

Fiscal Rules and Unemployment[†]

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Abstract

This paper analyzes fiscal policy under fiscal rules in a New Keynesian model with search and matching frictions and distortionary taxation. The model is estimated with US data including detailed information on fiscal instruments. Several findings stand out. First, fiscal rules enhance the positive effects of fiscal policy on output and unemployment. However, effects are smaller as suggested in earlier studies. Second, spending and consumption tax cuts have the largest multipliers, but multipliers are smaller than one. Third, under labor market frictions, multipliers for labor tax cuts are small.

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1 Introduction

Major economies face rising public debt that endangers economic stability. Requests to consolidate public debt and to counteract economic downturns by fiscal stimulus have provoked an active debate on fiscal policy. It is well known that the size of government spending multipliers interacts with fiscal rules (Corsetti et al., 2012). These are typically evaluated in the context of neoclassical labor markets. However, one main policy objective of fiscal policy is to prevent job losses. For an analysis of unemployment, a search and matching labor market is a natural choice. Several authors show that the effects of fiscal policy may change in the presence of labor market frictions (Monacelli et al., 2010, Campolmi et al., 2011, Faia et al., 2013). In a search and matching labor market, variations in the labor tax transmit to the economy through wage bargaining over rents from long term employment relationships.¹

This paper is the first to estimate a New Keynesian model with a frictional labor market and fiscal rules on US data. The results reveal that government spending has the strongest effects on output and unemployment among all different fiscal policy instruments, but multipliers are all smaller than one. Rising government spending by 1 percent of GDP increases output by 0.44 percent on impact. Unemployment is reduced by 0.44 percentage points if government spending goes up by one percentage point relative to GDP. Consumption tax cuts have sizable, but smaller effects. In contrast, the reaction of output and unemployment to labor tax cuts is small. The main reason for the latter finding is that bargained wages do not respond strongly to labor tax cuts in the estimated model. Strong interest rate smoothing and a sluggish response of consumption compounds this effect. The results hold in a model that transmits and propagates fiscal policy via the labor market. Then, the prior range of fiscal multipliers includes multipliers larger than one. Large multipliers result from private consumption crowding in generated from a theoretical complementarity in household preferences (Monacelli et al., 2010). The estimated model reveals that this transmission channel is of minor quantitative importance.

Fiscal rules enhance multipliers of discretionary fiscal policy. As stressed by

¹Arseneau and Chugh (2012) show that the optimal fiscal policy design depends on the labor market and wage setting. Under search and matching frictions, changes in consumption and labor taxes may exhibit distinct effects. In a neoclassical labor market, consumption and labor income taxes distort the households' labor leisure decision in a similar way (Cooley and Hansen, 1992, Leeper et al., 2010a).

Corsetti et al. (2012), under nominal rigidities, expected fiscal restraint in the future (in terms of lower spending and higher taxes), depresses inflation and interest rate expectations. Households optimally consume relatively more on impact. However, the structural estimation of fiscal rules highlights that the effects are smaller as suggested previously. Given that all fiscal instruments adjust to debt (and not only spending), private consumption is not crowded in after discretionary fiscal policy intervention.²

Fiscal policy does not only act through discretionary intervention. This paper accounts for distinct forms of automatic stabilization. First, given that taxes are proportional to the tax base, tax revenue declines in a recession. Total unemployment benefits rise with unemployment. Second, the fiscal rules allow for counter cyclical fiscal policy (Leeper et al., 2010a). Spending, transfers and tax rates react automatically, in a rule-based way, to the stance of the economy. The relative importance of the different components of automatic stabilization is controversial in the existing literature (in't Veld et al., 2013). Based on the estimated model with fiscal rules, this paper demonstrates that the additional stabilization of output and unemployment due to the latter component is small.

I analyze fiscal policy in a DSGE model with search and matching frictions à la Mortensen and Pissarides (1994) with endogenous job destruction and Nash wage bargaining. Endogenous separations give firms an additional adjustment margin in response to shocks. In general, this margin absorbs some of the dampening effect of the labor market friction on fiscal multipliers. As in Krause and Lubik (2007), the search and matching friction is incorporated in a New Keynesian setting with monopolistic competitors and price staggering (Rotemberg, 1982). I extend this setting along the policy dimension. First, monetary policy follows a Taylor rule. At least since the discussion on policy at the zero lower bound, it is well known that the effects of fiscal policy depend on the interaction with monetary policy. Second, I introduce distortionary taxation of labor income, profits and consumption (Faia et al., 2013). The government

²This paper is among the first to discuss the amplification of fiscal multipliers from fiscal rules as suggested by Corsetti et al. (2012) in a structurally estimated DSGE model. Leeper et al. (2010a) estimate similar fiscal rules but their model does not feature nominal rigidities. As a result, the Corsetti et al. (2012) effect does not exist. Forni et al. (2009) and Zubairy (2014) consider estimated tax rules, but not for government spending. Traum and Yang (2015) use a medium scale DSGE model with rule-of-thumb consumers that disguise the crowding in effect from fiscal rules. Fernández-Villaverde et al. (2011) focus on fiscal uncertainty and estimate fiscal rules with stochastic volatility. Drautzburg and Uhlig (2011) analyze a very special scenario for the Great Recession at the zero lower bound.

uses debt financing, whereas tax rates, transfers and government spending follow fiscal rules as in Corsetti et al. (2012).

The exact specification of fiscal policy is contended in the literature. For this reason, I estimate the model with detailed data on the fiscal sector using Bayesian techniques. The combination of data on government spending, debt, and effective tax rates (Mendoza et al., 1994) identifies fiscal policy along tax, spending, and debt dynamics. This analysis evaluates fiscal policy at the intersection between data-driven structural vector autoregressions (SVARs) and purely calibrated DSGE models.³ The previous empirical literature based on SVARs demonstrates that multipliers depend strongly on the identifying assumptions for fiscal shocks. Here, I use the structure of the DSGE model to identify the effects of fiscal policy in the data. Additionally, I use detailed data on job-finding and separation rates to clearly identify the labor market characteristics. As a result, my estimation does not only fit job creation but also job destruction to the data.⁴ The estimated model replicates correlations of US labor and fiscal variables including a negative Beveridge curve relationship.

The structural estimation of the DSGE model with search and matching frictions contributes to the discussion about the driving forces of labor market dynamics. My results highlight that the majority of flow rate dynamics is triggered by demand side disturbances. Productivity shocks explain only a small fraction of labor market flow rate volatility. This finding confirms the recent notion that one explanation for the lack of sufficient amplification towards the labor market in search and matching models (Shimer, 2005) is the focus on productivity shocks.

From the theoretical perspective, my approach towards fiscal policy is closest to Campolmi et al. (2011) and Faia et al. (2013). Mayer et al. (2010) and Brückner and Pappa (2012) also assess fiscal policy in models featuring unemployment. My results contribute to this literature as I, first, add important features to the

³Other studies examining fiscal multipliers in estimated DSGE models are Leeper et al. (2010a) and Zubairy (2014) for the US and Forni et al. (2009) for the Euro area. However, these studies do not allow for a frictional labor market.

⁴Several studies stress the importance of the endogenous separation margin (e.g., Fujita, 2011). Recent papers estimating DSGE models with labor market frictions are Gertler et al. (2008), Krause et al. (2008), Sala et al. (2008), Christoffel et al. (2009), Trigari (2009), Thomas and Zanetti (2009), Christiano et al. (2011) and Galí et al. (2011). However, most of these papers concentrate on monetary policy and inflation and none of them examines fiscal policy and rules or uses flow rate data in the estimation.

model (endogenous separations, a rich fiscal sector and multi-dimensional fiscal rules), and, second, take the model as close as possible to the data.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 describes the estimation strategy including a detailed account of the data and priors. Section 4 discusses the estimation results and model fit. Section 5 examines the effects of policy intervention. Section 6 concludes.

2 The model

The model is a basic New Keynesian setting with Rotemberg (1982) price adjustment costs. The model is augmented with a labor market characterized by search and matching frictions with endogenous separations as in Krause and Lubik (2007) and a rich fiscal sector as in Faia et al. (2013). As common in the literature on labor market frictions, I abstract from capital as an additional production factor.⁵

2.1 Households

Households maximize expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t d_t \frac{c_t^{1-\sigma}}{1-\sigma}, \quad (1)$$

choosing consumption c_t and bonds B_t subject to the budget constraint

$$(1 + \tau_t^c)c_t + \frac{B_t}{p_t} = (1 - \tau_t^n)w_t n_t + b u_t + (1 - \tau_t^p)\Pi_t - \frac{\tau_t^{ls}}{p_t} + (1 + i_{t-1})\frac{B_{t-1}}{p_t}. \quad (2)$$

The intertemporal preference shock d_t captures demand shifts and follows an exogenous AR(1) process $\log d_t = \rho_d \log d_{t-1} + \epsilon_t^d$ with $\rho^d \in [0, 1]$ and $\epsilon_t^d \sim \text{iid } N(0, \sigma_d^2)$.⁶ Households earn aggregate labor income $w_t n_t$ and receive unemployment benefits, b ,

⁵See, e.g., Trigari (2009) and Krause and Lubik (2007) for comparable model setups.

⁶Among others, Hall (1997) argues that preference shocks are important for labor market dynamics. The formulation here follows Forni et al. (2009) and Leeper et al. (2010a) in the fiscal policy context, and Gertler et al. (2008), Krause et al. (2008) and Sala et al. (2008) in the search and matching context.

for unemployed members $u_t = 1 - n_t$.⁷ Labor supply is inelastic. Households receive real profits, Π , from the firms and lump-sum transfers, τ^{ls} , from the government (e.g., social transfers). They pay taxes on consumption, τ^c , labor income, τ^n , and profits, τ^p .⁸ Last periods' bonds pay the net nominal interest rate, i_{t-1} , today. The price index is denoted by p_t . Optimal household behavior implies

$$\lambda_t = \frac{c_t^{-\sigma}}{1 + \tau_t^c}, \quad (3)$$

where λ_t is the marginal utility of consumption and

$$\lambda_t = E_t \beta \frac{d_{t+1}}{d_t} (1 + i_t) \lambda_{t+1} \frac{p_t}{p_{t+1}}. \quad (4)$$

This standard formulation of households' preferences and the Euler equation will result in the common finding of private consumption crowding out in response to an increase in government spending. Section 5.2 provides robustness and a discussion of this issue.

2.2 Production

For illustrative purposes, production is split in three parts as in Trigari (2009) or Faia et al. (2013).

- Step 1: Intermediate goods producers sell homogeneous goods in a perfectly competitive market, but are subject to search and matching frictions in employing labor.
- Step 2: The wholesale sector buys the intermediate goods and transforms them into differentiated consumption goods. Wholesalers sell under monopolistic competition and are subject to Rotemberg adjustment costs when adjusting prices.
- Step 3: Retailers combine the differentiated goods of the wholesale sector into a final consumption aggregate and sell them to households under perfect competition.

⁷As common in the literature, I assume households are so large that members perfectly insure each other against income fluctuations (Andolfatto, 1996 and Merz, 1995).

⁸Profit taxes are taxes on profits of monopolistic competitors and intermediate firms that emerge from the labor market friction. This representation is a short cut to capture distortions along the firms' profit margin in a model without capital.

2.2.1 Intermediate goods producers and the labor market

Intermediate goods producers employ homogeneous labor to produce the intermediate good z_t with

$$z_t = a_t n_t. \quad (5)$$

Aggregate productivity a_t follows an exogenous AR(1) process $\log a_t = \rho_a \log a_{t-1} + \epsilon_t$ with $\rho_a \in [0, 1]$ and $\epsilon \sim \text{iid } N(0, \sigma_a^2)$. Intermediate producers sell in a competitive market and their real relative price equals marginal costs $m_{C_t} = \frac{p_{z,t}}{p_t}$.

Employment n_t is determined on a labor market characterized by search and matching frictions. Timing is as follows: each firm inherits n_{t-1} workers from the last period. The end of last period unemployed u_{t-1} search for a job in the current period. Firms post vacancies v_t to increase their current employment stock. Existing and new matches are then subject to exogenous separation risk ϕ^x . If the match survives, the match is hit by idiosyncratic productivity shocks that may result in endogenous separation at rate ϕ_t^e . The total separation rate is $\phi_t = \phi^x + (1 - \phi^x)\phi_t^e$. Wages are determined from Nash bargaining. New matches become productive immediately. Employment at the end of period t is given by $n_t = (1 - \phi_t)n_{t-1} + (1 - \phi_t)\eta_t u_{t-1}$, where η_t denotes the quarterly job-finding rate.

New matches m_t evolve from a standard Cobb-Douglas matching function

$$m_t = \mu_t u_{t-1}^\alpha v_t^{1-\alpha}, \quad (6)$$

where $0 < \alpha < 1$ is the matching elasticity with respect to unemployment and $\mu_t > 0$ represents a stochastic process of aggregate matching efficiency with $\mu_t/\mu = (\mu_{t-1}/\mu)^{\rho_\mu} \exp(\epsilon_t^\mu)$. This process is characterized by steady state matching efficiency μ , $\rho_\mu \in [0, 1]$ and $\epsilon^\mu \sim \text{iid } N(0, \sigma_\mu^2)$.⁹ As a result, vacancies are filled with probability $q(\theta_t) = m_t/v_t = \mu_t \theta_t^{-\alpha}$ with labor market tightness $\theta_t = v_t/u_{t-1}$. An unemployed worker finds a job in period t at rate $\eta_t = m_t/u_{t-1} = \theta_t q(\theta_t) = \mu_t \theta_t^{1-\alpha}$.

Matches are separated exogenously (quits) and endogenously (firings) as in

⁹The aggregate matching efficiency is treated as an exogenous parameter in the baseline search and matching model. I introduce stochastic fluctuations in matching efficiency μ_t as in Krause et al. (2008) or Lubik (2009) to capture stochastic disturbances in the labor market itself.

Krause and Lubik (2007). Endogenous separations at rate ϕ_t^e occur as follows. In each period, existing and new worker-firm pairs are hit by idiosyncratic random shocks ε to current profits with time-invariant pdf $g(\varepsilon)$ and cdf $G(\varepsilon)$. I assume that idiosyncratic shocks are additive. As a result, contemporaneous profits of a match may be negative. Endogenous separations generate firing costs denoted by f . The value of a match for the firm after the shock realization ε is known is

$$\tilde{J}_t(\varepsilon) = \left(a_t m c_t - \varepsilon_t - w_t(\varepsilon_t) \right) (1 - \tau_t^p) + E_t \Lambda_{t,t+1} J_{t+1}. \quad (7)$$

The worker-firm pair knows at this stage that they are not exogenously separated. The expected stochastic discount factor is $E_t \Lambda_{t,t+1} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{d_{t+1}}{d_t}$ and $w_t(\varepsilon)$ denotes individual wages that depend on the idiosyncratic shock realization ε . The future value of a match for the firm is given by

$$\begin{aligned} E_t J_{t+1} = & E_t (1 - \phi_{t+1}) \int_{-\infty}^{v_{t+1}^f} \frac{(a_{t+1} m c_{t+1} - \varepsilon_{t+1} - w_{t+1}(\varepsilon_{t+1})) g(\varepsilon)}{1 - \phi_{t+1}^e} d\varepsilon_{t+1} (1 - \tau_{t+1}^p) \\ & - E_t \left[(1 - \phi^x) \phi_{t+1}^e (f(1 - \tau_{t+1}^p) + V_{t+1}) + \phi^x V_{t+1} + (1 - \phi_{t+1}) \Lambda_{t+1,t+2} J_{t+2} \right]. \end{aligned} \quad (8)$$

The first term captures the expected profits of the match in period $t + 1$, i.e., aggregate revenue minus expected idiosyncratic costs and expected wages, given that no separation occurs. Production is priced at marginal costs given that intermediate good producers sell on a perfectly competitive market. The second term represents the firing costs that the firm has to pay in case of endogenous separation plus the value of a vacancy. The third term captures the value of a vacancy in case of exogenous separation. The last term represents the expected discounted future value of the continued match in case of no separation. With sticky prices, expansionary fiscal policy generates counter-cyclical price mark-up movements. The inverse of the price mark-up determines the marginal costs of production. The rise in marginal costs drives up the current and future value of a job and, as a result, hiring and employment.

Vacancy posting induces vacancy posting costs $\kappa > 0$. New hires turn productive

immediately (instantaneous hiring). Consequently, the value of a vacancy is

$$V_t = -\kappa(1 - \tau_t^p) + q(\theta_t)J_t + (1 - q(\theta_t))E_t\Lambda_{t,t+1}V_{t+1}. \quad (9)$$

As usual, I assume free entry in vacancy posting. Consequently, firms enter the market until the value of a vacancy is zero ($V_t = 0 \forall t$) and

$$J_t = \frac{\kappa(1 - \tau_t^p)}{q(\theta_t)}. \quad (10)$$

With the definition of the value of a job (Eq. 8), this equation defines the job creation condition as

$$\begin{aligned} \frac{\kappa(1 - \tau_t^p)}{q(\theta_t)} = & (1 - \phi_t) \int_{-\infty}^{v_t^f} \frac{(a_t m c_t - \varepsilon_t - w_t(\varepsilon_t))g(\varepsilon)}{1 - \phi_t^e} d\varepsilon_t (1 - \tau_t^p) \\ & - (1 - \phi^x)\phi_t^e f(1 - \tau_t^p) + (1 - \phi_t)E_t\Lambda_{t,t+1} \frac{\kappa(1 - \tau_{t+1}^p)}{q(\theta_{t+1})}. \end{aligned} \quad (11)$$

Workers are fired if the costs incurred by retaining the match are larger than the firing costs, i.e., $(a_t m c_t - w_t(\varepsilon_t) - \varepsilon)(1 - \tau_t^p) + E_t\Lambda_{t,t+1}J_{t+1} < -f(1 - \tau_t^p)$. As a result, the endogenous firing threshold is

$$v_t^f = a_t m c_t - w_t(v_t^f) + \frac{1}{1 - \tau_t^p} E_t\Lambda_{t,t+1}J_{t+1} + f \quad (12)$$

and the endogenous separation rate is $\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon) d\varepsilon_t = 1 - G(v_t^f)$. Expansionary fiscal policy that affects mark-ups and marginal costs will, as it boosts hiring, also dampen job destruction.

2.2.2 Wage determination

Each firm bargains with each worker individually to split the surplus of a match by Nash bargaining. The wage maximizes the Nash product $(\tilde{J}_t(\varepsilon_t) - V_t + f)^{1-\gamma}(W_t(\varepsilon_t) - U_t)^\gamma$.¹⁰ The workers' bargaining power is denoted by γ . The value of a match for the worker

¹⁰The wage derivation is only sketched here. Details are available on request.

with shock realization ε is

$$W_t(\varepsilon_t) = w_t(\varepsilon_t)(1 - \tau_t^n) + E_t \Lambda_{t,t+1} \left[\phi_{t+1} U_{t+1} + (1 - \phi_{t+1}) \int_{-\infty}^{v_{t+1}^f} \frac{W_{t+1}(\varepsilon_{t+1})}{1 - \phi_{t+1}^e} g(\varepsilon) d\varepsilon_{t+1} \right] \quad (13)$$

and the value of an unemployed worker is

$$U_t = b + E_t \Lambda_{t,t+1} \left[\eta_{t+1} (1 - \phi_{t+1}) \int_{-\infty}^{v_{t+1}^f} \frac{W_{t+1}(\varepsilon_{t+1})}{1 - \phi_{t+1}^e} g(\varepsilon) d\varepsilon_{t+1} + (1 - \eta_{t+1} (1 - \phi_{t+1})) U_{t+1} \right]. \quad (14)$$

As a result, the bargained wage for each realization of the idiosyncratic shock ε_t is

$$w_t(\varepsilon_t) = \gamma \left[a_t m c_t - \varepsilon_t + E_t \Lambda_{t,t+1} \frac{\kappa}{q(\theta_{t+1})} \left(\frac{1 - \tau_{t+1}^p}{1 - \tau_t^p} - (1 - \eta_{t+1}) \frac{1 - \tau_{t+1}^n}{1 - \tau_t^n} \right) - E_t \Lambda_{t,t+1} (1 - \phi_{t+1}) (1 - \eta_{t+1}) \frac{1 - \tau_{t+1}^n}{1 - \tau_t^n} \frac{f}{1 - \tau_{t+1}^p} \right] + (1 - \gamma) \frac{b}{1 - \tau_t^n}. \quad (15)$$

The aggregate wage is the mean of individual wages weighted with the idiosyncratic shock distribution

$$w_t = \int_{-\infty}^{v_t^f} w_t(\varepsilon_t) g(\varepsilon | \varepsilon < v_t^f) d\varepsilon_t = \int_{-\infty}^{v_t^f} w_t(\varepsilon_t) \frac{g(\varepsilon)}{1 - \phi_t^e} d\varepsilon_t. \quad (16)$$

2.2.3 Wholesalers and retailers

Monopolistic wholesalers, indexed by (i) , adjust their prices $p(i)$ every period subject to quadratic Rotemberg (1982) adjustment costs maximizing

$$E_0 \sum_{t=0}^{\infty} \Lambda_{t,t+1} (1 - \tau_t^p) \left[\frac{p_t(i)}{p_t} \tilde{y}_t(i) - m c_t \tilde{y}_t(i) - \frac{\Psi}{2} \left(\frac{p_t(i)}{p_{t-1}(i)} - 1 \right)^2 \tilde{y}_t \right], \quad (17)$$

where Ψ measures price adjustment costs. In equilibrium, total production is $\tilde{y}_t = a_t n_t$. Retailers aggregate with a CES production function $\tilde{y}_t = \left(\int_0^1 \tilde{y}_t(i)^{\frac{\nu_t-1}{\nu_t}} di \right)^{\frac{\nu_t}{\nu_t-1}}$, where ν_t is the time-varying elasticity of substitution between individual goods, $\tilde{y}_t(i)$. Each individual wholesale firm faces downward sloping demand $\tilde{y}_t(i) = \left(\frac{p_t(i)}{p_t} \right)^{-\nu_t} \tilde{y}_t$

in individual prices. Optimal price setting follows

$$\Psi(\pi_t - 1)\pi_t = (1 - \nu_t) + \nu_t mc_t + E_t \left[\Lambda_{t,t+1} \Psi(\pi_{t+1} - 1) \frac{\tilde{y}_{t+1}}{\tilde{y}_t} \frac{1 - \tau_{t+1}^p}{1 - \tau_t^p} \pi_{t+1} \right]. \quad (18)$$

Due to the labor market friction, real marginal costs of production mc differ from marginal costs in a perfectly competitive market. They capture the long run value of a match.¹¹ The time-varying elasticity of substitution ν_t captures price mark-up shocks. They evolve as $\frac{\varphi_t}{\varphi} = (\frac{\varphi_{t-1}}{\varphi})^{\rho_\varphi} \exp(\epsilon_t^\varphi)$ with $\varphi_t = \nu_t/(\nu_t - 1)$, $\rho_\varphi \in [0, 1]$ and $\epsilon^\varphi \sim \text{iid } N(0, \sigma_\varphi^2)$.¹²

2.3 Fiscal and monetary policy

The government finances spending, g , unemployment benefits, b and transfers, τ^{ls} , through tax revenues and issuing debt, D . The model includes distortionary labor taxes, τ^n , consumption taxes, τ^c , and profit taxes, τ^p . Lump-sum transfers, τ^{ls} , can be interpreted as the conventional lump-sum tax in models without fiscal rules. The government budget constraint is

$$g_t + bu_t + \frac{1 + i_{t-1}}{\pi_t} D_{t-1} = \tau_t^{ls} + \tau_t^n w_t n_t + \tau_t^c c_t + \Pi_t \tau_t^p + D_t. \quad (19)$$

Fiscal policy follows fiscal rules in the spirit of Leeper et al. (2010a) and Corsetti et al. (2012). The fiscal rules are multi-dimensional as all policy instruments respond to government debt and output. First, government spending and tax rates react to the overall debt level. Second, I allow for automatic stabilization of tax rates, transfers and spending as all fiscal instruments respond to the output gap. Here, all fiscal instruments adjust in order to consolidate debt (Leeper et al., 2010a). The estimation determines the exact share that each instruments takes over.

¹¹See Faia et al. (2013) for a discussion. Given that marginal costs generate inflation dynamics, their different nature under labor market frictions has been discussed in detail in the literature on monetary policy (Krause and Lubik, 2007, Trigari, 2009).

¹²This formulation follows Thomas and Zanetti (2009) and is, among others, also applied in Krause et al. (2008), Sala et al. (2008), Gertler et al. (2008), Christoffel et al. (2009), and Forni et al. (2009). Price mark-up shocks are necessary to explain the dynamics of economic data, in particular inflation (e.g., Del Negro and Schorfheide, 2006).

The policy rule for government spending is

$$\frac{g_t}{g} = \left(\frac{g_{t-1}}{g}\right)^{\rho_g} \left(\frac{D_{t-1}}{D}\right)^{-\psi_{g,d}} \left(\frac{y_t}{y}\right)^{-\psi_{g,y}} \exp(\epsilon_t^g). \quad (20)$$

Lump-sum transfers evolve as

$$\frac{\tau_t^{ls}}{\tau^{ls}} = \left(\frac{\tau_{t-1}^{ls}}{\tau^{ls}}\right)^{\rho_{\tau^{ls}}} \left(\frac{D_{t-1}}{D}\right)^{-\psi_{\tau^{ls},d}} \left(\frac{y_t}{y}\right)^{-\psi_{\tau^{ls},y}} \exp(\epsilon_t^{\tau^{ls}}), \quad (21)$$

and rules for tax rates are given by

$$\frac{\tau_t^i}{\tau^i} = \left(\frac{\tau_{t-1}^i}{\tau^i}\right)^{\rho_{\tau^i}} \left(\frac{D_{t-1}}{D}\right)^{\psi_{\tau^i,d}} \left(\frac{y_t}{y}\right)^{\psi_{\tau^i,y}} \exp(\epsilon_t^{\tau^i}), \quad (22)$$

for $i = \{w, k, c\}$. The speed of adjustment of each fiscal instrument to government debt is determined by the $\psi_{.,d}$ parameters. The $\psi_{.,y}$ parameters capture the response of each fiscal instrument to the deviation of output from steady state. Shocks to government spending, tax rates and transfers are given by ϵ^g and ϵ^{τ^i} for $i = \{ls, w, k, c\}$ and are specified as iid $N(0, \sigma_j^2)$ with $\rho_j \in [0, 1]$ for $j = \{g, ls, w, k, c\}$.

Monetary policy follows a Taylor (1993) rule

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left[\left(\frac{\pi_t}{\pi}\right)^{\xi_\pi} \left(\frac{y_t}{y}\right)^{\xi_y} \left(\frac{u_t}{u}\right)^{\xi_u}\right]^{1-\rho_i} \exp(\epsilon_t^m). \quad (23)$$

The central bank reacts to deviations from steady state of inflation, output and unemployment, but smooths interest rates. The Taylor rule response to unemployment addresses the trade off between unemployment and inflation for optimal monetary policy under labor market frictions (see Blanchard and Galí, 2010, Faia, 2008, or Faia et al., 2014). The monetary policy shock ϵ^m is distributed iid $N(0, \sigma_m^2)$.

2.4 Aggregation and resource constraint

Aggregate real profits (before taxes) in this economy are defined by the sum of aggregate profits of intermediate firms ($mc_t a_t n_t - w_t n_t - n_{t-1} \phi_t^e f - n_t \int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon - \kappa v_t$) and the wholesale sector ($\tilde{y}_t - mc_t a_t n_t - \frac{\Psi}{2}(\pi_t - 1)^2 \tilde{y}_t$). Perfectly competitive retailers

make zero profits. Real profits are

$$\Pi_t = \tilde{y}_t - w_t n_t - n_{t-1} \phi_t^e f - n_t \int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon_t - \kappa v_t - \frac{\Psi}{2} (\pi_t - 1)^2 \tilde{y}_t. \quad (24)$$

The resource constraint (using the household's and the government's budget constraint and equilibrium in the bond market) is defined as

$$c_t + g_t = \tilde{y}_t - n_{t-1} \phi_t^e f - n_t \int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon_t - \kappa v_t - \frac{\Psi}{2} (\pi_t - 1)^2 \tilde{y}_t. \quad (25)$$

Private and public consumption equals production \tilde{y}_t minus resource costs for firing, aggregate profitability shocks, vacancy posting and price adjustment. The sum of private and public consumption defines output (or GDP) y_t as

$$y_t = c_t + g_t. \quad (26)$$

3 Estimation and calibration

I estimate the log-linearized model with Bayesian techniques as described, e.g., in the survey by An and Schorfheide (2007). The mode of the posterior distribution is obtained using numerical maximization and the full posterior is explored with the Random Walk Metropolis Hastings algorithm.¹³

3.1 Data and measurement

The model is estimated with quarterly US data on GDP, inflation and interest rates. As labor market variables, I include the job-finding and the separation rate computed as by Shimer (2012). The fiscal sector is characterized by series on government spending, government debt and tax rates. The series span from 1965Q1 to 2011Q4.¹⁴ Inflation and interest rates are demeaned. GDP, flow rates, spending, debt and tax rates are filtered

¹³At the mode, I checked the gradient by inspecting the shape of slices of the likelihood and the posterior. I ensure convergence of the Markov chain by diagnostic tools such as CUSUM and trace plots.

¹⁴Appendix A discusses data sources and the construction of effective tax rates in more detail. The sample includes the Great Recession. The general results remain unchanged if the Great Recession period is excluded given that the sample is very long with almost 50 years of data.

with the one-sided HP filter of Stock and Watson (1999) (in logs).¹⁵ These observables are matched with their model counterparts using log deviations from steady state. The model features ten structural shocks for ten observable variables: shocks to aggregate productivity, ϵ , monetary policy, ϵ^m , government spending, ϵ^g , shocks to each tax rate, ϵ^{τ^w} , ϵ^{τ^c} , ϵ^{τ^k} , shocks to lump-sum transfers, $\epsilon^{\tau^{ls}}$, preference shocks, ϵ^d , price-mark up shocks, ϵ^ν and shocks to the matching efficiency, ϵ^μ .

3.2 Discussion of priors and identification

Table 1 summarizes the steady state targets and the fixed parameters. The steady state targets of the model correspond to averages in the data. The average real return is 2.27 percent (as derived from inflation and nominal interest rates). The corresponding discount factor, β , is 0.994. Steady state gross inflation is normalized to unity.

		Value
Discount factor	β	0.9944
Elasticity of substitution	ν	10
Firing costs	f	0
Mean of idiosyncratic shock distribution	a_1	0
Gross inflation	π	1
Job-finding rate	η	0.7939
Separation rate	ϕ	0.0975
Worker finding rate	$q(\theta)$	0.7
Exogenous separations	ϕ^x	0.065
Government spending (relative to GDP)	g/y	0.2081
Government debt (relative to annualized GDP)	D/y	0.3199
Labor tax rate	τ^n	0.2543
Profit tax rate	τ^k	0.3907
Consumption tax rate	τ^c	0.0518

Table 1: Fixed parameters and steady state targets. Quarterly calibration. Annual productivity is normalized to 1.

Unemployed workers find a job at an average rate of 79.4 percent. Employed workers are separated at an average rate of 9.75 percent. In line with den Haan et al. (2000),

¹⁵As also discussed by Jones (2002), the tax rates exhibit long run trends that have no representation in the model. The one-sided HP filter removes these trends.

exogenous separations constitute two thirds of total separations. I target the steady state job-finding rate with the vacancy posting costs κ . The target for the separation rate is met by adjusting the variance of the idiosyncratic shock distribution $g(\varepsilon)$. I assume that the idiosyncratic shocks follow a logistic distribution with mean $a_1 = 0$ and scale parameter a_2 . The logistic distribution allows to derive closed form solutions for the expected shock realizations.¹⁶ Following den Haan et al. (2000), the average quarterly worker finding rate is set to 70 percent. This target is matched with the steady state matching efficiency. Firing costs are set to zero.

The methods of Iskrev (2010) allow to check parameter identification, i.e., to determine for which model parameters the estimation contains no information.¹⁷ Most parameters, especially those of the fiscal rules, are well identified. However, the steady state demand elasticity, ν , and price adjustment cost, Ψ , are collinear in the model and only weakly identified. Smets and Wouters (2007) document the same observation. In line with Smets and Wouters (2007), I set a very tight prior for the demand elasticity and estimate only the price adjustment costs, Ψ . The steady state elasticity of substitution between different product types, ν , is set to 10 (Faia et al., 2013).

All remaining parameters are estimated. The prior distributions are summarized in Table 2. Priors for labor market parameters follow Lubik (2009). Prior distributions are rather wide and cover a broad region of reasonable parameter values, in particular, for the matching elasticity α , workers' bargaining power γ , and the replacement rate $rr = b/w$. A Beta prior with mean 0.5 and standard deviation 0.2 reflects that these parameters are bounded between zero and one.

The risk aversion parameter follows a Gamma distribution centered at 2 with standard deviation 0.5. This prior captures values typically used in the literature (e.g., Christoffel et al., 2009 or Faia et al., 2013). Priors for the monetary policy parameters are in line with Smets and Wouters (2003) and Gertler et al. (2008), among others. The prior mean for the Taylor coefficient on inflation is 1.7.¹⁸ The prior mean for the output

¹⁶To be precise here, targeting flow rates does not mean that the scale parameter of the logistic distribution and the vacancy posting costs are fixed during the estimation. Instead, these parameters depend on the targets and on the deep parameters and are updated, while the deep parameters are estimated.

¹⁷See e.g., Canova and Sala (2009) for a discussion of the problem of parameter identification in DSGE models. Here, I follow Iskrev (2010) who derives conditions for identification based on the Jacobian matrix of the first and second order moments of the observables to the structural parameters of the model.

¹⁸This relatively large number ensures that the model remains in determinacy regions

		Density	Mean	Std.dev.
<i>Labor market</i>				
Matching elasticity on unemployment	α	Beta	0.5	0.2
Bargaining power of the worker	γ	Beta	0.5	0.2
Replacement rate	rr	Beta	0.4	0.2
<i>Price setting, monetary policy, and preferences</i>				
Price adjustment costs	Ψ	Normal	100	$1000^{1/2}$
Interest rate smoothing	ρ_i	Beta	0.75	0.1
Taylor rule response to inflation	ξ_π	Normal	1.7	0.1
Taylor rule response to output	ξ_y	Normal	0.125	0.05
Taylor rule response to unemployment	ξ_u	Normal	-0.2	0.25
Relative risk aversion	σ	Gamma	2	0.5
<i>Fiscal policy</i>				
Feedback of gvmt. debt on gvmt. spending	$\psi_{g,d}$	Normal	0.15	0.1
Feedback of output on gvmt. spending	$\psi_{g,y}$	Gamma	0.07	0.05
Feedback of gvmt. debt on each tax rate	ψ_{τ^j}	Normal	0.15	0.1
Feedback of output on labor tax	$\psi_{\tau^w,y}$	Gamma	0.5	0.25
Feedback of output on profit tax	$\psi_{\tau^k,y}$	Gamma	1	0.3
Feedback of output on consumption tax	$\psi_{\tau^c,y}$	Gamma	0.05	0.025
Feedback of output on transfer	$\psi_{\tau^{ls},y}$	Gamma	0.2	0.1
<i>Shock processes</i>				
AR-coefficients of shocks (fixed at zero in case of monetary policy shock)	ρ_j	Beta	0.5	0.2
Std.dev. of shocks	σ_j	Inv. Gamma	0.01	1

Table 2: Estimated parameters and prior distributions. Quarterly calibration.

response is 0.125, which corresponds to a Taylor coefficient of 0.5 with annualized inflation. The optimal Taylor coefficient on unemployment differs depending on the type of labor market friction introduced in the model. Faia (2008) finds an optimal coefficient of -0.15 with search and matching unemployment, Blanchard and Galí (2010) argue in favor of -0.8 for the US and -0.6 for Europe. A Normal prior with mean -0.2 and standard deviation 0.25 covers all these values. Evidence on the average duration (Smets and Wouters, 2003).

of a price contract varies between 2 and 4 quarters. I set a broad Normal prior centered at 100 with standard deviation $1000^{1/2}$ (Forni et al., 2009).¹⁹

The priors for the fiscal policy parameters follow Leeper et al. (2010a) and Traum and Yang (2015). The fiscal elasticities with respect to government debt have a Normal prior that is centered at 0.15 with standard deviation 0.1.²⁰ The elasticities with respect to output follow Gamma distributions as in Leeper et al. (2010a). The prior mean of the spending and transfer elasticity for the automatic response to output is rather small, whereas profit and labor taxes respond rather strongly. A prior mean of 0.05 captures that the effect of automatic stabilization in consumption taxes is potentially small. Finally, the prior standard deviations of the structural shocks are inverse Gamma distributed with mean 0.01 and standard deviation 1 (Krause et al., 2008). The persistence of the shock processes, except for the monetary policy shock, follows Beta distributions with mean 0.5 and standard deviation 0.2 (Smets and Wouters, 2003).

4 Estimation results

4.1 Parameter estimates

Table 3 summarizes the estimated posterior mean and 5 and 95 percentiles of the model parameters. The data is informative for the parameters as the estimated posterior distributions, including those of labor market and fiscal policy parameters, are moved away from the prior.²¹ The estimation renders a high level of price stickiness with a posterior mean of $\Psi = 244.93$. This value corresponds to a Calvo parameter, i.e., a probability of not adjusting prices in a given quarter, of approximately 0.81 and an average price duration of roughly five quarters. Numbers in an equally high range have frequently been found in other studies, e.g., Sala et al. (2008), Thomas and Zanetti (2009), and Forni et al. (2009). Monetary policy reacts to inflation with a coefficient of 1.56, while output reaction is modest with a posterior mean of 0.10. However, monetary policy

¹⁹Up to a first order approximation around a zero net inflation steady state, the prior mean of 100 corresponds to an average Calvo price stickiness of approximately 0.75.

²⁰Forni et al. (2009) use a Gamma prior with mean 0.5 and standard deviation 0.1 for these parameters. This region and the calibrated value of 0.02 used by Corsetti et al. (2012) are covered by the prior region applied here.

²¹Appendix B collects plots of the prior and posterior distributions and CUSUM plots that illustrate the convergence of the Markov chain.

reacts strongly to unemployment (-0.40). This result provides empirical foundations for the theoretical arguments for unemployment in Taylor rules (Faia et al., 2014). The monetary authority exerts a high degree of interest rate smoothing (ρ_i is approximately 0.94). Relative risk aversion σ is reduced to 1.46 compared to the prior mean.

		Prior mean	Posterior Mean	Posterior 90% interval
<i>Price setting, monetary policy, and preferences</i>				
Price adjustment costs	Ψ	100.00	244.9315	[179.33; 308.56]
Interest rate smoothing	ρ_i	0.75	0.9355	[0.92; 0.95]
Taylor rule response to inflation	ξ_π	1.70	1.5630	[1.39; 1.73]
Taylor rule response to output	ξ_y	0.13	0.1002	[0.04; 0.16]
Taylor rule response to unemployment	ξ_u	-0.20	-0.3985	$[-0.51; -0.29]$
Relative risk aversion	σ	2.00	1.4607	[1.09; 1.84]
<i>Labor market</i>				
Bargaining power	γ	0.50	0.8895	[0.82; 0.96]
Matching elasticity on unemployment	α	0.50	0.5087	[0.46; 0.56]
Replacement rate	rr	0.40	0.6195	[0.57; 0.68]
<i>Fiscal policy</i>				
Feedback of gvmt. debt on gvmt. spending	ψ_g	0.15	0.0352	[0.03; 0.04]
Feedback of gvmt. debt on consumption taxes	ψ_{τ^c}	0.15	0.0232	[0.01; 0.04]
Feedback of gvmt. debt on profit taxes	ψ_{τ^k}	0.15	0.0911	[0.07; 0.12]
Feedback of gvmt. debt on labor taxes	ψ_{τ^w}	0.15	0.1052	[0.09; 0.12]
Feedback of gvmt. debt on transfers	$\psi_{\tau^{ls}}$	0.15	0.3482	[0.18; 0.52]
Feedback of output on gvmt. spending	$\psi_{g,y}$	0.07	0.0151	[0.00; 0.03]
Feedback of output on consumption tax	$\psi_{\tau^c,y}$	0.05	0.0378	[0.01; 0.06]
Feedback of output on profit tax	$\psi_{\tau^k,y}$	0.75	0.2861	[0.16; 0.41]
Feedback of output on labor tax	$\psi_{\tau^w,y}$	0.40	0.2486	[0.15; 0.35]
Feedback of output on transfer	$\psi_{\tau^{ls},y}$	0.20	0.1949	[0.05; 0.34]

Table 3: Posterior distributions of the estimated model parameters. The posterior is explored using the random-walk metropolis hastings algorithm with 500,000 draws. I discard the first 250,000 draws. The average acceptance rate is 0.35. The log marginal data density is computed using the modified harmonic mean estimator.

The data is informative for the labor market parameters. The posterior mean of the

elasticity of the matching function with respect to unemployment, α , is 0.51.²² The posterior mean of the workers' bargaining power is high ($\gamma = 0.89$). In contrast, the posterior mean of the replacement rate is of moderate size (0.62) but larger than the prior and more concentrated.²³ The high bargaining power of workers generates strongly procyclical wages, i.e., wages respond forcefully to aggregate productivity, marginal costs of production and labor market tightness (see Eq. 16). A similar observation was made by Krause et al. (2008) in an estimation of a comparable DSGE model with search and matching frictions (although without fiscal rules, data on flow rates and endogenous separations). They also find a relatively strong bargaining power of workers and their posterior coverage region includes the estimates here. Flexible wages are well in line with the empirical observation of Haefke et al. (2013) that wages of new entrants in the US are highly flexible and move one to one with productivity. Hagedorn and Manovskii (2013) find that US wages do only depend on current conditions, not on past variables. Krause et al. (2008) argue that the labor market itself does not trigger persistence and volatility of the model under flexible wages. Instead, persistence and volatility originate from other model ingredients (e.g., strong nominal rigidities) and the exogenous shock processes. Endogenous job separations and a model fitted to flow rates instead of unemployment rates emphasize this effect.²⁴ Nevertheless, as discussed below, the labor market influences the transmission of fiscal and non-fiscal shocks.

The posterior distributions of the fiscal rule parameters are different from zero. Spending, transfers and distortionary taxation respond to the level of debt. Government spending reacts to debt even though the feedback is relatively small with $\psi_g = 0.04$. This value is smaller than the estimate of Leeper et al. (2010a), but close to the value set by Corsetti et al. (2012). According to the posterior means, transfers show the strongest reaction to current debt levels (ψ_{ls}); consumption taxes the smallest. This ranking corresponds to the findings of Leeper et al. (2010a).²⁵

²²Although the posterior mean is close to the prior, the standard deviation is reduced substantially compared to the prior.

²³At the posterior mean, the implied value of the vacancy posting costs, κ , is 0.015 and of the scaling parameter of the logistic distribution, a_2 , is 0.06.

²⁴Note that the prior regions cover a model parameterization in the spirit of Hagedorn and Manovskii (2008) that would amplify the role of productivity shocks. However, the estimated posterior distributions do not show evidence in favor of this mechanism.

²⁵Leeper et al. (2010a) discuss that the strong reaction of transfers is partly model specific as transfers are non-distortionary, in contrast to taxes. I perform a robustness check where the response of lump-sum

At the posterior mean, profit taxes show a highly procyclical behavior, closely followed by labor taxes. Transfers are strongly countercyclical. In contrast, the countercyclical reaction of government spending is small ($\psi_{g,y} = 0.015$). Overall, the estimates of fiscal rule parameters are approximately in line with the results of Leeper et al. (2010a) and Traum and Yang (2015). However, as discussed later, in the model with nominal rigidities and a frictional labor market, these rules imply different effects of fiscal policy.

Turning to the shock processes, posterior estimates of autocorrelation and shock size vary considerably across the different shocks (see Table 4). Preference shocks are highly autocorrelated (approximately 0.84). The same holds for government spending and aggregate productivity. Likewise, shocks to tax rates exhibit strong autocorrelation (between 0.7 and 0.9). Shocks to matching efficiency are less persistent (approximately 0.6). The price mark-up and the transfer shock is effectively white noise. The price mark-up shock and the transfer shock have the largest standard deviations.²⁶ However, given that the absolute shock size is hard to interpret, the relative importance of the different structural shocks is discussed below in the context of a structural variance decomposition.

4.2 Model fit and properties

In order to check whether the estimated model fits the data sufficiently well, I compare the moments (auto- and cross-covariances at different leads and lags) of the data and of the estimated model (see Figure 13 in Appendix B for a visual representation of the moment comparison). The estimated model captures most of the covariances in US data fairly well (given that the baseline model does not embed typical features to increase model fit such as habit persistence, real wage rigidities, capital adjustment costs or further frictions, e.g., financial frictions). In particular, the model replicates the data

transfers to debt is fixed at zero. Results are discussed below.

²⁶The relatively large standard deviation of the price mark-up shock is also found by Thomas and Zanetti (2009). Given that their model does not feature capital and investment adjustment costs, just as my model, the missing disturbances from the capital side possibly explain this finding. However, as revealed by the variance decomposition in the next section, mark-up shocks only drive inflation dynamics. This shock is of minor relevance for the labor market and for fiscal policy. Thomas and Zanetti (2009) estimate a very large standard deviation of the shock to government spending. In my estimation, the data on government spending naturally restricts the size of the standard deviation of this shock.

		Prior mean	Posterior	
			Mean	90% interval
<i>Autoregressive parameters</i>				
Productivity	ρ_a	0.50	0.7386	[0.69; 0.78]
Government spending	ρ_g	0.50	0.8328	[0.80; 0.86]
Matching efficiency	ρ_μ	0.50	0.6040	[0.52; 0.70]
Price mark-up	ρ_φ	0.50	0.0312	[0.00; 0.06]
Preferences	ρ_d	0.50	0.8361	[0.80; 0.87]
Consumption taxes	ρ_{τ^c}	0.50	0.8874	[0.86; 0.92]
Labor taxes	ρ_{τ^w}	0.50	0.6862	[0.64; 0.73]
Profit taxes	ρ_{τ^k}	0.50	0.7681	[0.72; 0.81]
Transfers	$\rho_{\tau^{ls}}$	0.50	0.0427	[0.01; 0.08]
<i>Standard deviations</i>				
Monetary policy	σ_m	0.01	0.0022	[0.00; 0.00]
Productivity	σ_a	0.01	0.0054	[0.00; 0.01]
Government spending	σ_g	0.01	0.0071	[0.01; 0.01]
Matching efficiency	σ_μ	0.01	0.0208	[0.02; 0.02]
Price mark-up	σ_φ	0.01	0.2410	[0.17; 0.30]
Preferences	σ_d	0.01	0.0289	[0.02; 0.03]
Consumption taxes	σ_{τ^c}	0.01	0.0091	[0.01; 0.01]
Profit taxes	σ_{τ^k}	0.01	0.0201	[0.02; 0.02]
Labor taxes	σ_{τ^w}	0.01	0.0184	[0.02; 0.02]
Transfers	$\sigma_{\tau^{ls}}$	0.01	1.2864	[0.81; 1.78]
log marginal data density			−3,315.76	

Table 4: Posterior distributions of the shock processes. The posterior is explored using the random-walk metropolis hastings algorithm with 500,000 draws. I discard the first 250,000 draws. The average acceptance rate is 0.35. The log marginal data density is computed using the modified harmonic mean estimator.

correlations of fiscal and labor market variables. Besides, the model generates a fairly strong Beveridge curve relationship with a correlation of -0.5 of unemployment and vacancies (HP filtered), even though vacancies are not used as an observable variable in the estimation.

Figure 1 confirms the satisfactory model fit. The one-step ahead Kalman forecast of the estimated model matches the data series including the flow rates.²⁷ Figure 2

²⁷The one-period ahead forecast of inflation is too volatile in the model compared to the data as

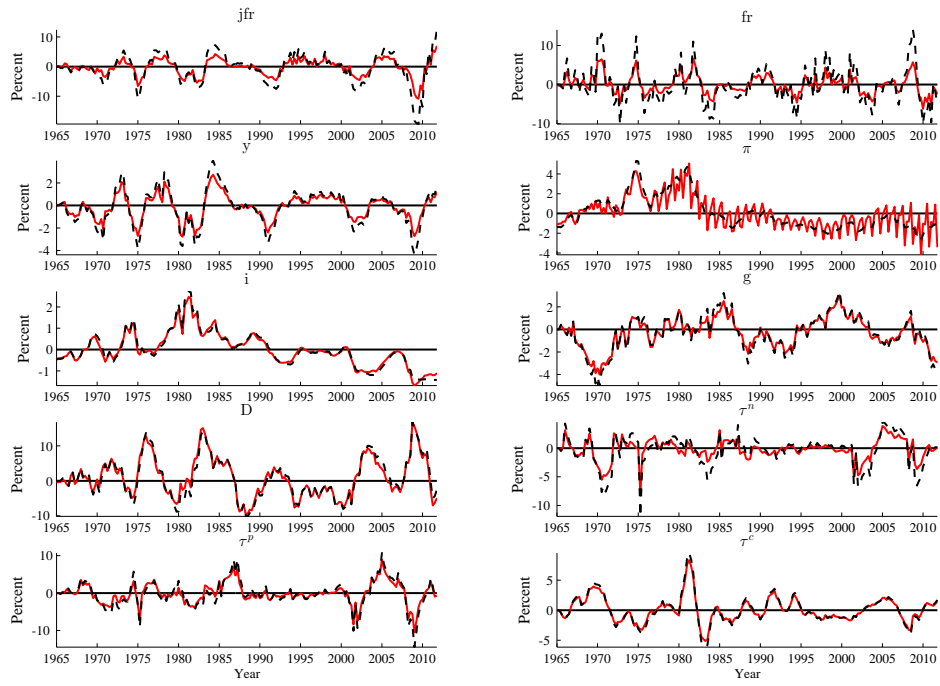


Figure 1: Comparison of US data (black dashed line) versus one-period ahead forecasts of observables of the estimated model (red solid lines). The plot shows deviations from steady state/trend. The one-period ahead forecast is obtained by Kalman filtering the state space representation of the estimated model at the posterior mean.

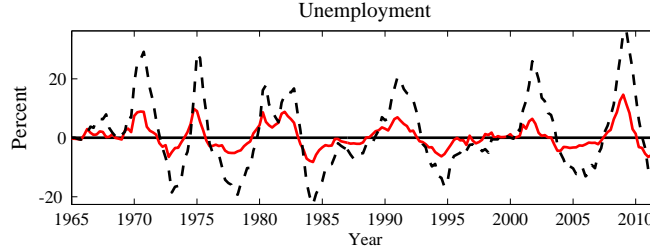


Figure 2: Comparison of unemployment in US (black dashed line) versus one-period ahead forecasts of unemployment of the estimated model (red solid lines). The plot shows deviations from an steady state/trend. The one-period ahead forecast is obtained by Kalman filtering the state space representation of the estimated model at the posterior mean.

compares the one-step ahead Kalman forecast of the unemployment rate of the estimated model and the true dynamics of the unemployment rate in the US economy. Even though the unemployment rate is not used as an observable variable in the estimation, the model replicates the true unemployment dynamics closely. However, the one-step forecast of the unemployment series is only half as volatile as in the data. Unemployment is, nevertheless, still approximately four times as volatile as GDP. This finding illustrates that the model is not subject to the Shimer (2005) criticism. Standard search and matching models predict that unemployment is less volatile than productivity. There are two reasons for this difference. First, the model features an endogenous separation margin. Second, model dynamics are triggered by several shocks in addition to productivity shocks. Measurement error potentially explains the remaining discrepancy. The model assumes that unemployment is solely driven by job-finding and separation rates (from employment to unemployment). In reality, unemployment further responds to changes in labor market participation.

The estimated structural model allows to assess the role of each structural shock for the data dynamics. Table 5 illustrates the conditional and unconditional cross-correlations in the data and in artificial data simulated from the estimated model. In line with the discussion above, the estimated model perturbed by all structural shocks replicates the data correlations. The conditional correlations highlight the role of supply versus demand side disturbances. In the data, the correlation of GDP and interest rates

inflation is purely forward looking in this model. Given that this paper does not focus on monetary policy and inflation, I do not allow for indexation to last period's inflation as introduced in estimated medium scale DSGE models (e.g., Smets and Wouters, 2007).

is negative, but close to zero (-0.02). Productivity shocks generate a strong negative correlation of GDP and interest rates (-0.94). Preference shocks induce a positive correlation (0.32).²⁸ For this reason, a combination of productivity and preference shocks is a necessary model feature to explain aggregate data dynamics.

Preference shocks (and demand shocks in general) generate a strong correlation (close to one) of GDP and labor market flow rates. Given productivity stays constant, demand side disturbances necessarily amplify towards the labor market as production can then only rise if employment increases. Consequently, there is no Shimer (2005) puzzle in light of demand side disturbances. In contrast, in response to a positive productivity shock, production rises at least partly due to productivity gains. As a result, the corresponding correlation of GDP and labor market flows is far below one. In fact, in the estimated model, employment falls after a positive productivity shock.²⁹ This result is well in line with the prediction of standard New Keynesian models and the SVAR result by Galí (1999) on hours worked. Similarly, Balleer (2012) documents that job-finding rates show a negative, while separation rates show a positive response to productivity shocks in a similar SVAR.

All in all, the estimation fits the model sufficiently close to the true data dynamics in the US. The estimated model forms a valid framework to assess fiscal policy.

4.3 Variance decomposition of labor market variables

The search and matching literature still disagrees about the sources of labor market fluctuations. Given that search and matching models stand in the tradition of RBC models, the literature has focused on productivity shocks. Recently, fueled by the discussion on the Shimer (2005) puzzle and the incorporation of search and matching frictions in New Keynesian models, demand shocks have been put forward.

Table 6 illustrates the conditional forecast error variance decomposition of the estimated model. Productivity shocks explain only 15 percent of the dynamics of the

²⁸Fiscal policy shocks also imply a positive correlation of GDP and interest rates. However, fiscal shocks are restricted by the data on the observable fiscal instruments.

²⁹The sign of the employment response depends on the exact parameterization of the model, in particular, on monetary policy and the shock persistence. Intuitively, employment rises only if households' consumption demands rise by more than the output increase from productivity gains. Monopolistic competitors only increase production if profits rise. The response of profits depends on the demand elasticity as monopolistic competitors face a downward sloping demand curve.

	GDP, job-finding rate	GDP, separation rate	GDP, interest rate	GDP, inflation
Data	0.83	-0.51	-0.02	-0.18
All shocks	0.52 [0.30; 0.69]	-0.52 [-0.68; -0.28]	-0.20 [-0.44; 0.07]	-0.30 [-0.49; -0.09]
Productivity shocks	-0.47 [-0.54; -0.38]	0.47 [0.38; 0.54]	-0.94 [-0.96; -0.92]	-0.89 [-0.94; -0.82]
Preference shocks	0.98 [0.97; 0.98]	-0.98 [-0.98; -0.97]	0.32 [0.26; 0.39]	0.15 [-0.01; 0.42]
Monetary policy shocks	0.98 [0.97; 0.99]	-0.98 [-0.99; -0.97]	-0.98 [-0.99; -0.97]	-0.15 [-0.50; 0.38]
Government spending shocks	0.98 [0.97; 0.99]	-0.98 [-0.99; -0.97]	0.13 [0.00; 0.23]	-0.04 [-0.15; 0.08]

Table 5: Conditional and unconditional correlations in the model and in US data. Data correlations are obtained from one-sided HP filtered data (1965Q1 to 2011Q4). Model correlations are obtained from simulated data for the observable variables (deviations from trend). I report the median and the 5 and 95 percentiles. Simulations are based on 500 draws from the posterior distribution and 100 simulated data samples each. Simulated data is of the same size as the US data (after discarding the first 1,000 simulated periods). In order to compute conditional correlations, the model is simulated based on one structural shock only.

job-finding and the separation rate; approximately 20 percent of unemployment dynamics. Instead, demand shocks to preferences and monetary policy explain a large share. Preference shocks drive approximately 45 percent of US flow rates and 60 percent of the dynamics of the unemployment rate. This finding fits to the notion of Hall (1997). Strikingly, this finding does not change when allowing for real wage rigidities in the estimated model.³⁰ This finding corresponds to the empirical evidence of (Haefke et al., 2013) and the theoretical arguments of Krause and Lubik (2007) and Monacelli et al. (2010) who dismiss the relevance of real wage rigidities for inflation dynamics and the effects of fiscal stimulus. Nevertheless, productivity shocks are important for GDP. They explain more than 40 percent of output fluctuations in the long run. Approximately 30 percent of the variation in US flow rates is triggered by matching shocks. However, matching shocks do not explain movements in unemployment.

³⁰In a modified estimated model, the posterior region of the parameter governing real wage rigidities is moved towards zero. As a result, also fiscal multipliers are not much affected by this model change.

The reason is that a temporarily higher matching efficiency increases the job-finding rate, but, everything else equal, the effect is offset as firms separate more workers due to endogenous separations. Monetary policy explains approximately 10 percent of labor market flow and 15 percent of unemployment fluctuations. In general, fiscal shocks are not important for labor market variables.³¹

Overall, these findings on the driving forces of labor market flow rates are consistent with evidence based on SVARs (Ravn and Simonelli, 2007, Braun et al., 2009, Balleer, 2012). However, they are based on a very different identification of structural disturbances. Using estimated DSGE models, Gertler et al. (2008), Krause et al. (2008), Sala et al. (2012), and Furlanetto and Groshenny (2013) also find evidence for variation in labor market variables due to non-productivity shocks. Nevertheless, these studies do not analyze labor market flow rates.

5 The effects of fiscal policy

5.1 Multipliers of discretionary fiscal policy intervention

The present value multiplier of government spending for output at horizon k is defined as

$$\text{Present value multiplier}(k) = \frac{E_t \sum_{j=0}^k \beta^j (y_t - y)}{E_t \sum_{j=0}^k \beta^j (g_t - g)}. \quad (27)$$

Tax multipliers are computed equally by replacing the absolute deviation of government spending with the absolute deviation of tax revenue from steady state. I also evaluate unemployment multipliers (Monacelli et al., 2010). That implies a replacement of the numerator with the deviation of unemployment from steady state (measured in percentage points) and a replacement of the denominator with the percentage point deviation of each fiscal instrument from steady state (measured in percent of steady state GDP).

³¹I do not discuss the variance decomposition of the non-labor market variables here. Results are in line with common intuition. The price mark-up shock explains inflation dynamics, in particular, in the short run (Del Negro and Schorfheide, 2006 make a similar observation). Transfer shocks are important for debt dynamics. This finding reflects that the cyclical component of debt is relatively volatile in the data (compared to GDP).

Horizon	Productivity shock		Monetary shock		Spending shock		Mark-up shock		Preference shock		Matching shock		Transfer shock		Tax shocks	
	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval
<i>Variance decomposition of job creation</i>																
1	0.15	[0.11; 0.18]	0.10	[0.07; 0.12]	0.01	[0.00; 0.01]	0.02	[0.01; 0.04]	0.43	[0.37; 0.50]	0.29	[0.23; 0.36]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
5	0.12	[0.09; 0.15]	0.10	[0.08; 0.12]	0.01	[0.00; 0.01]	0.02	[0.01; 0.04]	0.38	[0.32; 0.45]	0.37	[0.28; 0.45]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]
20	0.12	[0.09; 0.16]	0.10	[0.08; 0.13]	0.01	[0.00; 0.01]	0.02	[0.01; 0.04]	0.38	[0.32; 0.46]	0.36	[0.27; 0.45]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
<i>Variance decomposition of job destruction</i>																
1	0.16	[0.12; 0.19]	0.10	[0.08; 0.12]	0.01	[0.00; 0.01]	0.02	[0.01; 0.04]	0.47	[0.38; 0.53]	0.24	[0.20; 0.29]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
5	0.13	[0.10; 0.16]	0.11	[0.09; 0.13]	0.01	[0.00; 0.01]	0.03	[0.01; 0.04]	0.43	[0.36; 0.49]	0.29	[0.24; 0.34]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]
20	0.14	[0.11; 0.17]	0.11	[0.09; 0.13]	0.01	[0.01; 0.01]	0.03	[0.01; 0.04]	0.43	[0.36; 0.49]	0.28	[0.23; 0.33]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
<i>Variance decomposition of unemployment</i>																
1	0.21	[0.15; 0.27]	0.14	[0.11; 0.16]	0.01	[0.01; 0.01]	0.03	[0.01; 0.05]	0.61	[0.54; 0.68]	0.00	[0.00; 0.00]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
5	0.18	[0.13; 0.23]	0.16	[0.14; 0.19]	0.01	[0.01; 0.01]	0.04	[0.02; 0.06]	0.60	[0.54; 0.66]	0.00	[0.00; 0.00]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
20	0.19	[0.13; 0.23]	0.16	[0.14; 0.19]	0.01	[0.01; 0.01]	0.04	[0.02; 0.06]	0.60	[0.53; 0.66]	0.00	[0.00; 0.00]	0.01	[0.00; 0.01]	0.00	[0.00; 0.00]
<i>Variance decomposition of GDP</i>																
1	0.18	[0.14; 0.23]	0.14	[0.11; 0.16]	0.01	[0.01; 0.01]	0.03	[0.01; 0.05]	0.63	[0.56; 0.69]	0.00	[0.00; 0.00]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
5	0.36	[0.29; 0.44]	0.13	[0.11; 0.15]	0.01	[0.00; 0.01]	0.03	[0.01; 0.05]	0.47	[0.39; 0.53]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]
20	0.40	[0.33; 0.50]	0.12	[0.10; 0.14]	0.01	[0.00; 0.01]	0.03	[0.01; 0.04]	0.43	[0.36; 0.51]	0.00	[0.00; 0.00]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
<i>Variance decomposition of inflation</i>																
1	0.02	[0.01; 0.03]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]	0.97	[0.96; 0.98]	0.01	[0.01; 0.01]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]	0.00	[0.00; 0.00]
5	0.09	[0.05; 0.12]	0.00	[0.00; 0.01]	0.01	[0.00; 0.01]	0.85	[0.81; 0.89]	0.03	[0.02; 0.04]	0.00	[0.00; 0.00]	0.02	[0.01; 0.02]	0.00	[0.00; 0.00]
20	0.13	[0.07; 0.19]	0.02	[0.01; 0.03]	0.02	[0.01; 0.03]	0.71	[0.61; 0.80]	0.08	[0.04; 0.12]	0.00	[0.00; 0.00]	0.03	[0.02; 0.04]	0.01	[0.01; 0.01]
<i>Variance decomposition of interest rates</i>																
1	0.11	[0.09; 0.13]	0.51	[0.41; 0.61]	0.01	[0.00; 0.01]	0.07	[0.03; 0.11]	0.30	[0.20; 0.40]	0.00	[0.00; 0.00]	0.00	[0.00; 0.01]	0.00	[0.00; 0.00]
5	0.18	[0.14; 0.22]	0.19	[0.13; 0.25]	0.01	[0.01; 0.02]	0.02	[0.01; 0.03]	0.59	[0.50; 0.69]	0.00	[0.00; 0.00]	0.01	[0.00; 0.01]	0.00	[0.00; 0.00]
20	0.17	[0.11; 0.22]	0.11	[0.08; 0.15]	0.02	[0.01; 0.02]	0.01	[0.00; 0.02]	0.68	[0.60; 0.77]	0.00	[0.00; 0.00]	0.01	[0.00; 0.01]	0.00	[0.00; 0.00]

Table 6: Posterior forecast error variance decomposition. The forecast horizon is measured in quarters.

For easier comparison, I report multipliers for expansionary fiscal policy, i.e., increases in expenditures and cuts in taxes.³²

Table 7 summarizes the estimated fiscal multipliers. The first rows of Table 7 represent the baseline scenario where all fiscal instruments follow fiscal rules. Several observations stand out. On impact, each fiscal instrument has positive output multipliers. However, the size of the multipliers varies depending on the fiscal instrument. Moreover, unemployment multipliers behave as output multipliers but with the opposite sign. Finally, multipliers are smaller than one as the government intervention crowds out private consumption. In the following, I discuss the effects of each fiscal instrument in turn.

Government spending Output increases in response to expansionary government spending. The impact output multiplier is 0.44 (−0.44 for unemployment). Figure 3 illustrates the responses of several key model variables to an increase in government spending. In the following figures, fiscal interventions are normalized to an increase in spending or a cut in taxes of 0.5 percent of steady state GDP. Solid lines show the responses at the posterior mean, dashed lines capture the 5 and 95 percent posterior intervals. In line with the multipliers, GDP increases and unemployment falls in response to a discretionary spending upsurge. The intuition for the positive effects is the following. As typical in a New Keynesian model, rising government demand drives up the marginal costs of production, but given that prices are sticky, inflation responds only gradually. Profit maximizing monopolistic firms react by producing more consumption goods and demanding more intermediate goods. In order to increase employment to meet this demand, intermediate goods producers post more vacancies which increases the job-finding rate and fire fewer workers. Hiring and retaining additional workers drives up the marginal costs of production. The unemployment rate falls, while wages rise. According to the Taylor rule, the monetary authority rises interest rates in response to the inflationary pressure and the deviation of output and unemployment from steady state. Higher interest rates crowd out private consumption. The estimated Taylor rule features strong interest rate smoothing. As a result, interest rates rise only moderately.

³²For the computation of tax revenue, I use steady state values of the corresponding tax base. I abstain from discussing multipliers of changes in the profit tax. As described before, the profit tax is a tax on firms' profits due to market frictions, and not on firms' capital stock. It should rather be considered as a proxy for movements along this margin that is not rich enough for policy evaluation.

Horizon	<i>Spending multipliers</i>		<i>Transfer multipliers</i>		<i>Labor tax multipliers</i>		<i>Consumption tax multipliers</i>	
	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment
<i>All instruments adjust (-3,315.70)</i>								
1	0.466 [0.38; 0.55]	-0.464 [-0.55; -0.39]	0.026 [0.02; 0.03]	-0.027 [-0.03; -0.02]	0.030 [0.02; 0.04]	-0.030 [-0.04; -0.02]	0.350 [0.27; 0.45]	-0.358 [-0.45; -0.29]
5	0.281 [0.20; 0.36]	-0.269 [-0.35; -0.21]	0.036 [0.03; 0.05]	-0.035 [-0.05; -0.02]	0.063 [0.05; 0.08]	-0.062 [-0.08; -0.05]	0.205 [0.15; 0.26]	-0.198 [-0.25; -0.15]
20	0.044 [0.01; 0.08]	-0.043 [-0.09; -0.01]	-0.047 [-0.08; -0.03]	0.046 [0.03; 0.07]	-0.001 [-0.02; 0.01]	0.001 [-0.01; 0.01]	0.013 [-0.02; 0.03]	-0.012 [-0.03; 0.01]
<i>Only transfers adjust, no fiscal rules (-3,328.63)</i>								
1	0.345 [0.26; 0.41]	-0.226 [-0.26; -0.16]	0	0	-0.039 [-0.07; -0.02]	0.025 [0.01; 0.04]	0.119 [0.07; 0.16]	-0.077 [-0.10; -0.04]
5	0.237 [0.17; 0.31]	-0.180 [-0.23; -0.13]	0	0	-0.001 [-0.02; 0.01]	0.002 [-0.01; 0.01]	0.083 [0.05; 0.11]	-0.063 [-0.08; -0.04]
20	0.094 [0.07; 0.13]	-0.072 [-0.10; -0.06]	0	0	0.040 [0.03; 0.05]	-0.031 [-0.04; -0.02]	0.033 [0.03; 0.04]	-0.027 [-0.03; -0.02]
<i>Transfers do not adjust (-3,319.23)</i>								
1	0.490 [0.39; 0.60]	-0.472 [-0.56; -0.38]	0.030 [0.02; 0.04]	-0.028 [-0.04; -0.02]	0.034 [0.02; 0.05]	-0.033 [-0.04; -0.02]	0.390 [0.30; 0.53]	-0.375 [-0.49; -0.29]
5	0.301 [0.22; 0.41]	-0.282 [-0.37; -0.21]	0.045 [0.03; 0.07]	-0.041 [-0.06; -0.03]	0.068 [0.05; 0.09]	-0.063 [-0.08; -0.05]	0.233 [0.17; 0.33]	-0.217 [-0.30; -0.16]
20	0.060 [0.02; 0.11]	-0.056 [-0.10; -0.02]	-0.044 [-0.07; -0.03]	0.041 [0.03; 0.06]	-0.000 [-0.02; 0.01]	0.001 [-0.01; 0.01]	0.027 [-0.00; 0.06]	-0.024 [-0.05; 0.00]
<i>Only government spending adjusts (-3,508.22)</i>								
1	0.500 [0.46; 0.53]	-0.471 [-0.51; -0.44]	0.018 [0.02; 0.02]	-0.017 [-0.02; -0.02]	0.028 [0.02; 0.03]	-0.027 [-0.03; -0.02]	0.207 [0.19; 0.24]	-0.194 [-0.22; -0.18]
5	0.355 [0.32; 0.38]	-0.330 [-0.35; -0.29]	0.031 [0.03; 0.04]	-0.029 [-0.03; -0.02]	0.073 [0.06; 0.09]	-0.067 [-0.08; -0.06]	0.156 [0.14; 0.18]	-0.144 [-0.16; -0.13]
20	0.400 [0.35; 0.46]	-0.369 [-0.43; -0.32]	-0.001 [-0.00; 0.00]	0.001 [-0.00; 0.00]	0.065 [0.05; 0.09]	-0.060 [-0.08; -0.04]	0.078 [0.07; 0.09]	-0.073 [-0.09; -0.07]

Table 7: Estimated fiscal multipliers. Numbers show the posterior median and the 5 and 95 percent posterior intervals. Multipliers are present value multipliers. Multipliers are reported for an increase in spending and transfers and for cuts in taxes. Numbers in paranthesis indicate the log marginal data density of each specification (based on the modified harmonic mean estimator).

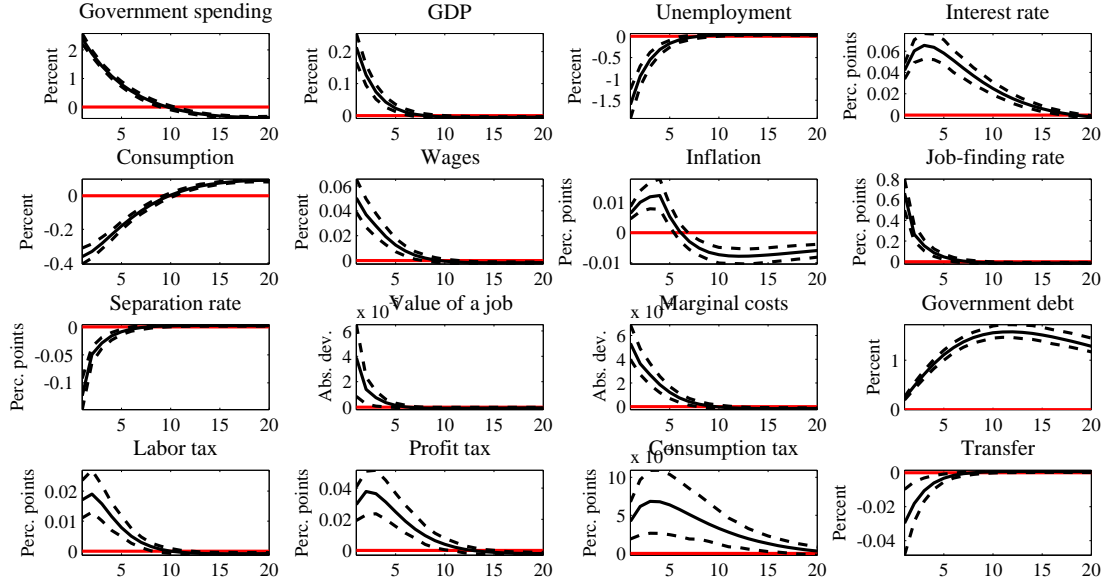


Figure 3: Estimated impulse responses to an increase in government spending (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

So far, none of the responses is surprising. However, due to the fiscal rules, the increase in government spending results in feedback effects on the other fiscal variables. The additional spending is financed by an increase in government debt on impact. The accumulated debt generates rising tax rates and lower spending in the future. Fiscal stabilization peaks around quarter 10 to 15 after the shock. Most of the fiscal adjustment is borne by lump-sum transfers. This finding reflects the large estimate of the fiscal rule parameter for transfers. In response to rising distortionary taxes and lower transfers, GDP falls below steady state approximately two years after the initial spending increase. Under nominal rigidities, a negative output gap depresses inflation and, consequently, interest rates. Accordingly, households' expected long term real interest rates fall already on impact. As suggested by Corsetti et al. (2012), lower long term interest rates dampen the induced impact decline in private consumption compared to a scenario without fiscal rules. Nevertheless, the effects are smaller as argued by Corsetti et al. (2012). Consumption crowding in does not arise as government spending hardly falls below steady state in the future (no spending reversal). Fiscal consolidation is pursued mainly by adjusting alternative fiscal instruments instead of government

spending.

Transfers An increase in transfers has very small positive multipliers on impact (0.03 for output), and small negative multipliers in the medium and the long run. Lump-sum transfers are non-distortionary in this model. Without the presence of fiscal rules, changes in transfers would not have any effect on the economy (except for government debt), i.e., Ricardian equivalence would hold. Figure 4 shows the responses of the US economy to an increase in transfers. Higher transfers generate rising government debt. As a result, fiscal policy will be contractionary in the future. Public spending falls and tax rates rise approximately two years after the rise in transfers. Then, GDP falls below steady state. The small impact increase of consumption results from (expected) future interest rates below steady state. This increase in demand generates very small positive output (and negative unemployment) effects as the value of a job increases. Nevertheless, the medium run and long run negative effects from contractionary fiscal policy are so large that they quickly offset these small positive effects. Given that the increase in lump-sum transfers is financed to some extent by distortionary taxation, the cumulative long run effect is negative (-0.05 for output and 0.05 for unemployment five years after the initial expansionary transfer shock).

Labor tax cuts Multipliers of discretionary labor tax cuts are very small (see Table 7). The impact multiplier is only 0.03. Unemployment falls but multipliers are equally small. Figure 5 shows the corresponding impulse responses. The labor tax cut influences output and unemployment through wages. The labor tax cut depresses households' wage demands as it increases the value of working relatively to non-working (after taxes, see Eq. 16). This indirect effect from the Nash wage bargaining differs from the outcome in a neoclassical labor market. Changes in the labor tax generate no direct effect on labor supply given that labor supply is exogenous due to the search and matching friction. Lower wages diminish marginal costs of production and firms' hire more and fire less workers. GDP rises, unemployment falls. Simultaneously, inflation decreases with marginal costs of production. Consequently, the central bank lowers interest rates, which in turn stimulates consumption. However, the effects are tiny and short-lived. The main reason is that the effect of the labor tax cut on wages and marginal costs is relatively small. According to the estimated model, wages move almost one to one with the marginal costs of production. As a result, they hardly move if the outside option of the workers changes (as the estimated workers' bargaining power

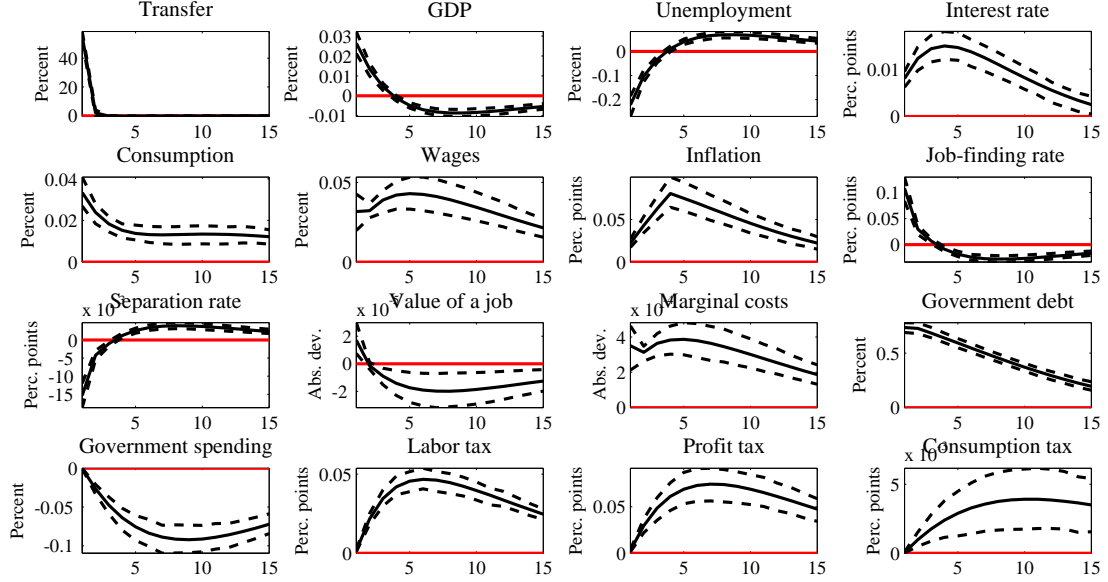


Figure 4: Estimated impulse responses to an increase in lump-sum transfers (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

is close to one, see Eq. 16). Small wage cuts provide only small incentives for intermediate firms to increase employment and production. Likewise, the effect on inflation and interest rates is limited (given that Rotemberg price adjustment costs and interest rate smoothing are high). According to the estimated fiscal rules, the labor tax cut is followed by rising tax rates and reluctant spending in the future. As described in the case of government spending, this promotes consumption (but effects are small).

Consumption tax cuts Multipliers for a cut in consumption taxes are larger than those for labor taxes. A cut in consumption taxes has an impact output multiplier of 0.34. The corresponding unemployment multiplier is -0.34 . Figure 6 illustrates the model responses to a cut in the consumption tax. Consumption becomes relatively cheaper and households consume more. Put differently, the marginal utility of consumption today increases relative to the marginal utility of consumption in the future (see Eq. 3). This increase in demand induces similar but smaller effects compared to an increase in government spending. The latter has stronger effects on aggregate variables as non of the additional spending is saved. Firms increase employment and GDP rises. Fiscal rules imply that spending, transfers and tax rates all adjust to rising debt levels (at peak approximately three years after the initial shock). These contractionary policies

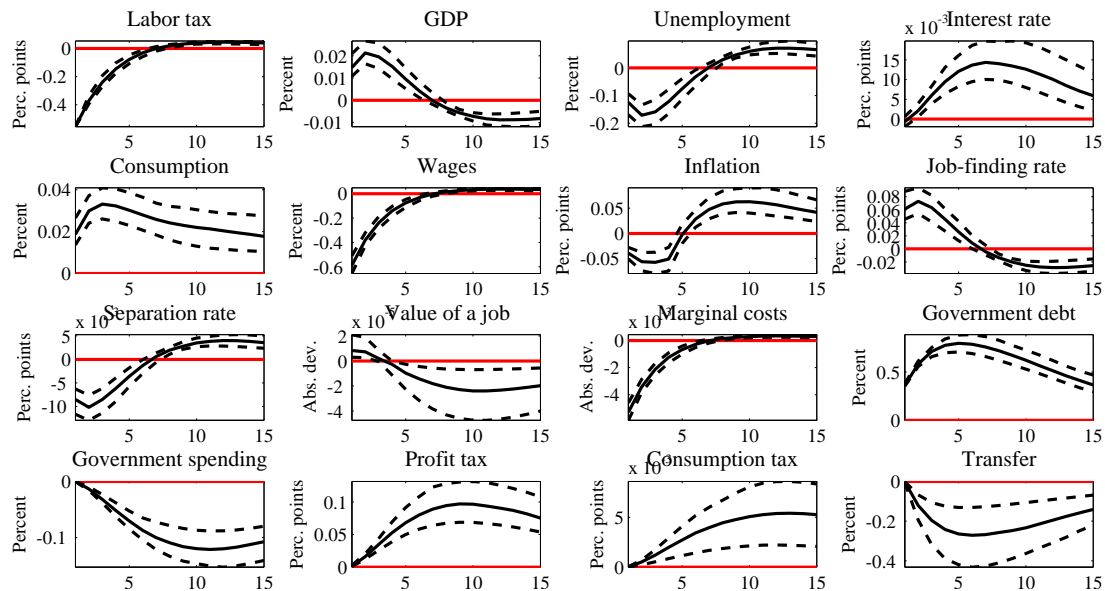


Figure 5: Estimated impulse responses to a cut in labor taxes (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

results in GDP slightly below steady state from quarter eight after the shock onward. Again, lower future inflation and interest rates compared to an economy without fiscal rules bolsters consumption already on impact (see Corsetti et al., 2012 in the context of government spending).

The results demonstrate that fiscal policy can be effective in terms of stabilizing output and unemployment, but the effect depends strongly on the fiscal instrument applied. Expansionary discretionary changes in government spending and consumption taxes stimulate demand and work well. However, an increase in government spending is more effective than a consumption tax cut. The effects of changes in labor tax rates are tiny. If the government stimulates demand by higher lump-sum transfers, the long run negative effects due to fiscal rules quickly offset the small short run positive effects.

5.2 Propagating fiscal policy with labor market frictions

One ongoing controversy in the literature is the effect of fiscal policy on private consumption. Empirical SVAR studies come to different results depending on the identification strategy. Some studies with narrative identification find either no or a slightly

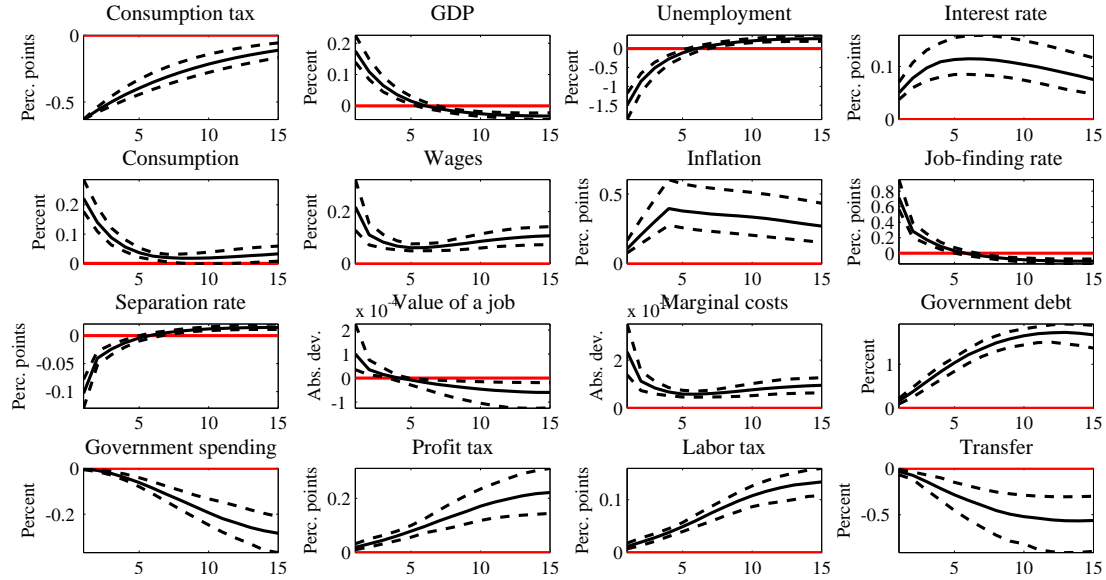


Figure 6: Estimated impulse responses to cut in consumption taxes (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

negative effect of government spending on private consumption (see, e.g., Ramey, 2011 for a discussion), whereas other studies applying short run restrictions find a significant increase of private consumption (e.g., Blanchard and Perotti, 2002, Fatás and Mihov, 2001, and Mountford and Uhlig, 2009). It is well-known that standard models with optimizing agents cannot replicate this positive correlation. The literature has found different answers to this problem.³³ These approaches have been criticized for a lack of microeconomic foundations and empirical irrelevance (Kormilitsina and Zubairy, 2013). The frictional labor market setting in this paper allows me to follow a different route. Monacelli et al. (2010) show that a combination of complementarity in household's preferences and New Keynesian elements can generate private consumption crowding in and large fiscal multipliers in a general equilibrium model with search and matching labor market frictions. In the following, I modify my model such that it is able to replicate these large multipliers and private consumption crowding in. Then, I analyze in an estimated version of the model the preferred data specification.

³³Deep habits or rule-of-thumb consumers are two widespread extensions that generate consumption crowding in (e.g., Zubairy, 2014 and Galí et al., 2007). Alternatively, models may include government investment as part of the production function (Leeper et al., 2010b, Drautzburg and Uhlig, 2011).

	$b = 0.5$	$b = 0.75$	$b = 1$
$\sigma = 1$	0.01	0.27	0.66
$\sigma = 2$	0.38	0.78	1.13
$\sigma = 3$	0.80	1.14	1.40

Table 8: Impact output multiplier of government spending at prior mean and for different values of b and σ . Fiscal rules are set to zero; the Rotemberg price adjustment parameter is adjusted compared to the basic estimation such that the model avoids indeterminacy regions.

In line with Shimer (2010, Chap. 3) and Monacelli et al. (2010), I modify households' preferences in (1) towards a complementarity in consumption and leisure

$$E_0 \sum_{t=0}^{\infty} \beta^t d_t \frac{c_t^{1-\sigma} [1 + (\sigma - 1)bn_t]^{\sigma} - 1}{1 - \sigma}. \quad (28)$$

As before, b denotes unemployment benefits that are interpreted as the relative disutility of work (or the foregone earnings/value of leisure of non-working) and n_t captures the share of employed household members. The parameter σ governs the degree of substitutability between consumption and leisure. Utility is separable with $\sigma = 1$.³⁴ The marginal value of consumption (3) becomes $\lambda_t = \left(\frac{1 + (\sigma - 1)bn_t}{c_t} \right)^{\sigma} \frac{1}{1 + \tau_t^c}$. The outside option in the wage bargaining now also depends on the current marginal value of consumption (see 14, $U_t = \sigma b \lambda_t^{-1/\sigma} + E_t \Lambda_{t,t+1} [\eta_{t+1} (1 - \phi_{t+1}) \int_{-\infty}^{v_{t+1}^f} \frac{W_{t+1}(\varepsilon_{t+1})}{1 - \phi_{t+1}^e} g(\varepsilon) d\varepsilon_{t+1} + (1 - \eta_{t+1} (1 - \phi_{t+1})) U_{t+1}]$) and the Nash wage becomes $w_t(\varepsilon_t) = \gamma \left[a_t m c_t - \varepsilon_t + E_t \Lambda_{t,t+1} \frac{\kappa}{q(\theta_{t+1})} \left(\frac{1 - \tau_{t+1}^p}{1 - \tau_t^p} - (1 - \eta_{t+1}) \frac{1 - \tau_{t+1}^n}{1 - \tau_t^n} \right) - E_t \Lambda_{t,t+1} (1 - \phi_{t+1}) (1 - \eta_{t+1}) \frac{1 - \tau_{t+1}^n}{1 - \tau_t^n} \frac{f}{1 - \tau_{t+1}^p} \right] + (1 - \gamma) \sigma b \lambda_t^{-1/\sigma} / (1 - \tau_t^n)$. As discussed by Monacelli et al. (2010), if $\sigma > 1$, expansionary fiscal policy transmits, first, by boosting private demand if employment rises. Second, the marginal value of non-working falls relative to the value of working. This depresses wage demands. The size of these effects depends strongly on the parameter values of σ and b . A simulation of the model at the prior mean shows the range of multipliers that can be generated with this model modification (see Table 8). Multipliers larger than one are driven by private consumption crowding in.

As before, I estimate the modified model with fiscal rules and data on labor market

³⁴As shown by Shimer (2010), the above preferences are the result of a representative household maximizing the sum of utilities of its individual (employed and unemployed) household members.

<i>Spending multipliers</i>		<i>Transfer multipliers</i>		<i>Labor tax multipliers</i>		<i>Consumption tax multipliers</i>	
GDP	Unemployment	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment
<i>Standard model (-3,315.70)</i>							
0.466	-0.464	0.026	-0.027	0.030	-0.030	0.350	-0.358
<i>Monacelli et al. (2010) model (-3,324.47)</i>							
0.274	-0.309	0.025	-0.028	0.036	-0.041	0.341	-0.388

Table 9: Impact fiscal multipliers across different models with full fiscal rules. Numbers show the posterior median and the 5 and 95 percent posterior intervals. Multipliers are present value multipliers. Multipliers are reported for an increase in spending and transfers and for cuts in taxes. Numbers in paranthesis indicate the log marginal data density of each specification (based on the modified harmonic mean estimator).

and fiscal variables. The prior range for the parameters b and σ covers all parameter constellations in Table 8 and thus allows for private consumption crowding in and multipliers larger than one. The results are, however, compellingly in line with the earlier findings. The posterior mean of the impact output multiplier for government spending is even smaller than in the baseline model (0.27). In the estimated model, the propagation of government spending via consumption crowding in is absent. The posterior mean of the parameter government complementarity σ is 1.025, i.e., very close to no complementarity. The posterior mean of unemployment benefits b is 0.61 (see Appendix C for detailed estimation output). The consumption tax multiplier is very close to the baseline estimate; income tax and transfer multipliers are close to zero. The estimation moves the modified model to a parameter region that is fully in line with the baseline model and rejects the alternative specification with private consumption crowding in. For this reason, the remaining analyses are restricted to the baseline model.

To shed some light on the role of the labor market friction for fiscal multipliers, I re-estimate the baseline model with two modifications. First, I switch off the endogenous separation margin. Second, I estimate a comparable model with a neoclassical labor market.³⁵ The endogenous separation margin gives firms an additional adjustment margin that to some extent cushions the rigidity compared to a model with exogenous

³⁵These model modifications imply to remove the time series on job destruction and in the latter case also job creation from the estimation. The parameters and prior regions are kept as close as possible to the above values.

separations only. As a result, multipliers in this model are slightly larger compared to a model with exogenous separations. The estimated impact output multiplier of government spending in a model with exogenous job destruction is 0.25, the unemployment multiplier is -0.22 . In general, a model with search and matching frictions will have smaller multipliers compared to a model without labor market frictions. The estimated impact output multiplier of government spending is 0.55 if no labor market friction is present. As a result, the modeling strategy on the labor market matters. The search and matching model with endogenous separations represents the most flexible way to introduce a labor market friction in the analysis of fiscal policy.

5.3 The influence of fiscal rules

This section analyzes the influence of fiscal rules on the multipliers in more detail. Table 7 summarizes the estimated fiscal multipliers. I compare results where all fiscal instruments adjust to debt to three alternative specifications: one where lump-sum transfers do not adjust, one where only government spending adjusts, and, finally, one where only lump-sum transfers adjust to debt.³⁶ The specification without an adjustment in transfers explores how results change if the only non-distortionary fiscal instrument is excluded from the fiscal rules. The specification where only government spending adjust is close to the study of Corsetti et al. (2012) and allows to analyze the role of spending reversals. The specification where only lump-sum transfers adjust replicates the results if the existence of fiscal rules would have been ignored. Then tax rates and spending follow conventional AR(1) processes and I set the parameters capturing automatic stabilization to zero. In this specification, Ricardian equivalence holds.

Table 7 highlights the following findings. First, all alternative fiscal rule specifications have a lower (log) marginal data density than the baseline scenario where all fiscal instruments adjust to debt. Model fit deteriorates by restricting certain fiscal rule components to zero. The data prefer the specification where all instruments adjust.³⁷ Second, multipliers are smaller if fiscal policy does not follow fiscal rules. The con-

³⁶These specifications are estimated as described in Section 3. The only difference is that the respective fiscal adjustment parameters are fixed at zero.

³⁷This result corresponds to the findings by Leeper et al. (2010a) in a different model.

sumption tax multiplier is reduced by two third if fiscal rules are switched off. The government spending multiplier is reduced by roughly one third. This finding stresses that the relatively large multipliers for consumption tax cuts are to a large extent driven by the presence of fiscal rules.³⁸

Third, the size of fiscal multipliers depends on the exact specification of the fiscal rules. Or put differently, multipliers differ depending on which fiscal instrument is used to adjust debt levels in the future. In general, present value multipliers are the larger, the more of the future debt adjustment is taken over by government spending. The reason for this finding is the Corsetti et al. (2012) effect. Reduced future government spending depresses output, inflation and interest rates in the future. Lower future interest rates stimulate consumption and reduce consumption crowding out already at present as the long run real interest rate declines. This effect is the largest for government spending as changes in tax rates exhibit smaller effects on the economy and on interest rates.

In the specification where only government spending adjusts, and only in this specification, the model replicates the spending reversals as described by Corsetti et al. (2012). However, this specification is the least favored by the data. A spending reversal generates government spending below steady state 10 quarters after the initial increase in spending to consolidate rising debt.³⁹ If tax rates or transfers are allowed to adjust to debt, spending does not react as strongly as to generate a reversal. This hypothetical scenario exhibits the largest fiscal multipliers. The impact output multiplier of government spending goes up to 0.50 (compared to 0.47 in the baseline). Nevertheless, according to the estimated rules, the effects are not so strong as to generate consumption crowding in.

Nevertheless, it is important to note that the short run benefit of enhanced multipliers if only government spending consolidates public debt is bought by stronger negative effects in the future. Even though the present value multipliers remain positive, GDP falls substantially more below steady state. The choice of the fiscal policy mix to con-

³⁸The impact multiplier of labor tax cuts turns negative if fiscal rules are excluded. This finding strongly depends on the parameterization. Here, inflation drops more than nominal interest rates (due to heavy interest rate smoothing). This increases the real interest rate and the stochastic discount factor falls on impact. The value of long run employment relationships depreciates which in turn depresses hiring and increases firing. The effects are, however, very small.

³⁹Appendix D shows the estimated impulse responses in response to a government spending shock for this model specification.

solidate debt trades off short run benefits versus medium run losses (in terms of output and unemployment).⁴⁰

In sum, the models with different fiscal rules provide evidence that consumption crowding out is reduced by expected lower government spending in the future as proposed by Corsetti et al. (2012). However, the estimation reveals that not only spending, but taxes and transfers also adjust. The size of fiscal multipliers depends on the fiscal policy mix used to consolidate rising debt levels and trades of future income losses versus short run gains.

5.4 Automatic stabilization from fiscal rules

The estimated fiscal rules provide a unique setting to not only analyze the effects of discretionary fiscal policy intervention but to also evaluate the extent of automatic stabilization. In the model, automatic stabilization consists of two distinct components. First, given that taxes are proportional to the respective tax base and total unemployment benefits move if unemployment moves, the government budget changes automatically in response to the business cycle. Second, rule-based changes in tax rates, spending, and transfers stabilize if output falls below steady state due to fiscal rules. Tax rates may change automatically because of two effects: first, due to progressive tax rates and allowances that are defined in the tax code, and, second, due to active changes in the tax code that are implemented in a rule-based manner. The literature on automatic stabilizers disagrees about the relative importance of the different components of automatic stabilization (in't Veld et al., 2013). The estimated fiscal rules in this paper clarify the effects of rule-based changes in fiscal instruments, i.e., automatic stabilization explicitly from fiscal rules.

The estimated structural model allows to create a counterfactual situation if fiscal rules do not respond to the current output level.⁴¹ This experiment captures a situation

⁴⁰A normative analysis of this question would be an interesting extension. Thus far, the literature on optimal fiscal rules concentrated on the question whether policy adjustment should be temporary or permanent or whether counter cyclical policy enhances welfare. The optimal fiscal policy mix under the possibility of spending reversals has not yet been analyzed. Arseneau and Chugh (2012) find that labor market frictions matter for the optimal conduct of fiscal policy.

⁴¹This implies that the $\psi_{.,y}$ -coefficients in the fiscal rules are set to zero. All other parameters are set at the posterior mean of the baseline estimated model. This exercise does not affect the steady state of the model.

	Relative to estimated model	Relative to model with enhanced stabilization
Output	1.03	8.27
Unemployment	0.88	6.76

Table 10: Reduction of the standard deviation (in percent) of output and unemployment in the estimated US model in case of automatic stabilization from fiscal rules in taxes, transfers, and government spending. Output and unemployment are measured in percentage deviations from steady state. Enhanced stabilization implies that the parameters governing the stabilization in fiscal rules are multiplied by a factor of 10.

in which neither government spending, nor lump-sum transfers, nor tax rates respond automatically to the business cycle. In the following, I measure stabilization in terms of the reduction of the volatility of output and unemployment. I compare the model with active automatic stabilization from fiscal rules to a model without this automatic policy component. The volatility of aggregate variables is driven by the full set of structural shocks. Table 10 summarizes the results from the baseline estimated model.

The results suggest that, according to the estimated fiscal rules, automatic stabilization from fiscal rules is present, but not large. The standard deviation of output is reduced by 1 percent; the standard deviation of unemployment is reduced by 0.88 percent. In case the government increases the parameters in the fiscal rules triggering the response of tax rates, spending and transfers to output (the $\psi_{.,y}$'s) by a factor of 10, automatic stabilization from fiscal rules would be more sizable. This scenario implies output stabilization of 8.27 percent and unemployment stabilization of 6.76 percent. Automatic stabilization from fiscal rules is possible, but has not been large in the US in the last 50 years. In this exercise, I examine the change in volatility. In contrast, Leeper et al. (2010a) find in a complementary exercise that the long run effects of discretionary policy intervention change under a different automatic response of fiscal instruments to output. They argue that stronger short run stabilization, i.e., larger absolute $\psi_{.,y}$'s, induce long run costs due to future debt consolidation. This finding may explain why the overall effect on volatility is small if short run stabilization is offset by long run costs.

The identified extent of automatic stabilization is smaller than suggested by findings in empirical studies. Although, empirical estimates vary depending on the methodology applied, in't Veld et al. (2013) argue that estimates of automatic stabilization of the

income tax system alone range between 8 and 20 percent for the US. However, numbers are only partly comparable as the empirical estimates refer to the total automatic stabilization including stabilization as a result of proportional taxation by itself. My results show that the additional stabilization from rule-based changes in tax rates, e.g., due to a progressive income tax system, are small. In turn, these findings suggest that the majority of the stabilization identified in empirical estimates arises from cyclical revenues that move one to one with the tax base. Balleer et al. (2014) show that policies directly aimed at the labor market, such as short-time work, may exhibit strong automatic stabilization, in particular, of unemployment.

5.5 Putting the results in perspective

A few comparable studies that analyze fiscal policy in the context of labor market frictions exist in the literature. However, non of these studies explores such detailed fiscal rules as I do, nor do they estimate their DSGE models. Monacelli et al. (2010) argue that a New Keynesian model with search and matching frictions and exogenous separations can only replicate sizable output and unemployment multipliers (i.e., 0.6 and larger) if one assumes a high replacement rate/value of non-work to work activities (approximately 0.9). For conventional values, they find multipliers close to zero. Due to the endogenous separation margin and the presence of fiscal rules, spending multipliers in this paper are closer to sizable values even without the complementarity assumption. However, strong complementarities and private consumption crowding in are dismissed by the estimated model (see Section 5.2).

Campolmi et al. (2011) allow for endogenous participation in a New Keynesian model augmented with search and matching frictions. They argue that output spending multipliers are small (around 0.2 with lump-sum financing and around 0.1 with distortionary financing). However, the model in Campolmi et al. (2011) has a substantially different representation of fiscal policy. Government spending is financed either by one hundred percent lump-sum taxes or by a fixed percentage of expenditures through labor taxes. This implies that fiscal rules do not influence future tax rates and spending, but current tax rates, and explains the different multipliers.

Faia et al. (2013) analyze fiscal policy in a labor selection model instead of a search and matching model. They find a short run output multiplier of government spending

of only 0.18 (in a European labor market without fiscal rules). They also conclude that multipliers can be larger under fiscal rules and spending reversals. However, given that they do not estimate their model, fiscal rules are applied equally for spending and labor taxes. My results show that multipliers depend on the exact specification of fiscal rules and that spending reversals do not necessarily occur. Interestingly, Faia et al. (2013) also analyze the effects of alternative fiscal instruments in addition to government spending. They find relatively large multipliers for labor tax cuts (0.4 to 0.7). My results show that this is not necessarily the case under a parameterization of wage setting and inflation dynamics that is chosen by the data and under multi-dimensional fiscal rules.⁴² In their working paper version, Faia et al. (2013) also evaluate the effects of changes in consumption taxes. They argue that those exhibit near zero multipliers under lump-sum financing. My results suggest that fiscal rules are of particular importance for the size of consumption tax multipliers. Even under lump-sum and debt financing, some small effects of consumption tax cuts arise. Strong interest rate smoothing of the central bank generates very moderate increases in interest rates in response to inflation. As a result, the positive effects of the tax cut on consumption are not dampened due to monetary policy intervention. This finding highlights the importance of modeling fiscal and monetary policy in a joint framework. Moreover, consumption tax cuts are relatively persistent according to the estimated model. Forni et al. (2009) find relatively strong multipliers for consumption tax cuts in an estimated model with rule-of-thumb households without labor market frictions.

SVAR evidence provides mixed results on the size of fiscal multipliers. Estimates vary largely depending on the method and identification applied. For the US, Hall (2010) concludes that most SVAR studies find positive output multipliers of government spending between 0.5 and 1.⁴³ These studies typically do not explicitly focus on

⁴²The difference is essentially driven by two effects. As explained above wages react less to labor tax cuts due to the high bargaining power. Furthermore, adjusting prices is relatively costly according to the estimated parameterization. Consequently, inflation falls less in response to the drop in marginal costs compared to an economy where price adjustment is less costly. For this reason, interest rates fall less which in turn depresses positive effects on consumption. Strong interest rate smoothing compounds this effect.

⁴³See Fatás and Mihov (2001), Blanchard and Perotti (2002), and Mountford and Uhlig (2009). There is evidence that spending multipliers can be much larger in recessions if the zero lower bound holds (see, e.g., Auerbach and Gorodnichenko, 2012 for evidence based on regime-switching SVARs and Eggertsson, 2011 for theoretical considerations). I focus on fiscal multipliers under conventional business cycle movements.

the labor market responses. One exception is Monacelli et al. (2010) who show that an increase in government spending (of 1 percent of GDP) stabilizes unemployment by 0.6 percentage points (at the peak).⁴⁴ Ravn and Simonelli (2007) find that unemployment decreases at maximum by 1.5 percent three years after an one percent spending shock. Mountford and Uhlig (2009) argue that tax multipliers can be very large, especially in the long run. However, estimates vary with the identification strategy. For example, Blanchard and Perotti (2002) find smaller tax than spending multipliers. Evidence on the direct effect of tax policy on unemployment is scarce.

My estimates are at the lower bound of the range for output multipliers. In contrast, the estimated unemployment multiplier of -0.32 percentage points for an increase in government spending of one percentage point of GDP is more sizable compared to the findings in the literature. However, my results sound a cautionary note on the effects of tax cuts. According to my model estimates, tax multipliers are always smaller than spending multipliers and may be close to zero in the case of labor tax cuts. This ranking nicely corresponds to the impact output effects of spending and tax policy changes identified by Zubairy (2014). In a model with labor market frictions and no habits in consumption, present value multipliers of tax cuts are always smaller than spending multipliers.

6 Conclusions

This paper provides evidence on the effects of fiscal policy in a model featuring labor market frictions, distortionary taxes and rich fiscal rules. The model is estimated with detailed US data on labor market flows, tax rates, government spending and debt. The results demonstrate that a discretionary upsurge in government spending is most effective in terms of increasing output and reducing unemployment. Likewise, consumption tax cuts are effective, but multipliers are smaller as for government spending. In contrast, the explicit acknowledgement of the labor market friction highlights that labor tax cuts are incapable of stabilizing output and unemployment. All fiscal multipliers are smaller than one. The data prefer a model specification where fiscal policy crowds out private consumption.

⁴⁴This estimate is probably in the upper range as they report a corresponding output multiplier of 1.2.

The results prove that multi-dimensional fiscal rules and labor market frictions are relevant features when modeling fiscal policy. Neglecting fiscal rules leads to an underestimation of the true effects of fiscal policy intervention. In an economic downturn, discretionary fiscal policy generates the largest stimulus if only government spending consolidates public debt in the future. However, these short run gains trade off against medium run losses. A normative analysis of the optimal policy mix to consolidate debt would be a valuable extension for future research. The results caution against overestimating the positive effects of tax cuts. Labor tax cuts may exhibit multipliers close to zero. Neglecting labor market frictions biases the estimates of fiscal multipliers upward. Accounting for an endogenous job separation margin results in relatively larger fiscal multipliers.

In light of soaring public debt levels in major economies, fiscal policy acts not only as a stimulus in times of crises, but unsustainable public debt may become a source of instability by itself. In order to consolidate debt, this paper suggests that cuts in government spending and rising consumption taxes generate output losses and rising unemployment. In contrast, raising labor taxes and transfers may induce substantially smaller losses. For practical policy evaluation, the findings in this paper call for a systematic account of the effects of fiscal policy in line with Cogan et al. (2010) that considers labor market frictions and fiscal rules explicitly.

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Appendix

A Data description

Data construction and sources

If necessary, series are seasonally adjusted using Census-X12-ARIMA. NIPA refers to the official national accounts as reported by the *Bureau of Economic Analysis* of the US.

General variables

- Gross domestic product (GDP): Real per capita GDP (NIPA). The nominal gross series is scaled with the GDP deflator (NIPA) and the labor force (NIPA).
- Inflation (yoy): Log difference of the GDP deflator in t and $t - 4$ (NIPA).
- Interest rates: Official federal funds rate. Series are averaged to quarterly frequency.

Labor market variables

- Official unemployment rate (Bureau of Labor Statistics, BLS).
- Job-finding and separation rates: I update the series of Shimer (2012) until 2011Q4. Labor market flows are deduced from data on employment, unemployment and short-term unemployment. The monthly US series is converted to quarterly terms as follows: The probability to find a job/lose a job in at least one of the three months is $\eta_q = 1 - (1 - \eta_{m1}) \times (1 - \eta_{m2}) \times (1 - \eta_{m3})$, etc.

Fiscal variables

- Government spending: Government consumption expenditures and gross investment of federal, state, and local government (NIPA). Series are transformed to real per capita terms and are seasonally adjusted.
- Government debt: Real per capita debt. Market value of federal debt held by public from the Dallas Federal Reserve. The market value more accurately represents the debt burden than the par value and has been used in a number of recent studies (e.g., Drautzburg and Uhlig, 2011, Zubairy, 2014).
- Effective tax rates on labor, profits and consumption (see below).

Constructing effective tax rates

In order to obtain aggregate effective tax rates for consumption, labor, and profit taxes, I follow Mendoza et al. (1994). The calculation uses data from the *OECD Revenue Statistics* and detailed national accounts that is partly only available at annual frequency. The data aggregates federal, state, and local government (see Fernández-Villaverde et al., 2011 for a discussion). I follow Forni et al. (2009) and interpolate annual series using quarterly indicators with Chow and Lin (1971) and Santos Silva and Cardoso (2001). Table 11 summarizes the variables and data series used in constructing the tax rates (notation follows Mendoza et al., 1994).

Following Mendoza et al. (1994), the tax rates are computed as

1. Effective tax rate on consumption

$$\tau_c = \left[\frac{5110 + 5121}{C + G - GW - 5110 - 5121} \right] \times 100$$

2. Household's average tax rate on total income:

$$\tau_h = \left[\frac{1100}{OSPUE + PEI + W} \right] \times 100$$

3. Effective tax rate on labor income:

$$\tau_w = \left[\frac{\tau_h W + 2000 + 3000}{W + 2200} \right] \times 100$$

4. Effective tax rate on capital income:

$$\tau_p = \left[\frac{\tau_h(OSPUE + PEI) + 1200 + 4100 + 4400}{OS} \right] \times 100.$$

Quarterly revenue data is available as part of the official NIPA tables (see Jones, 2002). The only variables that are required for the Mendoza et al. (1994) calculations and that are not available at quarterly frequency are taxes on payroll and workforce, taxes on financial and capital transactions, general taxes on goods and services, and excise taxes. I follow the proposition of Forni et al. (2009) and interpolate to quarterly levels using wages, private and public consumption, or a linear trend in the case of taxes on financial and capital transactions. The series span from 1965Q1 to 2011Q4.

Figure 7 shows the tax rates (aggregated to annual levels) in comparison to the annual effective tax rates constructed by Mendoza et al. (1994) and Trabandt and Uhlig (2011). The series constructed here are very close to the most recent data of Trabandt and Uhlig (2011) and also fit the overall movement of the Mendoza et al. (1994) data. Figure 8 shows the quarterly effective tax rates used in the estimation. The correlation with data constructed in line with Jones (2002) is 0.99, 0.98, and 0.96 for the labor tax, the consumption tax and the capital tax, respectively.

Variable	Description	Data source [quarterly indicator if interpolation is necessary]
<i>Revenue statistics</i>		
1100	Taxes on income, profits, and capital gains of individuals	NIPA (3.1: line 3+3.2: line 3)
1200	Taxes on income, profits, and capital gains of corporations	NIPA (3.1: line 5)
2000	Total social security contributions	NIPA (3.1: line 7)
2200	Employer's contribution to social security	NIPA (1.12: line 8)
3000	Taxes on payroll an workforce	OECD [wages]
4100	Recurrent taxes on immovable property	NIPA (3.3: line 8)
4400	Taxes on financial and capital transactions	OECD [linear trend]
5110	General taxes on goods and services	OECD [private and public consumption]
5121	Excise taxes	OECD [private and public consumption]
<i>National accounts</i>		
C	Private final consumption expenditure	NIPA (1.5: line 2)
G	Government final consumption expenditure	NIPA (1.5: line 22)
GW	Compensation of employees paid by producers of gvmt. services	NIPA (3.10.5: line 4)
OSPUE	Operating surplus of private unincorporated enterprises	NIPA (1.12: line 12 + 13 + 18)
PEI	Household's property and entrepreneurial income	NIPA (1.12: line 9)
W	Wages and salaries	NIPA (1.12: line 3)
OS	Total operating surplus of the economy	NIPA (1.10: line 9)

Table 11: Constructing quarterly effective tax rates. OECD refers to the *OECD Revenue Statistics*. NIPA refers to the official national accounts as reported by the *Bureau of Economic Analysis*.

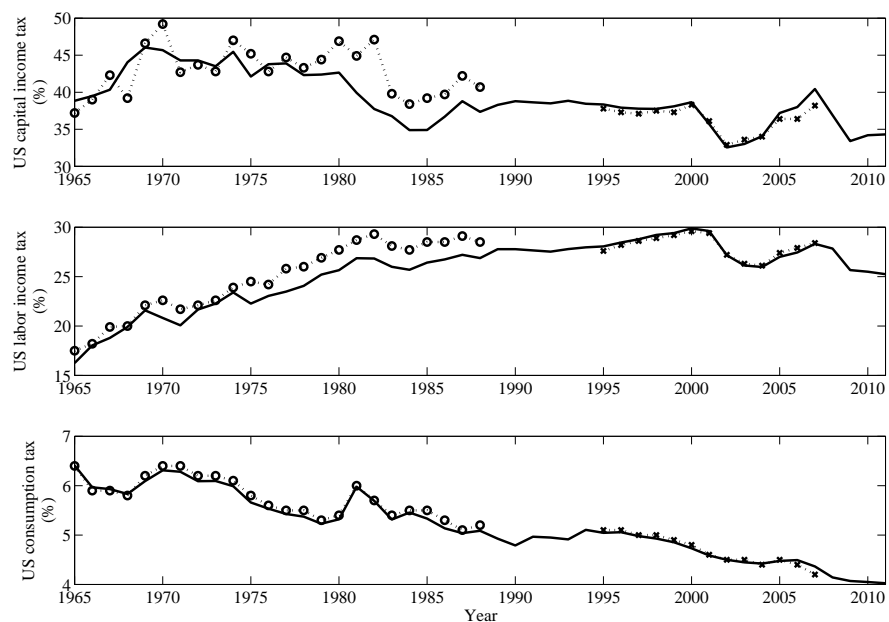


Figure 7: Annual effective tax rates. Comparison of data constructed here (solid lines), data of Mendoza et al., 1994 (lines marked by dots), and the data series computed by Trabandt and Uhlig, 2011 (lines marked by crosses).

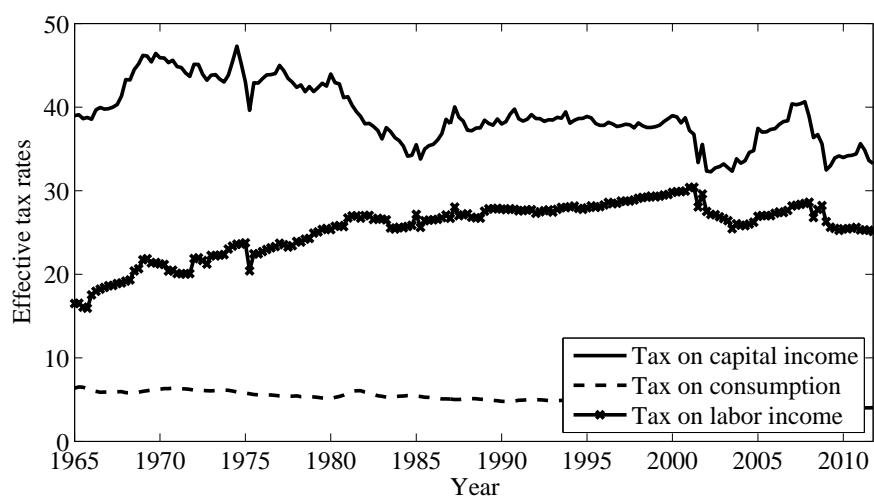


Figure 8: Quarterly effective tax rates in the US.

B Estimation output and model fit

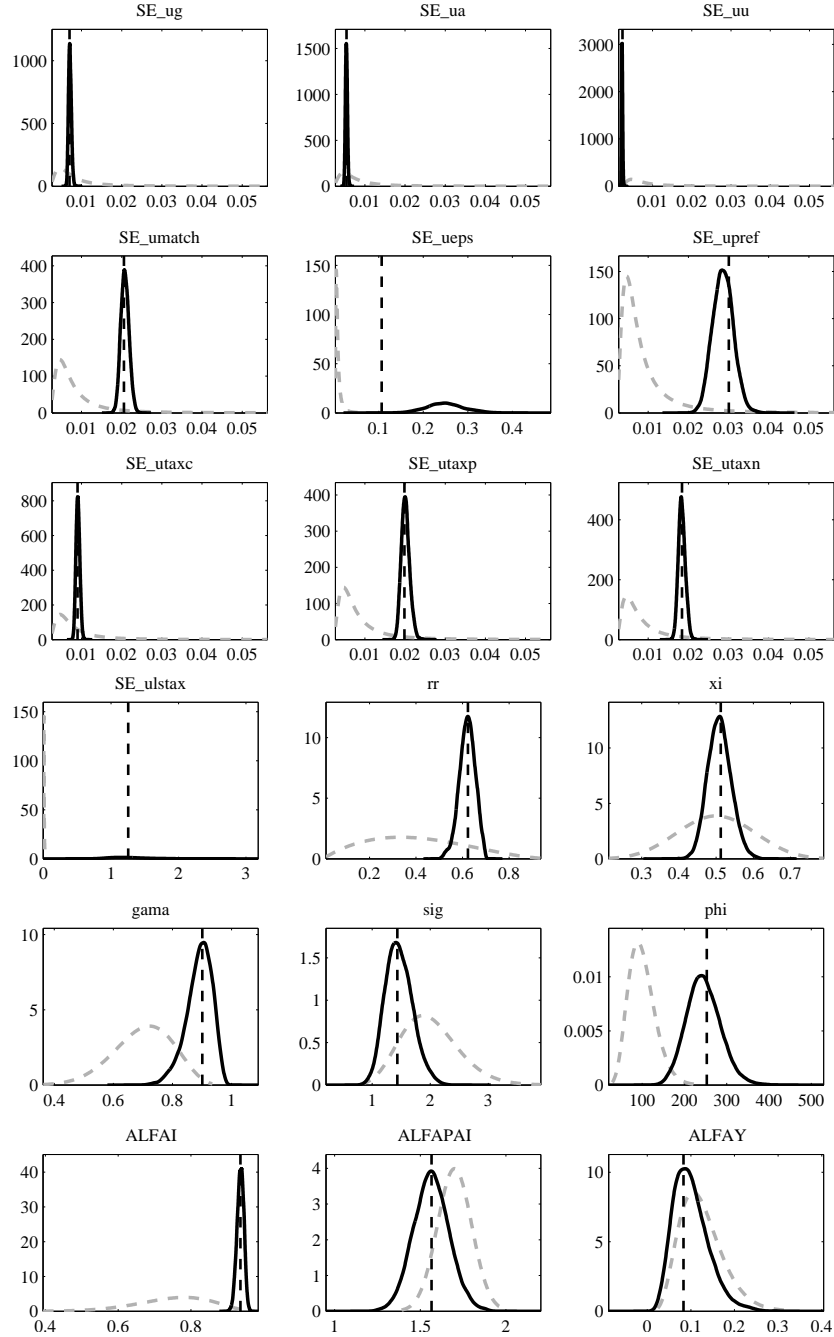


Figure 9: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation. The vertical lines mark the posterior mode.

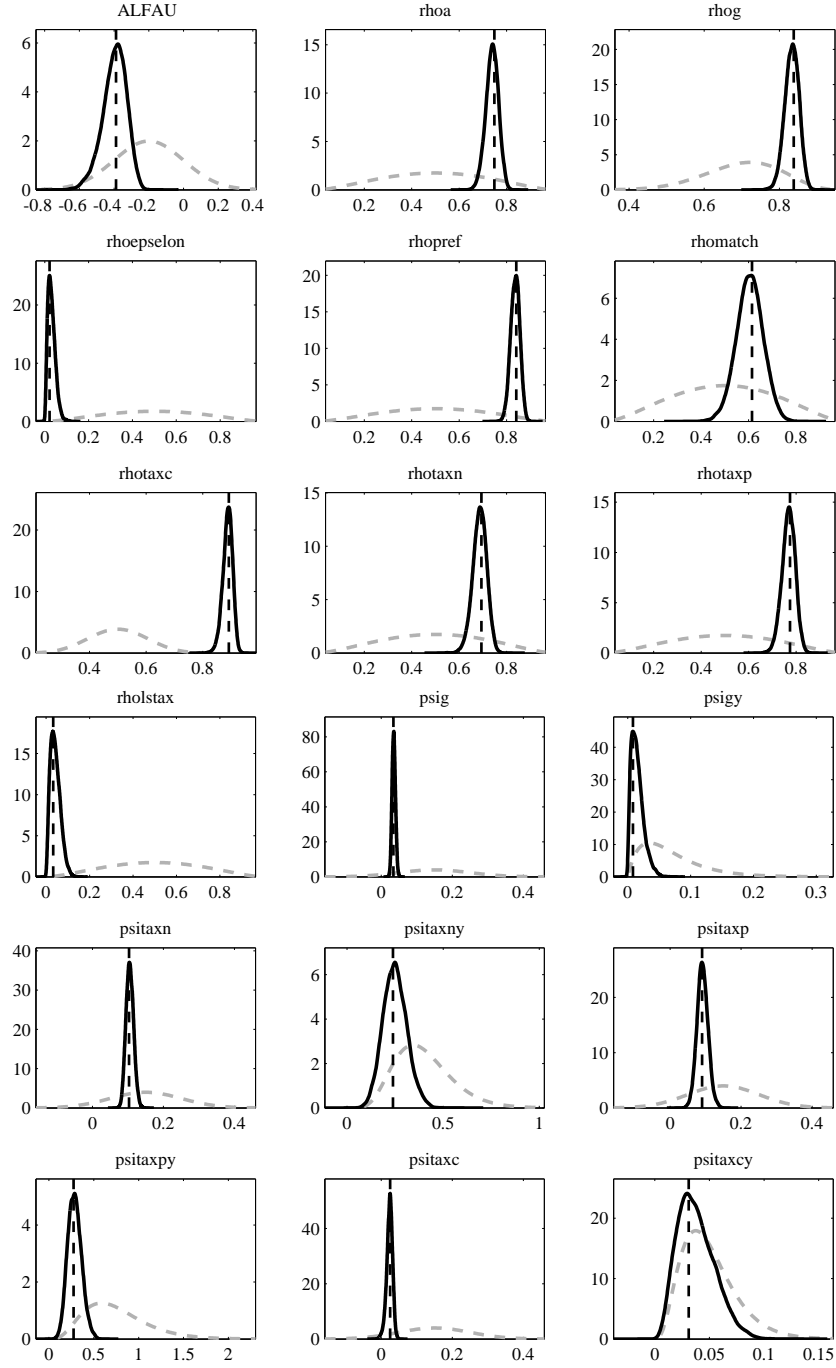


Figure 10: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation (ctd.). The vertical lines mark the posterior mode.

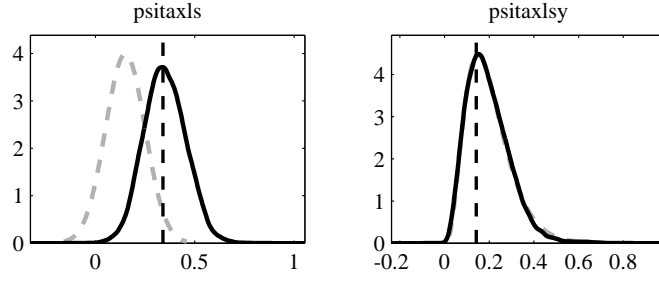


Figure 11: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation (ctd.). The vertical lines mark the posterior mode.

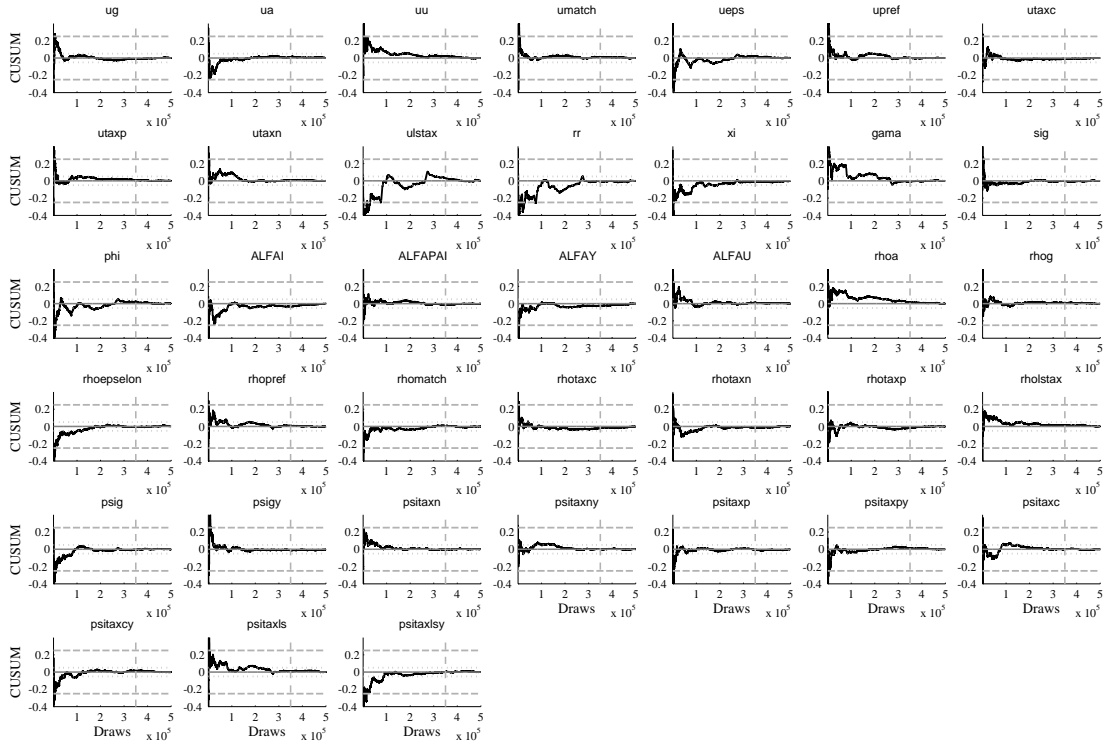


Figure 12: CUSUM charts for baseline estimation of US model. The horizontal lines indicate 5 and 25 percent bands. The vertical line indicates the burn-in of the Markov chain.

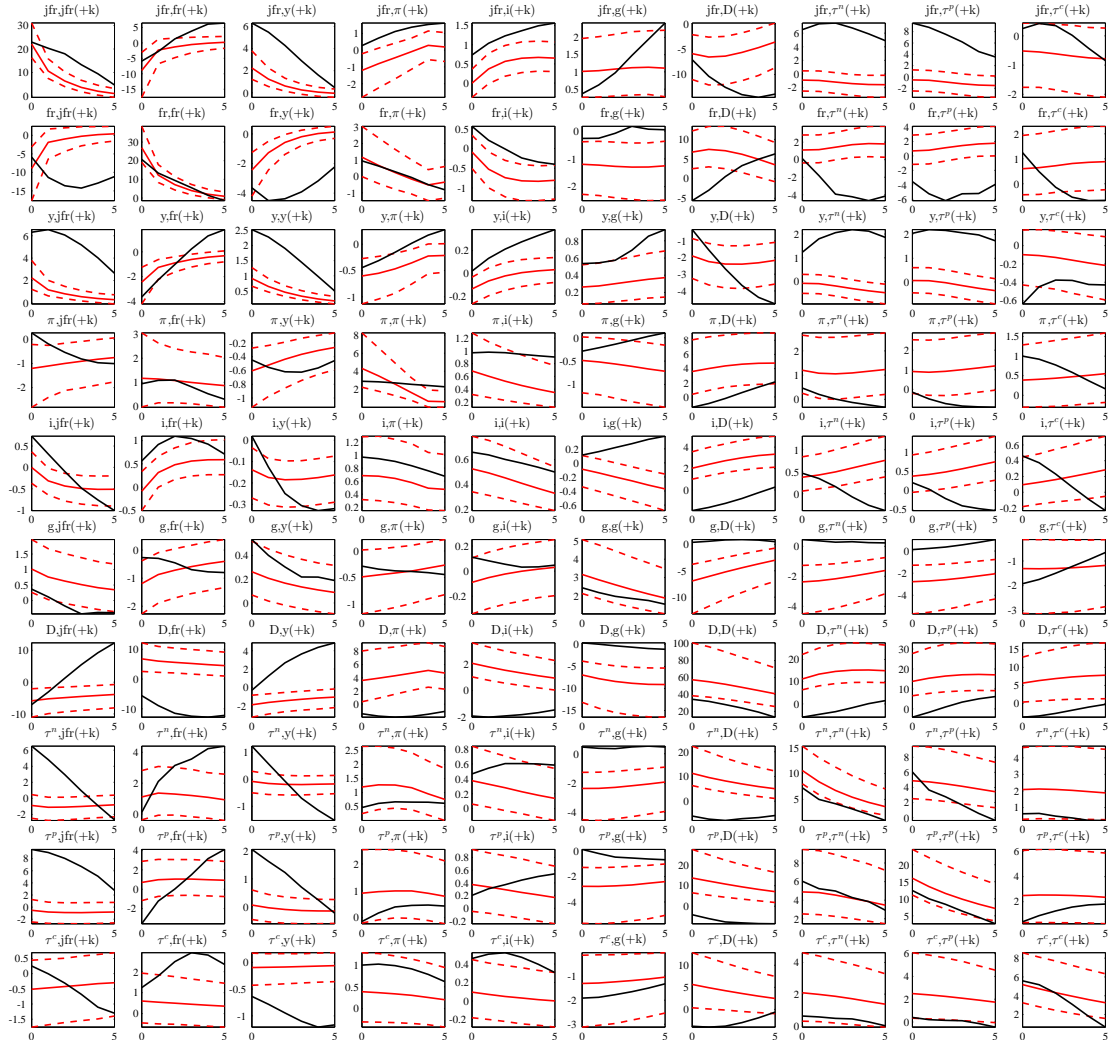


Figure 13: Auto- and cross-covariances at t and $t + k$ of US data (black solid line) and estimated model (red lines, dashed lines represent 5th and 95th percentiles, solid lines represent the posterior median). Model covariances are computed from simulated data as follows: I took 500 draws from the posterior distribution and simulated 100 samples for each draw of the same size as the observed data series after a burn-in of 1,000 periods. The diagonal elements show auto-covariances, off-diagonal elements show cross-covariances.

C Estimation output for complementarity model

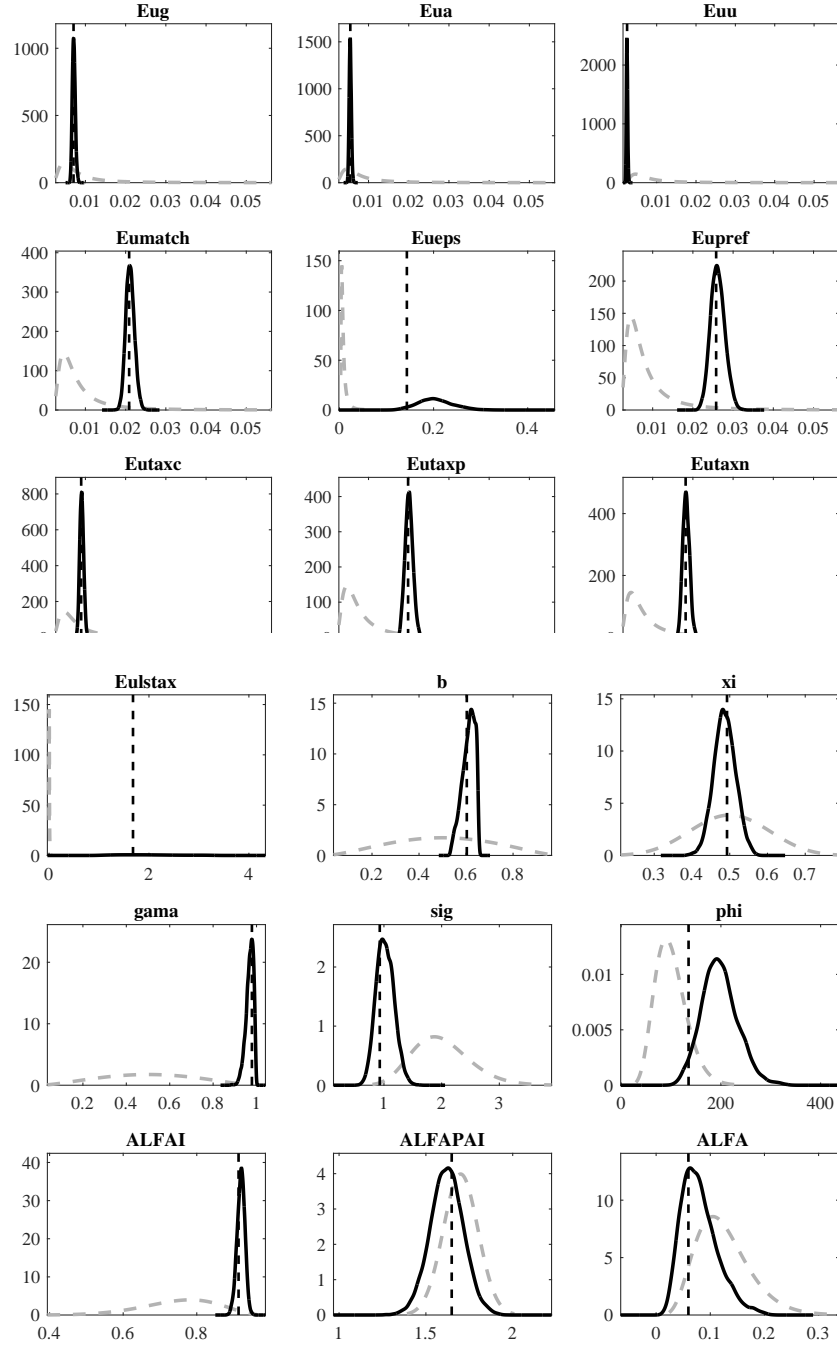


Figure 14: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences. The vertical lines mark the posterior mode.

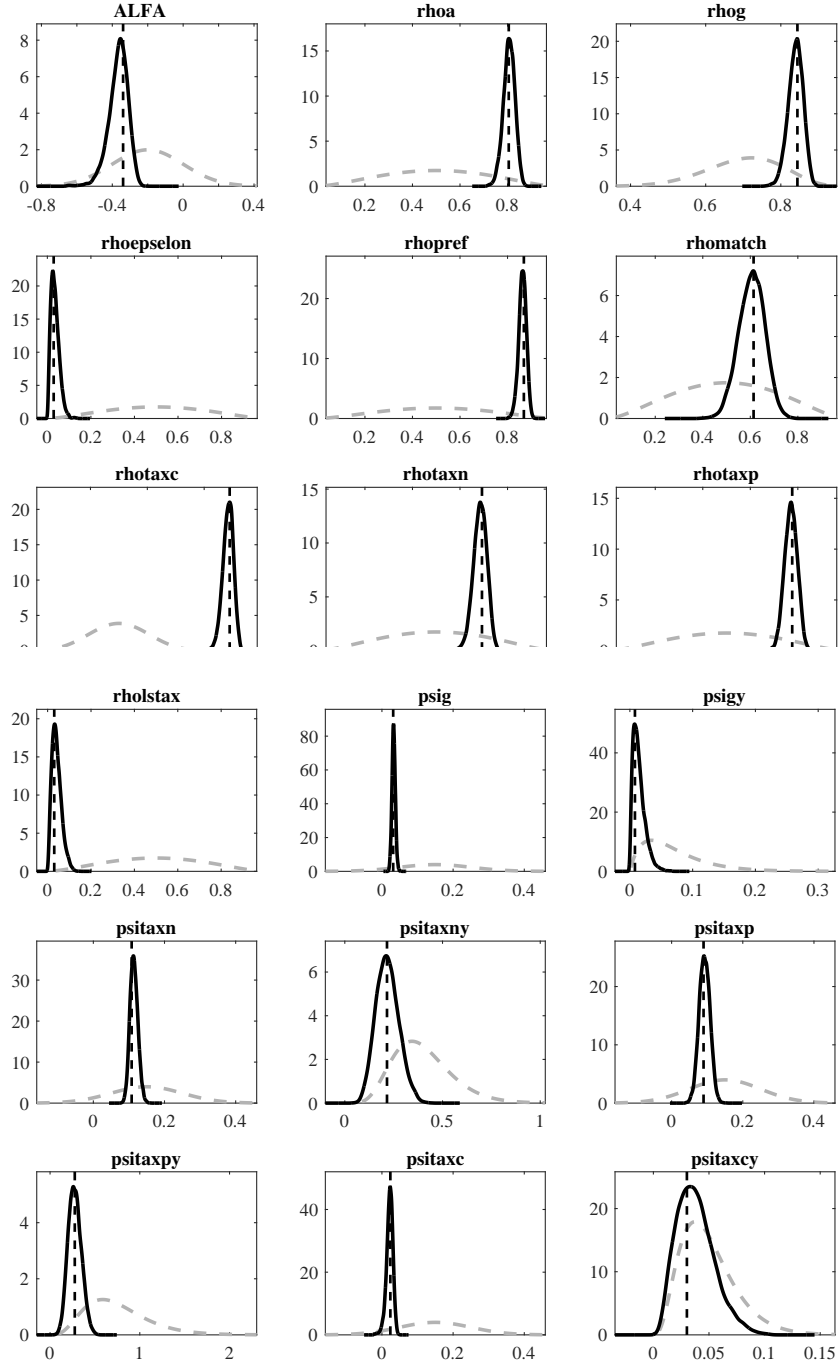


Figure 15: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences (ctd.). The vertical lines mark the posterior mode.

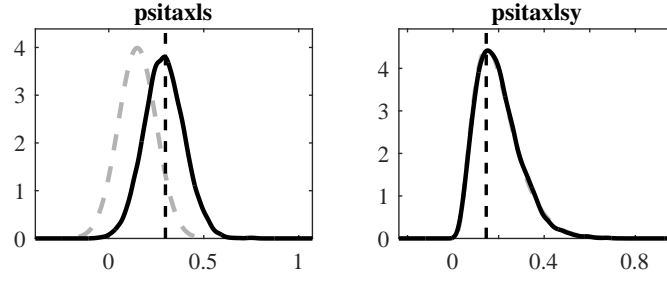


Figure 16: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences (ctd.). The vertical lines mark the posterior mode.

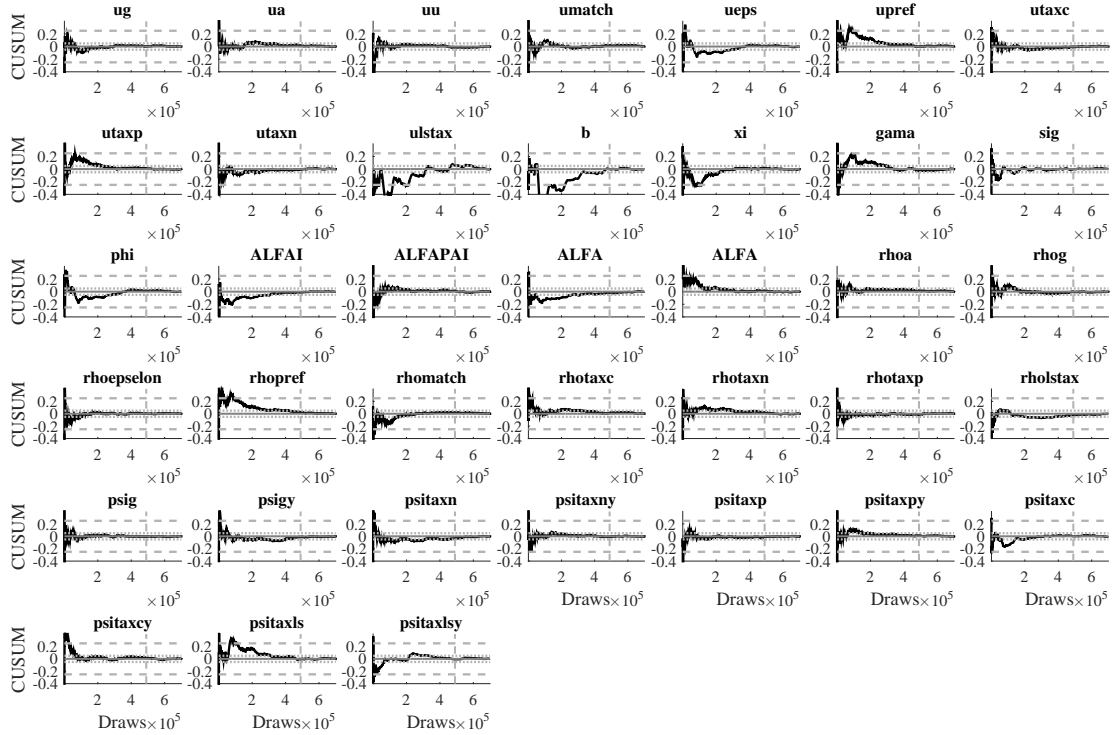


Figure 17: CUSUM charts for model estimation with complementarity in preferences. The horizontal lines indicate 5 and 25 percent bands. The vertical line indicates the burn-in of the Markov chain.

D Model responses under alternative fiscal rules

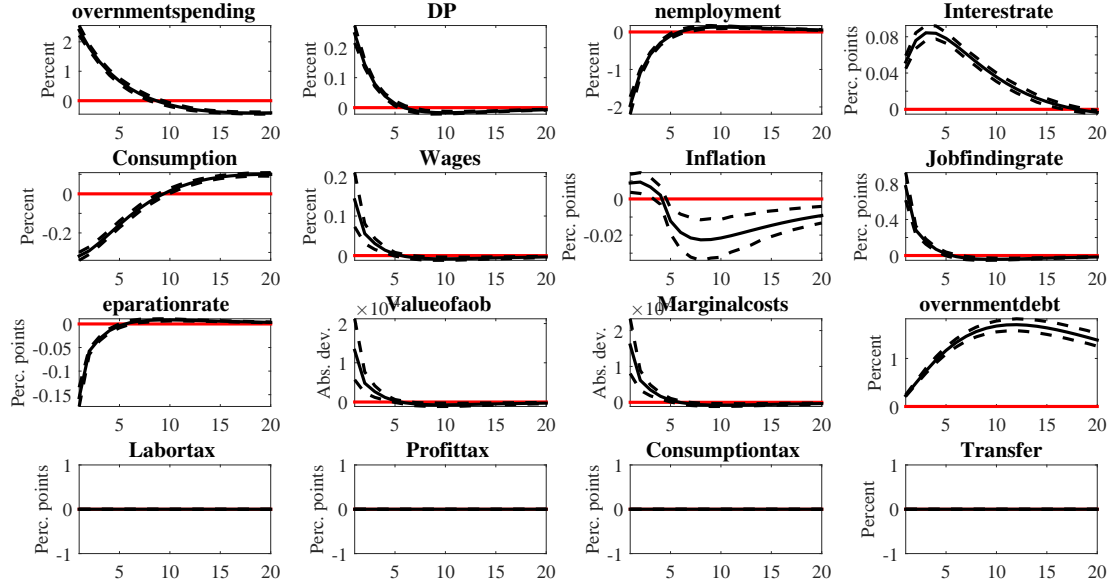


Figure 18: Estimated impulse responses to an increase in government spending (0.5 percent of GDP) in the US if only government spending adjusts to debt. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.