support our choice. Karras (1994) argues that the correlation between private and public consumption should depend on whether fiscal stimulus falls on substitute goods (defense, security, judicial system expenditures) or on goods characterized by

[1] The structure of the model is identical to a companion paper where we invetigate the role of fiscal policies in the Eurozone (Albonico et al. 2016).

[2] See Section 2.4 for more details.

complementarity (expenditures for services also available in the market, such as health and education). Further, if one postulates that private and public consumption enter a CES utility bundle, then the weight associated to public consumption should be estimated along with the elasticity of substitution between the two goods. Unfortunately, it is hard to identify these two parameters even in medium scale DSGE models (McGrattan, Rogerson and Wright, 1997; Cantore et al. 2014). Moreover, Ercolani and Valle e Azevedo (2014) show that fixing the weights in the utility bundle to match the weight of public consumption in total expenditures, as Leeper et al. (2010) and CST do, may bias the sign of the estimated public consumption externality.

Parameter $0 < b < 1$ measures the degree of external habit in consumption. Differently from SW (2007) who use habits in differences, our specification here is based on habits in ratios. The specification chosen for characterizing consumption habits is inconsequential under the representative agent hypothesis (Dennis, 2009). This may not be the case here because individual wealth holdings and consumption levels differ across the two groups, both in steady state and in response to shocks. Carroll (2000) supports the alternative habits-in-ratio specification to avoid the risk of obtaining negative marginal utility of consumption. In the context of LAMP in DSGE models, Motta and Tirelli (2013) show that under the habits-in-difference specification indeterminacy may arise even for relatively small values of θ. By contrast, Menna and Tirelli (2014) show that indeterminacy is a lesser problem under the habit-in-ratio specification adopted in (1). In the context of an empirical LAMP model, the habit-in-difference specification might bias posterior estimates of parameters because the Dynare estimation routine forces estimates of the posterior distribution to be located in the determinacy region, i.e., it discards all posterior draws associated to indeterminacy and the current entry of the Monte Carlo Markov Chain (MCMC) is set at the previous draw.

Each household supplies the bundle of labor services $h_t^i = \left\{ \int_0^1 \left[h_t^i (j) \right]^{\frac{1}{1+\lambda_t^w}} dj \right\}^{1+\lambda_t^w}$. For each labor type j, the wage setting decision is allocated to a specific labor union. At the given nominal wage W_t^j, households supply the amount of labor that firms demand. For each labor type j, the wage setting decision is allocated to a specific labor union. At the given nominal wage W_t^j,

households supply the amount of labor that firms demand

$$h_t^j = \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} h_t^d \tag{2}$$

where $h_t^i = \int_0^1 h_t^j dj$ is the total labor demand. Demand for labor type j is split uniformly across the households, so that households supply an identical amount of labor services, $h_t = h_t^i$ as in Colciago (2011). Combining these expressions with (2) we obtain:

$$h_t = h_t^d \int_0^1 \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj \tag{3}$$

Labor income is:

$$W_t^i h_t^i = h_t^d \int_0^1 W_t^j \left(\frac{W_t^j}{W_t} \right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj$$

Here, the parameter $\lambda_t^w < 1$ is inversely related to the intratemporal elasticity of substitution between the differentiated labour services supplied by the households, $\frac{1+\lambda_t^w}{\lambda_t^w}$. The parameter λ_t^w is assumed to follow an AR(1) process with i.i.d. Normal error term: $\log(\lambda_t^w) = (1-\rho_w)\log(\lambda^w) + \rho_w \log\left(\lambda_{t-1}^w\right) + \eta_t^w$, where η_t^w is typically defined as a wage markup shock (SW, 2007).

2.1 Ricardian households

The flow budget constraint of Ricardian households is

$$\begin{aligned} &(1+\tau_t^c) P_t c_t^o + P_t I_t^o + \frac{B_{t+1}^o}{\varepsilon_t^b} = R_{t-1} B_t^o + \left(1-\tau_t^l - \tau^{wh}\right) W_t h_t^o + P_t D_t^o + \\ &+ \left(1-\tau_t^k\right) \left[R_t^k u_t^o - a\left(u_t^o\right) P_t \right] K_t^o + \tau_t^k \delta P_t K_t^o + P_t T R_t^o - P_t T_t^o \end{aligned} \tag{4}$$

were P_t is the consumption price index, I_t^o defines investment in physical capital, B_t^o are nominally riskless government bonds, D_t^o are firms profits, R_t is the nominal interest rate, K_t^o is the

physical capital stock, u_t^o defines capacity utilization and R_t^k is the nominal rental rate of capital. Note that (4) accounts for tax rates levied on wage and capital incomes and on households consumption, τ_t^l, τ_t^k and τ_t^c respectively, for social contributions levied on labor incomes, τ^{wh}, for public transfers, TR_t^o, and for lump-sum taxes T_t^o. Term ε_t^b is a risk premium shock that affects the intertemporal margin, creating a wedge between the interest rate controlled by the central bank and the return on assets held by the households. It is assumed to follow a first-order autoregressive process with an i.i.d. Normal error term:

$$\log\left(\varepsilon_t^b\right) = (1-\rho_b)\log\left(\varepsilon^b\right) + \rho_b \log\left(\varepsilon_{t-1}^b\right) + \eta_t^b$$

Capital stock dynamics are as follows:

$$K_{t+1}^o = (1-\delta)\,K_t^o + \varepsilon_t^i\left[1 - S\left(\frac{I_t^o}{I_{t-1}^o}\right)\right] I_t^o \tag{5}$$

where δ is the depreciation rate and ε_t^i denotes an investment-specific technology shock that affects the real price of investment. It is assumed to evolve as an AR(1) process with i.i.d. Normal innovation term: $\log\left(\varepsilon_t^i\right) = (1-\rho_i)\log\left(\varepsilon^i\right) + \rho_i \log\left(\varepsilon_{t-1}^i\right) + \eta_t^i$.

The term $S\left(\frac{I_t^o}{I_{t-1}^o}\right)$ represents investment adjustment costs. In line with Christoffel et al. (2008, CCW henceforth), the adjustment costs function is:

$$S\left(\frac{I_t^o}{I_{t-1}^o}\right) = \frac{\gamma_I}{2}\left(\frac{I_t^o}{I_{t-1}^o} - g_z\right)^2 \tag{6}$$

where g_z is the steady state trend growth rate of the economy. The intensity of utilizing physical capital is subject to a proportional cost, as in Christiano et al. (2005):

$$a\left(u_t^o\right) = \gamma_{u1}\left(u_t^o - 1\right) + \frac{\gamma_{u2}}{2}\left(u_t^o - 1\right)^2 \tag{7}$$

Ricardian households maximize (1) with respect to C_t^o, B_{t+1}, I_t^o, K_{t+1}^o, u_t^o, subject to (4), (5), (6) and (7). The first order conditions are:

$$\frac{\left(c_t^o\right)^{-\sigma}\left(c_{t-1}\right)^{b(\sigma-1)}\exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_t^o\right)^{1+\phi_l}\right)\frac{1}{z_t}}{\left(1+\tau_t^c\right)}=\Lambda_t^o/P_t \tag{8}$$

$$R_t=\pi_{t+1}\frac{\Lambda_t^o}{\beta\varepsilon_t^b\Lambda_{t+1}^o} \tag{9}$$

$$\begin{aligned}1 \;=\; & Q_t^o\varepsilon_t^i\left\{1-\gamma_I\left(\frac{I_t^o}{I_{t-1}^o}-g_z\right)\frac{I_t^o}{I_{t-1}^o}-\frac{\gamma_I}{2}\left(\frac{I_t^o}{I_{t-1}^o}-g_z\right)^2\right\} \\ & +\frac{\Lambda_{t+1}^o}{\Lambda_t^o}Q_{t+1}^o\varepsilon_{t+1}^i\beta\gamma_I\left(\frac{I_{t+1}^o}{I_t^o}-g_z\right)\left(\frac{I_{t+1}^o}{I_t^o}\right)^2\end{aligned} \tag{10}$$

$$\frac{\Lambda_{t+1}^o}{\Lambda_t^o}\beta\left\{\left(1-\tau_t^k\right)\left[\frac{R_{t+1}^k}{P_{t+1}}u_{t+1}^o-a\left(u_{t+1}^o\right)\right]+\tau_t^k\delta+Q_{t+1}^o\left(1-\delta\right)\right\}=Q_t^o \tag{11}$$

$$\frac{R_t^k}{P_t}=\gamma_{u1}+\gamma_{u2}\left(u_t-1\right) \tag{12}$$

where Λ_t^o/P_t and $\Lambda_t^oQ_t^o$ are the Lagrange multipliers associated respectively with (4) and (5). Note that in (8) the consumption tax drives a wedge between the marginal utility of consumption and the marginal utility of wealth, Λ_t^o/P_t. We define $\pi_t=\frac{P_t}{P_{t-1}}$ as the gross rate of inflation. Equation (9) is the Euler equation. Q_t^o is the shadow price of a unit of investment good. Equations (10) and (11) are the first order conditions for investment and capital respectively. Equation (12) identifies the optimal degree of capital utilization.

2.2 Non-Ricardian households

LAMP households consume their disposable labor income in each period:

$$\left(1+\tau^c\right)P_tC_t^{rt}=\left(1-\tau_t^l-\tau^{wh}\right)W_t^{rt}h_t^{rt}+TR_t^{rt} \tag{13}$$

where TR_t^{rt} defines public transfers to Non-Ricardian households.

2.3 Wage setting

Nominal wages setting is based on the Calvo formalism. In each period, union j optimally chooses the nominal wage with probability $(1-\xi_w)$. Non-optimizing unions adopt the following indexation scheme (SW, 2007):

$$W_t^j = g_{z,t}\pi_{t-1}^{\chi_w}\bar{\pi}_t^{(1-\chi_w)}W_{t-1}^j$$

where $\bar{\pi}_t$ is the exogenous trend inflation rate.

We assume that the representative union objective function is a weighted average $(1-\theta,\ \theta)$ of the two households types' utility functions, as in Colciago (2011). The union problem therefore is:

$$\max_{\tilde{W}_t^j} E_t \sum_{s=0}^{\infty} (\xi_w\beta)^s \left\{ \begin{array}{l} \frac{1-\theta}{1-\sigma}\left(\frac{c_{t+s}^o}{(c_{t+s-1})^b}\right)^{1-\sigma}\exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}^o\right)^{1+\phi_l}\right) \\ +\frac{\theta}{1-\sigma}\left(\frac{c_{t+s}^{rt}}{(c_{t+s-1})^b}\right)^{1-\sigma}\exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}^{rt}\right)^{1+\phi_l}\right) \end{array} \right\} \tag{14}$$

subject to (3), (4) and (13).

Condition (14) establishes an importance difference with respect to previous empirical DSGE models that account for LAMP (Coenen and Straub, 2005; CST, 2012, 2013) but assume that Non-Ricardian households preferences cannot affect wage-setting decisions. Our assumption that unions take into account the interests of Non-Ricardian households implies a potentially quite different path for wage dynamics whenever the two household groups make different consumption choices in response to shocks, as shown in Motta and Tirelli (2013).

The representative union FOC is:

$$
\begin{aligned}
0 \;=\; & E_t \sum_{s=0}^{\infty} \left(\xi_w \beta\right)^s \left(c_{t+s-1}\right)^{b(\sigma-1)} \exp\left(\frac{(\sigma-1)}{1+\phi_l}\left(h_{t+s}\right)^{1+\phi_l}\right) h_{t+s}^{j} \cdot \\
& \cdot \left\{ \begin{array}{c} \tilde{W}_t^j \frac{\left(1-\tau_{t+s}^{l}\right) g_{z,t,t+s} \pi_{t,t+s-1}^{\chi_w} \bar{\pi}_{t,t+s}^{1-\chi_w}}{\left(1+\tau_{t+s}^{c}\right) P_{t+s} z_{t+s}} \left(1-\frac{1+\lambda_{t+s}^{w}}{\lambda_{t+s}^{w}}\right) \left[(1-\theta)\left(c_{t+s}^{o}\right)^{-\sigma} + \theta\left(c_{t+s}^{rt}\right)^{-\sigma}\right] \\ + \frac{1+\lambda_{t+s}^{w}}{\lambda_{t+s}^{w}} \left[(1-\theta)\left(c_{t+s}^{o}\right)^{-\sigma} MRS_{t+s}^{o} + \theta\left(c_{t+s}^{rt}\right)^{-\sigma} MRS_{t+s}^{rt}\right] \end{array} \right\}
\end{aligned}
$$

where:

$$
\pi_{t,t+s-1} = \begin{cases} 1 & \text{for } \; s = 0 \\ \pi_t \cdot \pi_{t+1} \cdot ... \cdot \pi_{t+s-1} & \text{for } \; s = 1, 2.... \end{cases}
$$

$$
\bar{\pi}_{t,t+s} = \begin{cases} 1 & \text{for } \; s = 0 \\ \bar{\pi}_t \cdot \bar{\pi}_{t+1} \cdot ... \cdot \bar{\pi}_{t+s} & \text{for } \; s = 1, 2.... \end{cases}
$$

$$
MRS_t^o = -\frac{U_h^o\left(c_t^o, h_t^o\right)}{U_c^o\left(c_t^o, h_t^o\right)} = c_t^o \left(h_t^o\right)^{\phi_l}
$$

$$
MRS_t^{rt} = -\frac{U_h^{rt}\left(c_t^{rt}, h_t^{rt}\right)}{U_c^{rt}\left(c_t^{rt}, h_t^{rt}\right)} = c_t^{rt} \left(h_t^{rt}\right)^{\phi_l}
$$

and $g_{z,t,t+s} = \prod_{s=1}^{s} g_{z,t+s}$.

2.4 Firms

2.4.1 Final good firms

The final good Y_t is produced under perfect competition. A continuum of intermediate inputs $Y_t(z)$ is combined as in Kimball (1995). The final good producers maximize profits:

$$
\max_{Y_t, Y_t^z} P_t Y_t - \int_0^1 P_t^z Y_t^z dz
$$

$$\text{s.t.} \int_0^1 G\left(\frac{Y_t^z}{Y_t}; \lambda_t^p\right) dz = 1$$

where G strictly concave and increasing and $G(1) = 1$ and λ_t^p is the net price markup, which is assumed to follow an AR(1) process with i.i.d. Normal error term: $\log(\lambda_t^p) = \left(1 - \rho_p\right) \log(\lambda^p) + \rho_p \log\left(\lambda_{t-1}^p\right) + \eta_t^p$.

From the first order conditions, we obtain:

$$Y_t^z = Y_t G'^{-1} \left[\frac{P_t^z}{P_t} \int_0^1 G'\left(\frac{Y_t^z}{Y_t}\right)\left(\frac{Y_t^z}{Y_t}\right) dz\right]$$

2.4.2 Intermediate good firms

Intermediate firms z are monopolistically competitive and use as inputs capital and labor services, $u_t^z K_t^z$ and h_t^z respectively. Firms are subject to a payroll tax, τ_t^{wf} when using the labor input. The production technology is:

$$Y_t^z = \varepsilon_t^a [u_t^z K_t^z]^\alpha [z_t h_t^z]^{1-\alpha} - z_t \Phi$$

where Φ are fixed production costs. ε_t^a defines a transitory total factor productivity shock, evolving as an AR(1) process:

$$\varepsilon_t^a = \rho_l^a \varepsilon_{t-1}^a + \eta_t^a$$

where η_t^a is an i.i.d. Normal innovation term. The term z_t denotes a labor-augmenting technology process with permanent effects. We posit that $g_{z,t} = \frac{z_t}{z_{t-1}}$ evolves according to:

$$\log(g_{z,t}) = \left(1 - \rho_{g_z}\right) \log(g_z) + \rho_{g_z} \log(g_{z,t-1}) + \eta_t^{g_z} \tag{15}$$

where $\eta_t^{g_z}$ is an i.i.d. Normal innovation term and g_z denotes a deterministic trend.

Profits maximization leads to the following:

$$\frac{u_t K_t}{h_t} = \frac{\alpha}{(1-\alpha)} \frac{\left(1+\tau^{wf}\right) W_t}{R_t^k} \tag{16}$$

In this framework, the capital-labour ratio is equal across firms and the marginal cost is therefore equal across firms:

$$MC_t = \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} \left(\varepsilon_t^a\right)^{-1} z_t^{-(1-\alpha)} \left(R_t^k\right)^{\alpha} \left[\left(1+\tau^{wf}\right) W_t\right]^{1-\alpha} \tag{17}$$

Price setting Intermediate goods prices are sticky à la Calvo (1983). Firm z receives permission to optimally reset its price with probability $\left(1-\xi_p\right)$. Firms that cannot re-optimize adjust the price according to the following scheme:

$$P_t^z = \pi_{t-1}^{\chi_p} \bar{\pi}_t^{1-\chi_p} P_{t-1}^z$$

The representative firm chooses the optimal price $\tilde{P}_t^z$ that expected maximizes profits :

$$\max_{\tilde{P}_t^z} E_t \sum_{s=0}^{\infty} \xi_p^s \Xi_{t,t+s} \left[\frac{\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p} \bar{\pi}_{t,t+s}^{1-\chi_p}}{P_{t+s}} Y_{t+s}^z - \frac{MC_{t+s}}{P_{t+s}} Y_{t+s}^z \right]$$

subject to

$$Y_{t+s}^z = G'^{-1} \left(\frac{\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p} \bar{\pi}_{t,t+s}^{1-\chi_p}}{P_{t+s}} \int_0^1 G' \left(\frac{Y_{t+s}^z}{Y_{t+s}} \right) \frac{Y_{t+s}^z}{Y_{t+s}} dz \right) Y_{t+s}$$

where MC_t is the nominal marginal cost and $\Xi_{t,t+s}$ is the stochastic discount factor for real payoffs:

$$\Xi_{t,t+s} = \varepsilon_{t+s}^b \beta^s \frac{\Lambda_{t+s}^o}{\Lambda_t^o}$$

Following Smets and Wouters (2007), we define $\omega_t = \frac{\tilde{P}_t^z}{P_t} \int_0^1 G' \left(\frac{Y_t^z}{Y_t} \right) \frac{Y_t^z}{Y_t} dz$ and $x_t = G'^{-1}(\omega_t)$, hence the first order condition is:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \frac{\Xi_{t,t+s}}{P_{t+s}} Y_{t+s}^z \left[\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p} \bar{\pi}_{t,t+s}^{1-\chi_p} + \left(\tilde{P}_t^z \pi_{t,t+s-1}^{\chi_p} \bar{\pi}_{t,t+s}^{1-\chi_p} - MC_{t+s} \right) \frac{1}{G'^{-1}\left(\omega_{t+s}\right)} \frac{G'\left(x_{t+s}\right)}{G''\left(x_{t+s}\right)} \right] = 0$$

The aggregate price index dynamic equation is:

$$\begin{aligned} P_t &= \left(1-\xi_p\right) \tilde{P}_t^z G'^{-1} \left(\frac{\tilde{P}_t^z \int_0^1 G' \left(\frac{Y_{t+s}^z}{Y_{t+s}} \right) \frac{Y_{t+s}^z}{Y_{t+s}} dz}{P_t} \right) \\ &\quad + \xi_p \pi_{t-1}^{\chi_p} \bar{\pi}_t^{1-\chi_p} P_{t-1} G'^{-1} \left(\frac{\pi_{t-1}^{\chi_p} \bar{\pi}_t^{1-\chi_p} P_{t-1} \int_0^1 G' \left(\frac{Y_{t+s}^z}{Y_{t+s}} \right) \frac{Y_{t+s}^z}{Y_{t+s}} dz}{P_t} \right) \end{aligned}$$

2.5 Government

The government budget constraint in nominal terms is:

$$\begin{aligned} & P_t G_t + R_{t-1} B_t + TR_t = \\ = \; & B_{t+1} + \tau_t^c P_t C_t + \left(\tau_t^l + \tau^{wh} + \tau^{wf} \right) W_t h_t + \tau_t^k \left[R_t^k u_t - \left(a\left(u_t\right) + \delta \right) P_t \right] K_t + T_t \end{aligned}$$

where G_t is public consumption and TR_t and T_t are aggregate transfers and lump-sum taxes respectively.

2.6 Aggregation

The relationship between aggregate and individual variables is:[3]

$$C_t = \theta C_t^{rt} + \left(1-\theta\right) C_t^o$$

[3] Aggregate and average variables here coincide. For this reason, wealth holdings of Ricardian households are larger than the corresponding aggregates.

$$K_t = (1-\theta)\, K_t^o$$

$$I_t = (1-\theta)\, I_t^o$$

$$B_t = (1-\theta)\, B_t^o$$

$$d_t = (1-\theta)\, d_t^o$$

$$T_t = (1-\theta)\, T_t^o$$

$$TR_t = \theta TR_t^{rt} + (1-\theta)\, TR_t^o$$

2.7 Market clearing

The aggregate resource constraint:

$$Y_t = C_t + G_t + I_t + a\,(u_t)\, K_t$$

Labor market clearing:

$$\begin{aligned} h_t &= \int_0^1 h_t^j dj \\ &= h_t^d \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj \\ &= s_{W,t} h_t^d \end{aligned}$$

where $s_{W,t} = \int_0^1 \left(\frac{W_t^j}{W_t}\right)^{-\frac{1+\lambda_t^w}{\lambda_t^w}} dj$ is the wage dispersion across the differentiated labor services.

Capital market:

$$u_t K_t = u_t \int_0^1 K_t^z dz$$

Firms' aggregate demand for labor input:

$$h_t^d = \int_0^1 h_t^z dz$$

Good market:

$$\int_0^1 Y_t^z dz = \int_0^1 \left(\frac{P_t^z}{P_t}\right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} dz Y_t = s_{P,t} Y_t$$

where $s_{P,t} = \int_0^1 \left(\frac{P_t^z}{P_t}\right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} dz$ is the price dispersion across differentiated goods.

Note that both $s_{W,t}$ and $s_{P,t}$ vanish in the log-linearized version of the model.

2.8 Monetary and fiscal policy rules

Following CCW, the Central Bank sets the nominal interest rate according to a log-linear Taylor rule:

$$\hat{R}_t = \left\{ \begin{array}{c} \phi_R \hat{R}_{t-1} + (1-\phi_R)\left(\phi_\pi \hat{\pi}_{t-1} + + \phi_y \hat{y}_t\right) \\ + \phi_{\Delta\pi}\left(\hat{\pi}_t - \hat{\pi}_{t-1}\right) + \phi_{\Delta y}\left(\hat{y}_t - \hat{y}_{t-1}\right) + \hat{\varepsilon}_t^r \end{array} \right\} \tag{18}$$

where the hatted variables define log-deviations from steady state. In particular, $\hat{y}_t = \widehat{Y_t/z_t}$ is the log-deviation of observed output from the trend output level implied by the permanent technology component. Variable $\hat{y}_t$ is also interpreted as the output gap measure. ε_t^r is a monetary shock that follows a first-order autoregressive process with an i.i.d. Normal error term:

$$\log\left(\varepsilon_t^r\right) = (1-\rho_r)\log\left(\varepsilon^r\right) + \rho_r \log\left(\varepsilon_{t-1}^r\right) + \eta_t^r$$

Similarly to CST (2011, 2012), we assume assume a set of log-linear fiscal feedback rules such that

$$\hat{x}_t = \rho \hat{x}_{t-1} + \phi_{x,b}\hat{b}_{t-1} + \phi_{x,y}\hat{y}_t + \eta_t^x \tag{19}$$

where $\hat{x}_t = \hat{g}_t$, $\widehat{tr}_t$, $\hat{\tau}_t^l$, $\hat{\tau}_t^k$, $\hat{\tau}_t^c$ and η_t^x defines the fiscal policy shock. Our priors imply that $\phi_{x,b}$ and

$\phi_{x,y}$ have stabilizing effects on the economy.[4]

3 Bayesian estimation

We estimate the model using Bayesian methods. The log-linearized model is solved by applying the algorithm proposed by Sims (2002). As in Bayesian practice, the likelihood function (evaluated by implementing the Kalman Filter) and the prior distributions of the parameters are combined to calculate the posterior distributions, using a numerical method, the Metropolis-Hasting algorithm with 1,500,000 replications for four chains. The fiscal DSGE model is estimated for the US quarterly data over the period 1985Q1-2012Q4, presenting results for the two samples: 1985-2007 and 1985-2012. We estimate the model using the standard seven macroeconomics observables: real GDP, real investment, real consumption, real wage inflation, hours worked, GDP deflator inflation and the Federal Funds rate. In addition, we include four fiscal variables: government spending, transfers and consumption and labor tax rates (as in Leeper et al. (2010) and Zubairy (2014)).[5] The Appendix contains a detailed discussion of data sources, definitions, and transformations.

To avoid stochastic singularity, we consider the same number of observables and shocks. Hence, we include eleven structural shocks: transitory and permanent TFP shocks, a risk premium shock, an investment specific shock, an interest rate shock, wage and price markup shocks, a government spending shock, a transfer shock, and consumption- and labor-tax shocks.

The measurement equations for the seven macroeconomic variables are:

[4]Government spending, transfers and debt have been defined as deviations from steady state output. Temporary variations in transfers to Ricardian households are unconsequential.

[5]Capital tax rates could not be treated as observables because tax revenues from capital incomes are available only at annual frequency. We chose not to apply standard statistical tools to get quarterly data because the focus of the paper is to detect comovements between fiscal variables and output and public debt, and the artificial generation of data at quarterly frequencies might in fact generate spurious correlations. Also note that in our estimated model we chose to switch off the capital tax rate feedback parameters on output and public debt.

$$Y_t = \begin{bmatrix} \Delta \ln y_t \\ \Delta \ln c_t \\ \Delta \ln i_t \\ \Delta \ln w_t \\ \ln e_t \\ \Delta \ln P_t \\ \ln R_t^a \end{bmatrix} = \begin{bmatrix} \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{\gamma} + \hat{g}_{z,t} \\ \overline{e} \\ \overline{\pi}_* \\ \overline{r} \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{\imath}_t - \hat{\imath}_{t-1} \\ \hat{w}_t - \hat{w}_{t-1} \\ \hat{e}_t \\ \hat{\pi}_t \\ \hat{r}_t \end{bmatrix}$$

where ln denotes 100 times log, $\Delta \ln$ refers to the log difference, $\overline{\gamma} = 100(g_z - 1)$ denotes a deterministic growth trend, common to the real variables GDP, consumption, investment and wages. Finally, as settled in Smets and Wouters (2007), $\overline{\pi}_* = 100(\overline{\pi} - 1)$ is the quarterly steady-state inflation rate, $\overline{r} = 100(\beta^{-1} g_z \overline{\pi} - 1)$ is the steady-state nominal interest rate, and $\overline{e}$ is the steady-state employment, normalized at zero.

When including the fiscal sector, we use the following measurement equation for government spending:

$$g_t^{obs} = \frac{y}{g} \hat{g}_t$$

where $\hat{g}_t = \frac{g_t - g}{y}$.[6] The tax rates observable variables are measured as deviation from HP-filter trend, thus their measurement equations are trivial.

3.1 Calibration and priors

It is common practice to calibrate some of the parameters that are hard to identify or pin down in steady state (Table 1). These include the discount factor β that is fixed at 0.99, corresponding to a 3% annualized real interest rate in steady-state. The steady-state depreciation rate δ is 0.025, corresponding to a 10% depreciation rate per year. The capital share α is set at 0.3, corresponding to a steady-state share of capital income roughly equal to 30%. Steady-state variables are also

[6] A similar measurement equation is used for transfers.

calibrated based on averages over the sample 1985-2012. The share of government spending in aggregate output is set at 0.20 and the annual average ratio of debt to GDP pins down the steady-state value to be 0.35. Moreover, the steady-state values of the consumption and labor tax rates are based on mean of the constructed series of average tax rates over the sample and are 0.016 and 0.24.

Table 1: Calibrated parameters

parameter	value
β	0.99
δ	0.025
α	0.3
α_p	6
λ_p	0.35
λ_w	0.3
$\bar{\pi} - 1$	0.0047
$g_z - 1$	0.004
$\frac{b}{y}$	0.35
$\frac{g}{y}$	0.20
τ^c	0.016
τ^l	0.24
τ^k	0.39
τ^{wh}	0.094
τ^{wf}	0.074

The remaining parameters are estimated with Bayesian techniques. Priors, reported in Table 2, are set in line with empirical DSGE models of US Economy (Smets and Wouters (2007), Leeper et al. (2010), and Zubairy (2014)).

In particular, parameters measuring the persistence of the shocks are Beta distributed and the standard errors of the innovations are assumed to follow an Inverse-gamma distribution. The parameters governing price and wage setting, habits, utilization elasticity, interest rate smoothing and the steady state fraction of LAMP are also Beta distributed. The fraction of LAMP θ is assumed to be Beta distributed with mean 0.3 and standard deviation 0.1[7]. The parameters of the Taylor are Normally distributed, whereas the parameter defining investment adjustment costs is Gamma distributed. Concerning the parameters characterizing the fiscal rules, the prior on

[7]We assume the prior of the fraction of LAMP as discussed in Albonico et al. (2014).

feedback parameter of the government spending to debt is a Gamma, while the prior on feedback parameter of the government spending to income is a Normal.

Right from the outset, it is worth mentioning that our estimates might be affected by the zero lower bound which constrained the interest rate policy after 2008. To check for this, we estimated the model over the 1985-2007 period. We could not detect significant variations in estimated parameters, in the IRFs to shocks and in the size of fiscal multipliers.[8]

4 Results

The estimates of the full model yield Highest Posterior Density intervals (HPD Int.) for the fiscal feedback parameters $\phi_{x,b}$ and $\phi_{x,y}$ ($\hat{x}_t = \widehat{tr}_t$, $\hat{\tau}^l_t$, $\hat{\tau}^c_t$) that include the zero value. The global sensitivity tests implemented in Dynare (Ratto, 2008) signal identification problems for some parameters, especially for those of the fiscal sector.[9] Further, the DSGE-VAR à la Del Negro and Schorfheide (2004) suggests the full model is not well specified because the hyperparameter which represents the weight of the DSGE model restrictions is close to zero, implying that the DSGE model fails to explain the data.

The next step has been to estimate a restricted DSGE model where the fiscal feedback parameters $\phi_{x,b}$ and $\phi_{x,y}$ have been removed for all the fiscal variables except for $\widehat{g}_t$. In this case however we estimate shocks to all the fiscal variables included in the set of observables. This restricted model is better specified than the model with fiscal reaction functions. Considering the DSGE-VAR à la Del Negro and Schorfheide (2004), we note a dramatic improvement in model ability to match the data. In fact the estimated hyperparameter is now around 1.25. For all parameters the marginal posterior distributions are unimodal, MCMC's convergence criteria are satisfied. Metropolis-Hastings convergence graphs suggest a fast and efficient convergence for all parameters.[10] The global sensitivity tests implemented in Dynare (Ratto, 2008) show that there

[8] Results available upon request.

[9] The problem persists even if we change shape (for example, an Inverse Gamma instead of a Normal) and parameters of the priors distributions.

[10] Visual diagnostics of the estimation results are available in the online Technical Appendix. The posterior distributions are computed considering 1,500,000 draws for 4 Markov chains, with 300,000 draws being discarded

Table 2: Estimated parameters sample 1985-2012

	Prior distribution			Posterior distribution		
parameters	shape	mean	std dev	post. mean	90% HPD interval	
σ	norm	1.5	0.37	0.992	0.897	1.083
b	beta	0.7	0.1	0.69	0.524	0.862
ϕ_l	norm	2	0.5	2.087	1.436	2.733
θ	beta	0.3	0.1	0.472	0.376	0.568
γ_I	gamma	3	1	3.251	2.057	4.391
σ_u	beta	0.5	0.15	0.881	0.836	0.926
χ_p	beta	0.5	0.15	0.113	0.038	0.185
ξ_p	beta	0.7	0.05	0.769	0.724	0.812
χ_w	beta	0.5	0.15	0.624	0.405	0.853
ξ_w	beta	0.8	0.05	0.817	0.781	0.852
ϕ_r	beta	0.75	0.1	0.824	0.776	0.872
ϕ_π	norm	2	0.5	3.514	2.930	4.087
ϕ_y	norm	0.3	0.05	0.088	0.049	0.127
$\phi_{\Delta y}$	norm	0.12	0.05	0.0035	-0.040	0.011
$\phi_{\Delta\pi}$	norm	0.3	0.1	0.420	0.327	0.512
$\phi_{g,b}$	gamma	0.7	0.25	0.018	0.017	0.019
$\phi_{g,y}$	norm	-0.2	0.05	0.001	-0.009	0.009
ρ_a	beta	0.5	0.2	0.975	0.963	0.987
ρ_b	beta	0.5	0.2	0.950	0.923	0.979
ρ_i	beta	0.5	0.2	0.742	0.627	0.86
ρ_r	beta	0.5	0.2	0.775	0.664	0.888
ρ_{gz}	beta	0.5	0.2	0.059	0.008	0.109
ρ_p	beta	0.5	0.2	0.868	0.819	0.919
ρ_w	beta	0.5	0.2	0.048	0.006	0.089
ρ_g	beta	0.5	0.2	0.227	0.041	0.401
ρ_{tr}	beta	0.5	0.2	0.858	0.788	0.933
$\rho_{\tau c}$	beta	0.5	0.2	0.73	0.636	0.828
$\rho_{\tau l}$	beta	0.5	0.2	0.714	0.615	0.816
σ^a	invg	0.1	2	0.853	0.758	0.945
σ^b	invg	0.1	2	0.305	0.241	0.369
σ^i	invg	0.1	2	0.359	0.287	0.428
σ^r	invg	0.1	2	0.122	0.105	0.139
σ^{gz}	invg	0.1	2	2.312	2.047	2.571
σ^p	invg	0.1	2	0.078	0.058	0.097
σ^w	invg	0.1	2	1.374	1.200	1.544
σ^g	invg	0.1	2	0.447	0.394	0.499
σ^{tr}	invg	0.1	2	0.146	0.13	0.1617
$\sigma^{\tau c}$	invg	0.1	2	0.481	0.428	0.533
$\sigma^{\tau l}$	invg	0.1	2	0.478	0.26	0.530
Log data density						-1515.895

are no identification problems.

Estimated parameters are reported in Table 2. We obtain a relatively large share of Non-Ricardian households ($\theta = 0.47$). We find no evidence of a systematic countercyclical fiscal policy.

as burn-in draws. The average acceptance rate is roughly 28 percent.

In fact the HPD interval estimated for the public expenditure feedback on output includes zero. However, we estimate a stabilizing response of $\widehat{g}_t$ to public debt ($\phi_{g,b} = 0.018$, HPD interval $0.017 - 0.019$). The interest rate policy reacts very strongly to inflation but exhibits a substantial degree of inertia. The remaining parameters are broadly in line with estimates obtained in SW (2007).

4.1 The Great Moderation, the 2007-2010 crisis and the recovery

Our sample includes the Great Moderation period, the Financial crisis and the post crisis recovery. We can therefore address the issue whether the financial crisis marked a watershed, and if the forces that drove output growth since the onset of the crisis were different from the ones that were at work during the Great Moderation. To begin with, Table 3 reports the variance decomposition for some key variables. Over the whole period technology shocks explain the bulk of growth volatility. Private sector demand shocks (risk-premium and investment-specific shocks) mainly drive investment dynamics. Fiscal policy shocks have significant effects for output growth volatility, but do not seem to matter for other variables.

Table 3: Variance decomposition: 1985-2012

	Cons. growth	GDP growth	Inflation	Wage growth	Investment	Int. Rate
Technology	62.73	60.83	38.68	44.49	25.01	28.10
Markup	8.23	8.42	19.64	54.55	11.17	33.53
Demand	16.68	9.67	25.02	0.41	62.29	29.76
Monetary	10.50	6.63	16.61	0.52	1.43	8.40
Fiscal	1.70	14.34	0.02	0.03	0.06	0.08

Figure 1 depicts the historical growth decomposition over the whole sample period, whereas Figures 2 3 4 focus on the historical growth decomposition for the three recessionary episodes that characterize our sample, that is 1989Q4-1991Q4, 2001Q1-2002Q1, 2007Q4-2010Q1. The 2007-2010 episode clearly stands on its own both for the larger size of the contraction and for the specific role played by demand (risk premium and investment specific) shocks. Further, our estimates detect a contractionary monetary policy shock that is possibly determined by the ZLB effect on the interest

rate policy, in line with the finding in Stock and Watson (2012). Figure 5 shows the GDP growth historical decomposition for the post 2010 recovery period, when demand shocks seem to play a supporting role. It is worth noting that the positive demand shocks detected by our model after 2010 might well be the consequence of the Fed unconventional measures. Further, our estimates would suggest that holding the Fed funds rate at the ZLB after 2010 did indeed produce a string of expansionary interest rate shocks. However, if we look at the historical decomposition for other variables, such as hours worked and inflation (Figures 6, 7), the picture changes completely. In fact, hours worked, whose fall lagged the slowdown in GDP growth, remained well below potential during the post 2010 GDP recovery, and their dynamics in this period are almost entirely determined by the interest rate stability at the ZLB. It is interesting to note that a symmetrical ZLB effect arises when we look at the historical decomposition for inflation, suggesting that the persistence of hours below steady state levels had a disciplining effect of wage dynamics, on unit labor costs and therefore on inflation. King and Watson (2012) document the prolonged fall in unit labor costs that companied inflation, but neglect the importance of the ZLB effect in determining this outcome. Our interpretation is also quite different from Stock and Watson (2012) who argue that the slow recovery in employment was due to a secular slowdown in trend labor force growth.

By and large, these results highlight the limitations suffered by monetary policy given the severity of the demand contraction, which would have required an interest rate fall well below the ZLB. In fact from Figure 5 we know that the post-2010 period was not characterized by overshooting of the long-run growth rate which had occurred during recoveries from previous recessionary episodes (see Figure 1). Insufficient monetary policy stimulus therefore induced a stagnation of employment and decisively contributed to the low inflation environment.

4.2 Fiscal policies during and after the crisis

Our estimates show that fiscal policies were not used as an active countercyclical tool throughout the sample period. However, the acyclical pattern of fiscal variables implies they did play a "passive" role in limiting volatility. To gauge their importance consider the historical decomposition

Figure 1: GDP growth historical decomposition: full sample.

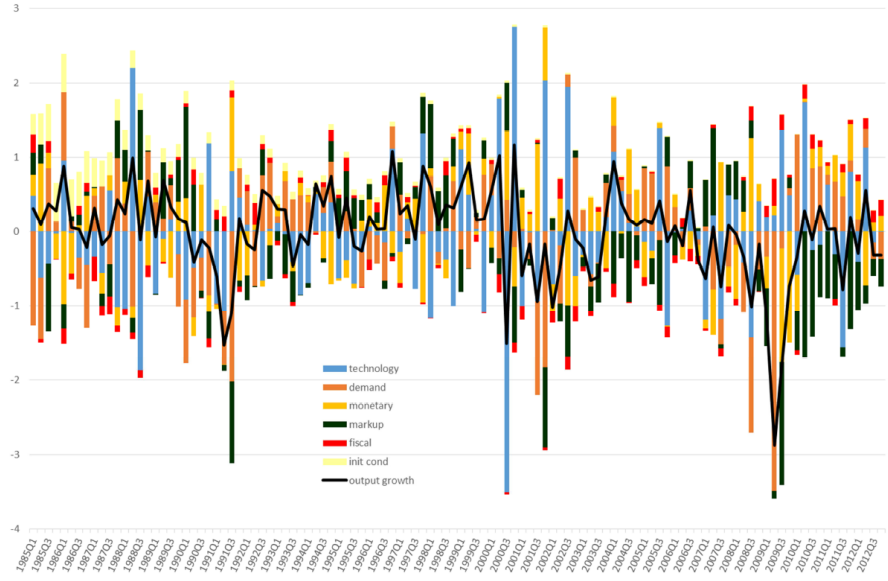


Figure 2: GDP growth historical decomposition: 1989Q1-1991Q4.

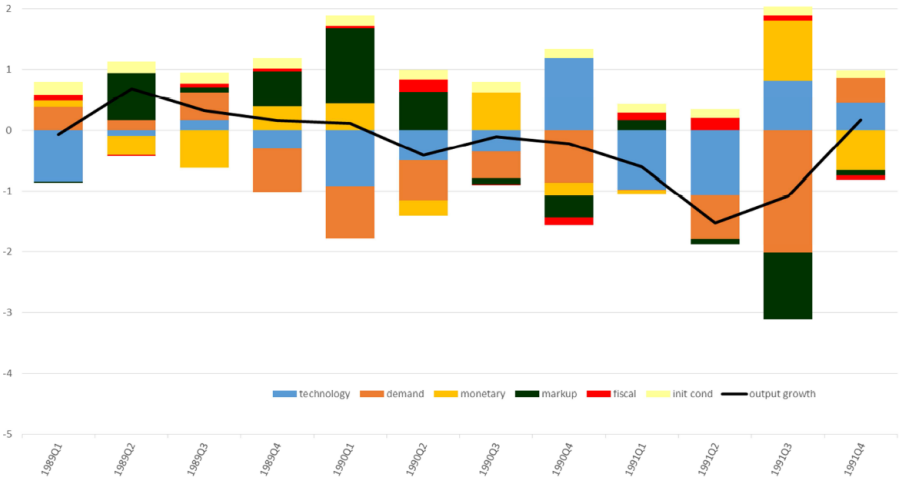


Figure 3: GDP growth historical decomposition: 2000Q2-2001Q2.

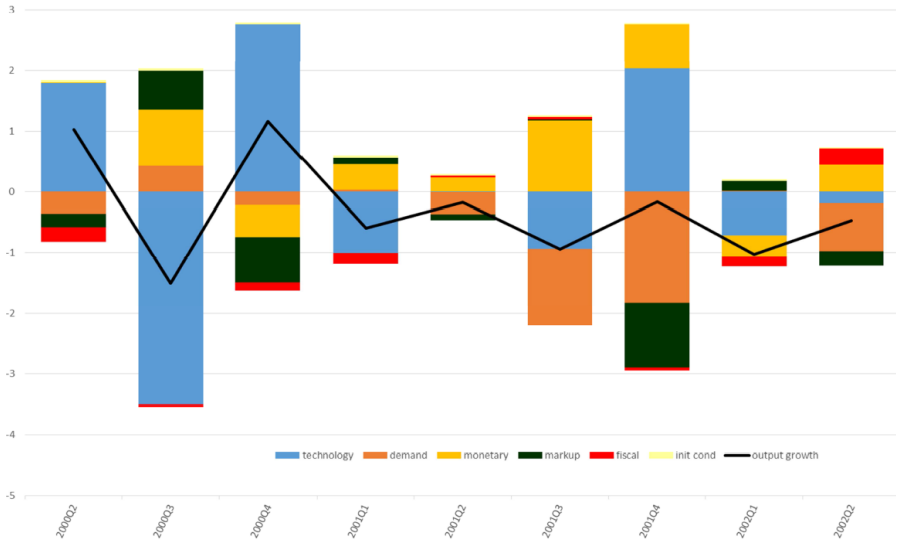


Figure 4: GDP growth historical decomposition: 2007Q1-2010Q2.

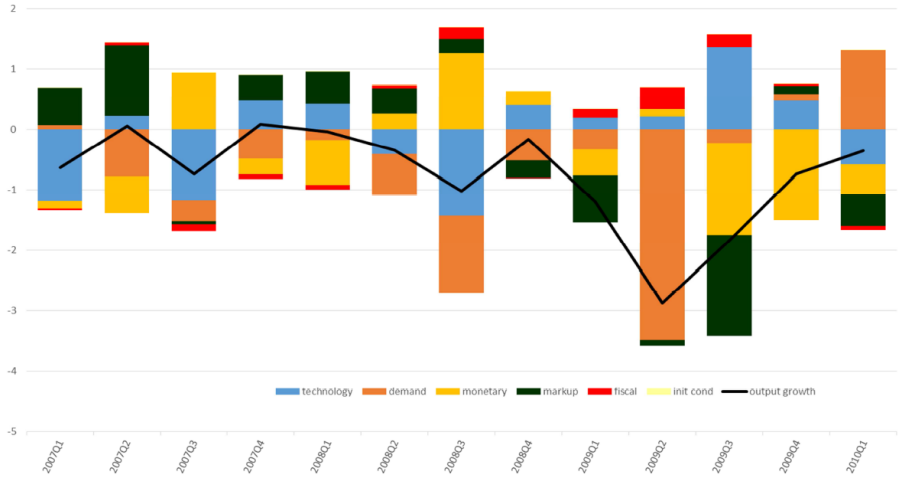


Figure 5: GDP growth historical decomposition: 2010Q2-2012Q4.

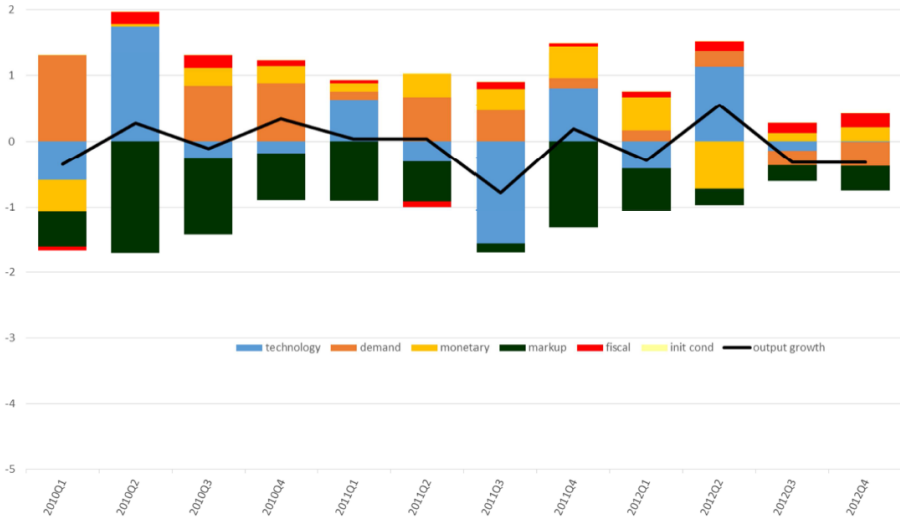


Figure 6: Hours worked historical decomposition, deviations from steady state: 2007Q1-2012Q4.

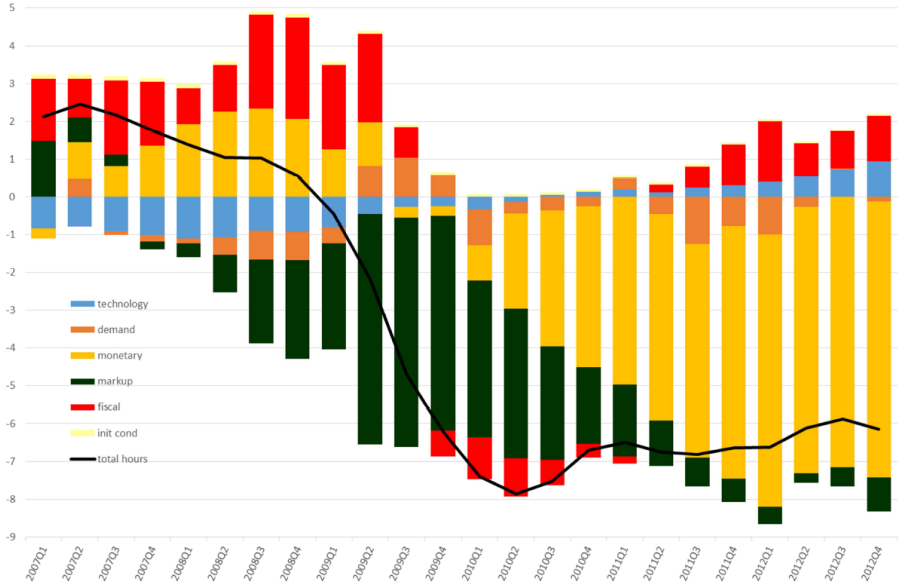
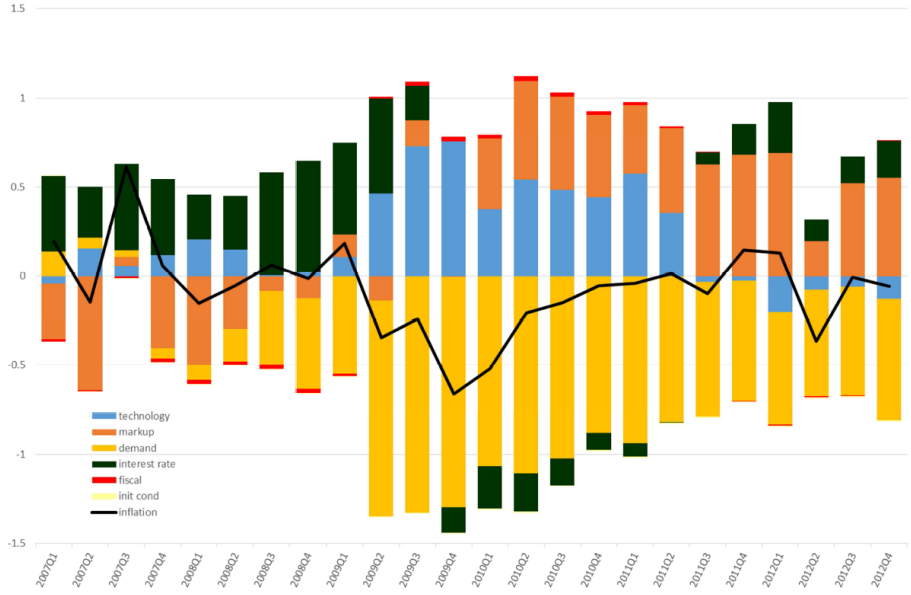


Figure 7: Inflation historical decomposition, deviations from target value: 2007Q1-2012Q4.



of the Public-Consumption-to-GDP growth rate (Figure 8). It is apparent that the adverse shocks which caused the recession also determined the growth in the public consumption ratio, which was then partly reversed due to the favorable shocks that occurred during the post 2010 recovery.

In Figure (9) we pinpoint the contribution of fiscal shocks during the crisis and the recovery. During the crisis discretionary fiscal policy mainly relied on public transfers and labor taxes, whereas during the recovery we observe positive shocks to public consumption.

4.2.1 Fiscal policy: a missed opportunity?

In spite of the relatively large swings in fiscal ratios - total government spending was about 33% of GDP between 2000s and 2007, rose to 41% during the Great Recession and gradually swung back to about 34% in 2015 - our results show that the discretionary fiscal stimulus has been negligible. The large share of Non-Ricardian household we estimate over the sample suggests that more active use of fiscal tools might have had important effects in stabilizing the economy.

In fact, our implied fiscal multipliers (Table 4) are large in comparison with previous studies that assume away the existence of Non-Ricardian households.[11] Zubairy (2014) obtains government

[11] Following Faia et al. (2013), short-run multipliers are impact multipliers, long-run multipliers are computed

Figure 8: Public-consumption-to-GDP growth historical decomposition.

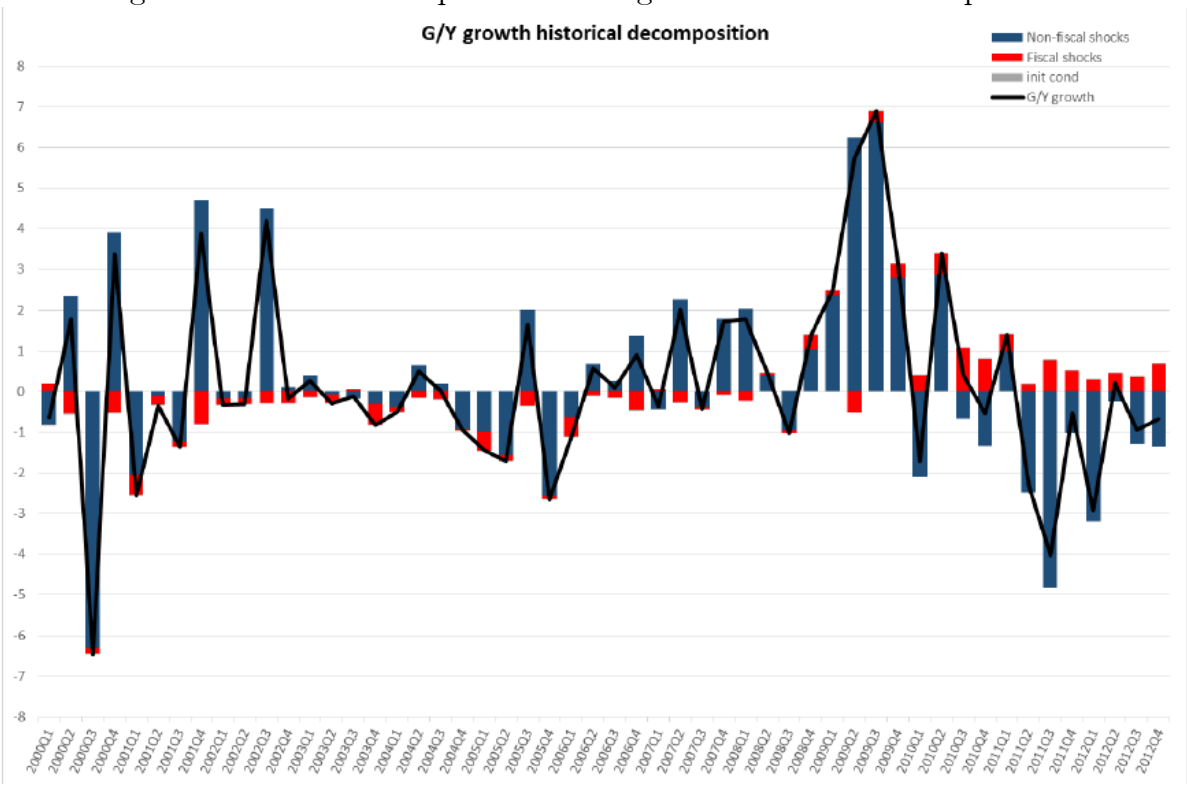
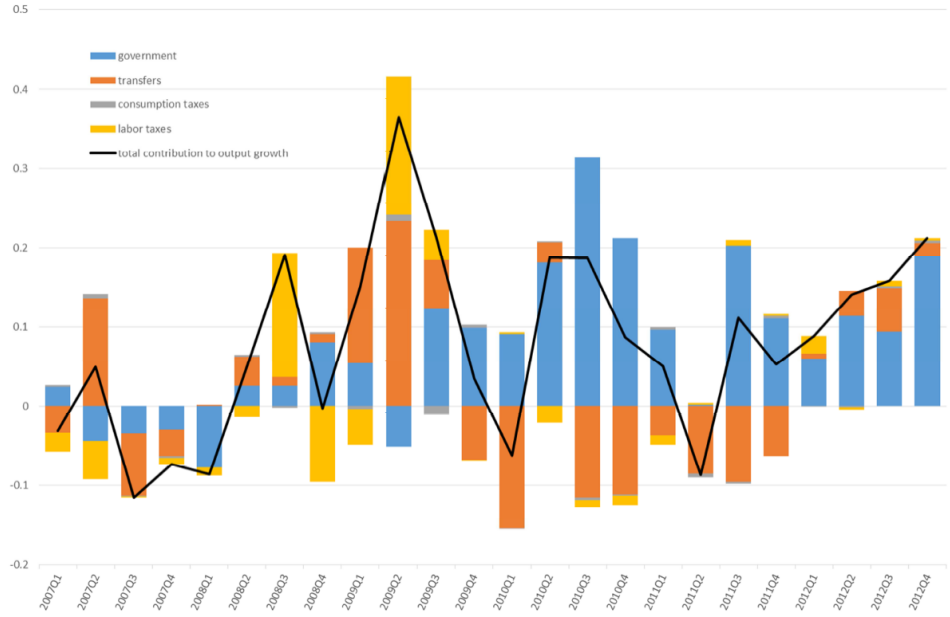


Figure 9: Contribution of fiscal shocks to GDP growth.



spending and labor tax multipliers respectively equal to 1.07 and 0.13 on impact. Leeper et al. (2010) obtain even smaller public consumption multipliers. Our results might have been affected by the persistence of nominal interest rate at the ZLB. In fact, Christiano et al. (2011), using the model estimated in Altig et al. (2011) find that the multiplier effect is substantially larger than one when the zero bound binds, and quite modest otherwise. Our estimates that exclude the post-2008 part of the sample yield values that are identical to those reported in Table 4.[12]

IRFs presented in Figure 10 show that the presence of Non-Ricardian households determines a strong Keynesian multiplier effect in response to public consumption shocks.[13] The increase in output has a limited effect on inflation, eliciting a small real interest rate increase. This is sufficient, however, to induce a persistent fall in the consumption of Ricardian households.

The public transfers multiplier is substantial in our model. Figure 11 shows that the positive response in the consumption of these households is reinforced by the surge in real wages and hours worked.

A labor tax rate shock has a contractionary effect on the economy. Figure 12 shows that Non-Ricardian households suffer from the sharp reduction in disposable income, whereas Ricardian households are able to smooth their consumption. The accommodative monetary stance favours a growth in investments.

The multiplier associated to the consumption tax is larger than the one associated to the labor tax shock, the difference being almost entirely determined by the stronger reduction in Non-Ricardian households consumption. This latter effect is the consequence of the intertemporal substitution effect that induces Ricardian households to postpone their consumption as long as the consumption tax is higher than in steady state.

over 40 periods.

[12] Results availabe upon request.

[13] Here we plot IRFs obtained at the posterior mean (solid lines) and the 90% confidence bands (dotted lines). The standard deviations for each shock is shown in Table 3.

Table 4: Fiscal multipliers 1985-2012. Tax rates multipliers are computed as a percentage increase in output or consumption following a 1 basis point increase in the tax rate.

	gov spending	transfers	consumption tax	labor tax
	output			
short run	1.25	0.39	-0.66	-0.44
long run	1.04	-0.58	-0.01	-0.25
	aggregate consumption			
short run	0.36	0.71	-0.02	-0.15
long run	0.41	0.51	0.00	-0.05
	Ricardians consumption			
short run	-0.14	-0.36	-0.74	0.01
long run	-0.14	-0.29	-0.58	-0.60
	LAMP consumption			
short run	1.06	2.18	-1.55	-1.68
long run	1.16	1.58	-1.15	-1.51

Figure 10: IRFs to a government spending shock.

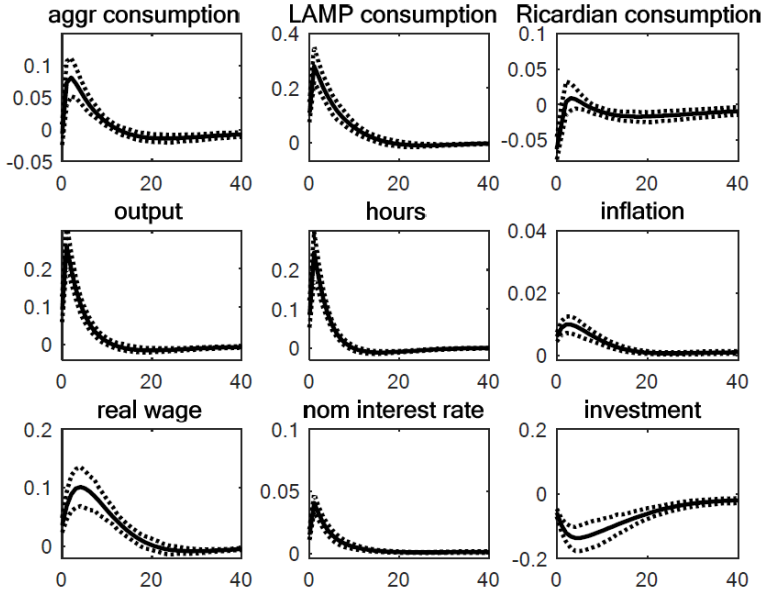


Figure 11: IRFs to a transfers shock.

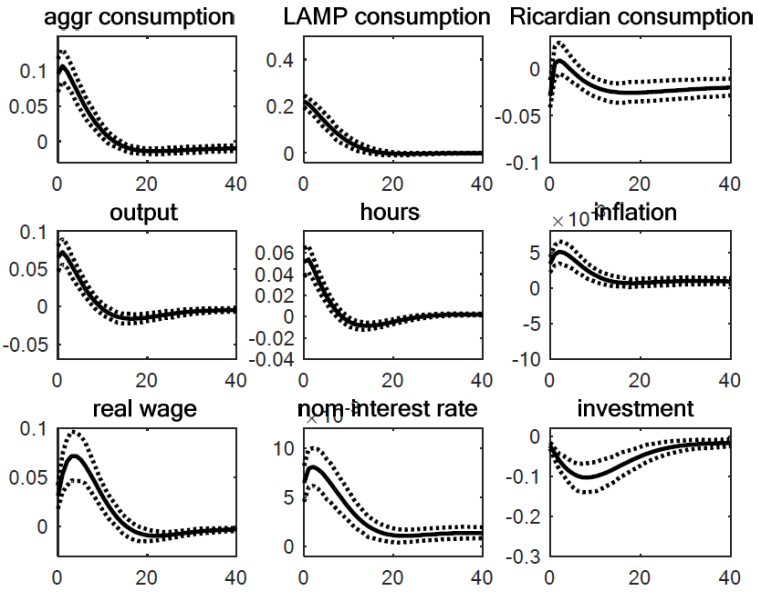


Figure 12: IRFs to a labor tax rate shock.

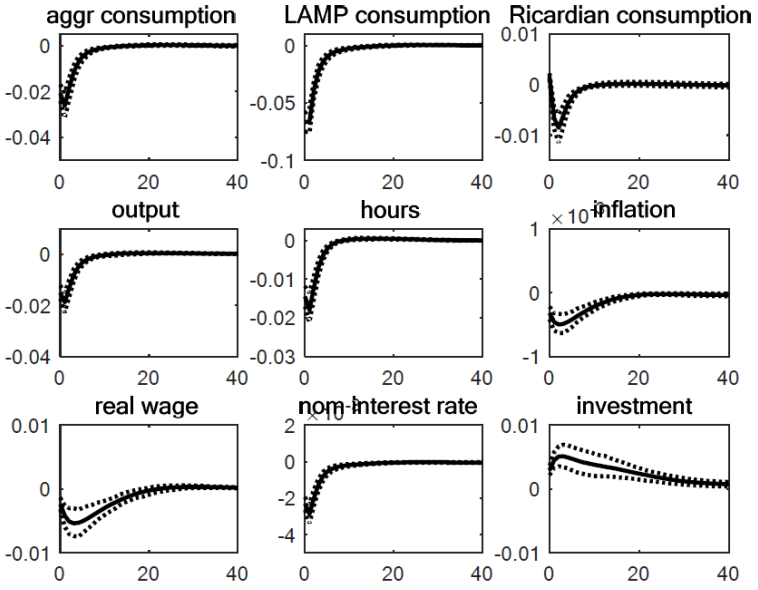
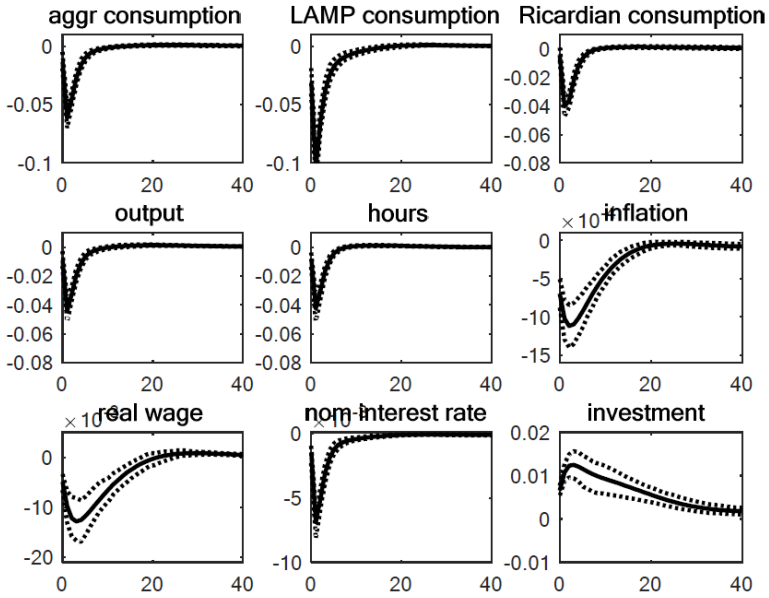


Figure 13: IRFs to a consumption tax shocks.



5 Conclusions

We investigate the role of macroeconomic shocks and policies in determining the Great Recession and the subsequent recovery in the US. Our innovation is twofold: we account for LAMP and also explore the contribution of fiscal policies.

In contrast with previous recessions during the Great Moderation, the Great Recession was mainly caused by a large demand shock and was exacerbated by the ZLB on the interest rate policy. Differently from previous findings, we find that the subsequent jobless recovery is largely explained by the ZLB effect. We estimate a fraction of non-Ricardian households which is close to 50%, and obtain comparatively large fiscal multipliers. However we cannot detect a significant contribution of discretionary fiscal policies in stabilizing the US economy. For instance, the 2007-2009 large increase in expenditure-to-GDP ratios was apparently determined by the adverse non-policy shocks that caused the recession.

The potentially large fiscal multipliers and the apparent importance of LAMP in our empirical model suggest that countercyclical fiscal policies should play in the future a more important role than in the recent past, and that the new attention should be devoted to the design of automatic

stabilizers and discretionary stimuli. We leave this for future research.

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6 Appendix

6.1 Data sources and transformations

This section discusses the sources of the eleven observables used in the estimation and their transformation. We consider quarterly data from 1985 to 2012. GDP, GDP deflator inflation, the Federal Funds rate, civilian population (CNP160V) and civilian employment (CE160V), are downloaded from the ALFRED database of the Federal Reserve Bank of St. Louis. Private consumption expenditures and fixed private investment are extracted from the NIPA Table 1.1.5 of the Bureau of Economic Analysis. Average weekly hours worked (PRS85006023) and compensation per hour (PRS85006103) are downloaded from the Bureau of Labor Statistics. For the fiscal variables, we follow Leeper et al. (2010) and Zubairy (2014). The government spending is composed by government consumption expenditures and gross investment (NIPA Table 1.1.5, Line 20) divided by the GDP deflator and by population. The consumption tax rate is given by the average consumption tax rate defined as:

$$\tau^c = \frac{T^c}{C - T^c - T^c_s},$$

where T^c is the consumption tax revenues (which include excise taxes and customs duties, NIPA Table 3.2, Line 5 and Line 6) and T^c_s is state and local sales taxes (NIPA Table 3.3, Line 12). The labor tax rate is built following the method of Jones (2002). The first step is to construct the average personal income tax rate:

$$\tau^p = \frac{FIT + SIT}{W + PRI/2 + CI},$$

where FIT denotes federal income taxes (NIPA Table 3.2, Line 3), SIT denotes state and local income taxes (NIPA Table 3.3, Line 3), W denotes wages and salaries (NIPA Table 1.12, Line 3), PRI denotes proprietor's income (NIPA Table 1.12, Line 9) and CI denotes capital income which is the sum of rental income (NIPA Table 1.12, Line 12), corporate profits (NIPA Table 1.12, Line

13), net interest rate (NIPA Table 1.12, Line 18), and $PRI/2$. The labor tax rate, τ^l, is then calculated as,

$$\tau^l = \frac{\tau^p \left[W + PRI/2\right] + CSI}{EC + PRI/2},$$

where CSI is total contributions to government social insurance (NIPA Table 3.1, Line 7) and EC denotes total compensation of employees (NIPA Table 1.12, Line 2).

Transfers, TR, are defined as net current transfers, net capital transfers, and subsidies (NIPA Table 3.2, Line 31), minus the tax residual. Net current transfers are defined as current transfer payments (NIPA Table 3.2 Line 21) minus current transfer receipts (NIPA Table 3.2 Line 15). Net capital transfers are defined as capital transfer payments (NIPA Table 3.2 Line 42) minus capital transfer receipts (NIPA Table 3.2 Line 38). The tax residual is defined as current tax receipts (NIPA Table 3.2 line 2), contributions for government social insurance (NIPA Table 3.2 Line 11), income receipts on assets (NIPA Table 3.2 Line 12), and the current surplus of government enterprises (NIPA Table 3.2 Line 18), minus total tax revenue, T (consumption, labor, and capital tax revenues).

Macroeconomics data are transformed as in Smets et al. (2007). In particular, GDP, consumption, investment and net worth are transformed in real per-capita terms by dividing their nominal values by the GDP deflator and the civilian population. Real wages are computed by dividing compensation per hour by the GDP deflator. As shown in the measurement equations, the observable variables of GDP, consumption, investment, wages and net worth are expressed in first differences. Hours worked are multiplied by civilian employment, expressed in per capita terms and demeaned. The inflation rate is computed as a quarter-on-quarter difference of the log of the GDP deflator. The Fed Funds rate is expressed in quarterly terms. Remaining variables are expressed in 100 times log. All series are seasonally adjusted. In the robustness exercise in Section [rob-spread], the spread is computed as the difference between the bank prime loan rate and the 3-month Treasury bill rate and it is expressed in quarterly terms. Data on spreads are also extracted from the ALFRED database of the Federal Reserve Bank of St. Louis.

Fiscal data are were detrended to get stationary series using Hodrick-Prescott filter (1997).

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