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Fiscal Rules and Unemployment[†]

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Abstract

This paper shows how fiscal policy affects unemployment in a New Keynesian model with search and matching frictions and distortionary taxation. The model is estimated using US data that includes labor market flows and distinct fiscal instruments. Several findings stand out. First, unemployment multipliers for spending and consumption tax cuts are substantial, even though output multipliers turn out to be less than one. Second, multipliers for labor tax cuts are small. Third, fiscal rules enhance the positive effects of discretionary fiscal policy. However, these expansionary effects on the multipliers are modest compared to earlier studies.

JEL Classification: E62, J20, C11
Keywords: Fiscal policy, Fiscal rules, Unemployment, Search and matching

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1 Introduction

In response to the financial and economic crisis in the late 2000s, major economies implemented large scale fiscal packages to counteract economic downturns. These policies have provoked a debate on the effectiveness of fiscal stimulus. One major policy objective in this context is to prevent job losses. For this reason, a recent line of literature assesses the effects of fiscal policy in models that feature unemployment and labor market frictions (Monacelli et al., 2010, Campolmi et al., 2011, Faia et al., 2013). These studies conclude that the effects of fiscal stimulus are generally small in the presence of frictional labor markets. This is the case in particular if fiscal stimulus is financed via distortionary taxation and debt and not via lump-sum taxation.

This paper contributes to this discussion with an analysis of fiscal policy in a business cycle model with search and matching unemployment and a detailed fiscal sector. The model focuses on how governments adjust (distortionary) fiscal instruments to finance the fiscal budget and serve the public debt. This fiscal adjustment is represented via fiscal rules. With rational expectations, fiscal rules affect the agents' beliefs about government behavior and in turn their responses to discretionary policy. In a model with rigid prices and monopolistic behavior, the short run effects of debt-financed fiscal stimulus can be amplified with rules that imply expected fiscal restraint in the future (Corsetti et al., 2012). However, existing analyses have thus far been restricted to models with neoclassical labor markets and allow no statements about unemployment. This paper aims to fill this gap.

For an analysis of unemployment, this paper uses a search and matching labor market à la Mortensen and Pissarides (1994). The labor market is combined with a New Keynesian model in the spirit of standard DSGE models with labor market frictions that have been widely used for monetary policy analysis (Krause and Lubik, 2007, Faia, 2009, Trigari, 2009). I add a fiscal sector with distortionary taxation and fiscal rules as proposed by Leeper et al. (2010a) and estimate the model on US data. The estimation fits the model to time series on labor market flows and detailed fiscal instruments. The results reveal that raising government spending by one percent of GDP reduces unemployment by 0.46 percentage points. For comparison, this number shows that the increase in US federal purchases in the context of the American Recovery and Reinvestment Act in 2009 (21 billion dollars or 0.15 percent of GDP) implied roughly 100,000 unemployed persons less.[1] The output multiplier of a one percent increase in government spending turns out to be relatively small with 0.47. The output multiplier below unity is the result of private consumption crowding out in response to expansionary fiscal stimulus. This paper shows, however, that this finding holds in a modified version of my model that explicitly allows for private consumption crowding in via a complementarity in household preferences as proposed by Monacelli et al. (2010). Then, the prior range of fiscal multipliers includes multipliers larger than one. However, the estimated model reveals that this transmission channel is of minor quantitative importance.

A cut in consumption taxes has sizable, but smaller effects in terms of unemployment and output compared to an increase in government consumption. In contrast, cutting labor taxes has hardly any expansionary effects on the economy. The main reason for the latter finding is that bargained wages in the estimated search and matching setting respond only mildly to labor tax cuts. Interest rate smoothing and a sluggish response of consumption strengthen this effect. In sum, government consumption emerges as the most effective fiscal policy in terms of stabilizing unemployment.

The model in this paper is related to Monacelli et al. (2010), Campolmi et al. (2011) and Faia et al. (2013) who also investigate fiscal policy in frictional labor market models. My results contribute to this literature as I, first, add important features to the model (endogenous separations, a comprehensive fiscal sector with diverse fiscal instruments and multi-dimensional fiscal rules), and, second, take the model as close as possible to the data. The short run output multiplier of government spending that I identify is larger compared to the findings in the two latter papers. Monacelli et al. (2010) find that multipliers are only substantial in a model with unemployment under special parameterizations and lump-sum taxation. One reason for the larger effects in my model is that firms adjust employment via both hiring and separations to aggregate shocks.[2] However, the multiplier of 0.47 may still seem relatively small compared to findings of other studies based on estimated DSGE models (e.g., Cogan et al., 2010, Fève et al., 2013 and Zubairy, 2014). The main difference is that these studies abstract from frictional labor markets and in parts from distortionary taxation.

[1] Numbers on government purchases in the context of the American Recovery and Reinvestment Act are taken from Cogan et al. (2010).

[2] The standard search and matching model treats separations as exogenous. In contrast, my model accounts for empirical evidence that stresses that job destruction also moves substantially over the business cycle (Elsby et al., 2009, Fujita and Ramey, 2009, Zanetti, 2017).

According to the estimated model in this paper, the Corsetti et al. (2012) hypothesis that fiscal rules enhance the multipliers of discretionary fiscal policy holds also in a model with a frictional labor market. Under nominal rigidities, forward looking households optimally consume more on impact in response to an increase in government spending, if they expect fiscal restraint in the future due to rules. Expected fiscal restraint depresses long term real interest rates. My paper is among the first to analyze the amplification of fiscal multipliers from fiscal rules in a structurally estimated DSGE model.[3] The structural estimation in this paper highlights that the effects are smaller than suggested previously. Given that, in the spirit of Leeper et al. (2010a), all fiscal instruments adjust to debt (and not only spending that would have the largest effects), the effects of future fiscal restraint on private consumption are not large enough to reverse the consumption crowding out and lead to consumption crowding in after discretionary fiscal policy intervention. The fiscal rules in this paper further allow for an endogenous response of fiscal instruments to the business cycle. Fève et al. (2013) show that not accounting for this endogeneity biases the estimates of multipliers in DSGE models.

What is the practical implication of fiscal multipliers depending on fiscal rules? The estimated rules in the model summarize the historical behavior of policy makers in the last decades. The responses to the business cycle further capture automatic stabilization, e.g., due to a progressive tax system. Economic agents take these rules into account by adjusting their expectations and behavior accordingly. This paper shows that an analysis of fiscal policy that does not consider fiscal rules biases the conclusions about the size of fiscal multipliers.

Going one step further, one could argue that agents' expectations change under certain conditions. In turn, this would affect the fiscal multipliers. For example, policy may adjust towards a new policy regime (e.g., from active to passive). Then, large discretionary policy shocks could constitute a new form of systematic policy behavior. In this case, agents may adjust expectations and decision rules in response to major policy

[3]Leeper et al. (2010a) estimate similar fiscal rules but their model does not feature nominal rigidities. Forni et al. (2009) consider estimated tax rules, but not for government spending. Traum and Yang (2015) use a medium scale DSGE model with rule-of-thumb consumers and Zubairy (2014) with habit formation. Both channels disguise the crowding in effect from fiscal rules. Fernández-Villaverde et al. (2015) focus on fiscal uncertainty and estimate fiscal rules with stochastic volatility. Drautzburg and Uhlig (2015) analyze a special scenario for the Great Recession at the zero lower bound.

changes. As a result, the difference of discretionary shocks and rules may become indeterminate and the two may interact introducing a non-linearity in the model (see, e.g., Leeper and Zha (2003)). Similarly, in extreme economic situations such as deep recessions or a period with very high public debt agents may develop different expectations if existing rules become non-credible. The business cycle model in this paper, however, focuses on the effects of policy in normal times. Thus, in extreme situations and in case of very large shocks, policy may develop effects different to the ones described here.

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, priors and model fit. Section 4 examines the effects of policy intervention. Section 5 concludes.

2 The model

The model is a 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 detailed fiscal sector as in Faia et al. (2013).

2.1 Households

Households maximize expected lifetime utility

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

choosing consumption c_t and bonds B_t subject to the budget constraint

$$(1+\tau_t^c)c_t + B_t = (1-\tau_t^n)w_t n_t + bu_t + (1-\tau_t^p)\Pi_t - \tau_t^{ls} + \frac{1+i_{t-1}}{\pi_t}B_{t-1}. \tag{2}$$

The preference shock d_t to the discount rate affects the intertemporal substitution of households and captures shifts of private demand.[4] The preference shock follows an ex-

[4]Among others, Hall (1997) argues that preference shocks are important for labor market dynamics. Hall (2017) shows that there is a connection between high discount factors that originate in financial mar-

ogenous AR(1) process $\log d_t = \rho_d \log d_{t-1} + \epsilon_t^d$ with $\rho^d \in [0, 1]$ and $\epsilon_t^d \sim$ iid $N(0, \sigma_d^2)$. Households earn aggregate labor income $w_t n_t$ and receive unemployment benefits, b, for unemployed members $u_t = 1 - n_t$.[5] 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. Last periods' bonds pay the net nominal interest rate, i_{t-1}, today. Inflation is denoted by $\pi_t = \frac{p_t}{p_{t-1}}$. Optimal household behavior implies

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

where λ_t is the marginal utility of consumption and

$$\lambda_t = E_t \Big[\beta \frac{d_{t+1}}{d_t} \frac{1 + i_t}{\pi_{t+1}} \lambda_{t+1} \Big]. \tag{4}$$

This standard formulation of households' preferences and the Euler equation will result in the common finding of private consumption crowding out in response to fiscal stimulus that triggers a monetary policy tightening. Section 4.2 shows that the findings on the fiscal multipliers in the baseline model are robust towards an alternative specification of household preferences that allows for private consumption crowding in via a complementarity in preferences.

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.

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kets and high unemployment. From this perspective, this shock can also be interpreted as representing financial shocks in a model without explicit financial markets. 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.

[5]Households are so large that members perfectly insure each other against income fluctuations (Andolfatto, 1996 and Merz, 1995).

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.

2.2.1 Intermediate goods producers and the labor market

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

$$z_t = a_t n_t. \tag{5}$$

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 $\epsilon \sim$ iid $N(0, \sigma_a^2)$. The model abstracts from capital as an additional production factor and focuses on the labor adjustment. Intermediate producers sell in a competitive market and their real relative price equals marginal costs $mc_t = \frac{p_{z,t}}{p_t}$.

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 and endogenous separation risk (ϕ^x and ϕ_t^e). The total separation rate is $\phi_t = \phi^x + (1-\phi^x)\phi_t^e$. 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

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

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 $\epsilon^\mu \sim$ iid $N(0, \sigma_\mu^2)$.[6] 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 Krause and Lubik (2007). Endogenous separations at rate ϕ_t^e give firms an additional adjustment margin next to job creation in response to aggregate shocks. This additional flexibility allows for amplification of shocks including fiscal shocks towards the labor market. The extent of this amplification will be determined by the data. Endogenous separations 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 and enter with a negative sign. As a result, contemporaneous profits of a match may be negative.

Vacancy posting induces costs $\kappa > 0$. Given that vacancy posting costs depress firm profits (the definition of profits follows in Eq. 23), these are scaled by the tax rate on profits τ^p. New hires turn productive immediately (instantaneous hiring) and deliver the value of a job J_t to the firm. Consequently, the value of a vacancy is

$$V_t = -\kappa(1-\tau_t^p) + q(\theta_t)J_t + \big(1 - q(\theta_t)\big)E_t\Lambda_{t,t+1}V_{t+1}. \tag{7}$$

Due to free entry in vacancy posting, firms enter the market until the value of a vacancy is zero ($V_t = 0\ \forall t$) and

$$\frac{\kappa(1-\tau_t^p)}{q(\theta_t)} = J_t. \tag{8}$$

With the definition of the value of a job J_t (see online Appendix A.1 for details), this equation defines the job creation condition as

$$\begin{aligned}\frac{\kappa(1-\tau_t^p)}{q(\theta_t)} =& (1-\phi_t)\int_{-\infty}^{v_t^f} \frac{\big(a_t mc_t - \varepsilon_t - w_t(\varepsilon_t)\big)g(\varepsilon)}{1-\phi_t^e} d\varepsilon_t (1-\tau_t^p) \\ &+ (1-\phi_t)E_t\Lambda_{t,t+1}\frac{\kappa(1-\tau_{t+1}^p)}{q(\theta_{t+1})}.\end{aligned} \tag{9}$$

[6] The 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), Lubik (2009), and Zhang (2017) to capture stochastic disturbances in the labor market itself.

Firms create vacancies until the search cost of another vacancy equals the expected value of profits of the vacancy. The expected profits depend on the current revenue of production and the expected future value of the job minus expected idiosyncratic shocks and wages (net of profit taxes). Workers are fired if the costs incurred by retaining the match are larger than zero, i.e., $(a_t mc_t - w_t(\varepsilon_t) - \varepsilon)(1-\tau_t^p) + E_t\Lambda_{t,t+1}J_{t+1} < 0$. As a result, the endogenous firing threshold is

$$v_t^f = a_t mc_t - w_t(v_t^f) + \frac{1}{1-\tau_t^p}E_t\Lambda_{t,t+1}J_{t+1} \tag{10}$$

and the endogenous separation rate is $\phi_t^e = \int_{v_t^f}^{\infty} g(\varepsilon)d\varepsilon_t = 1 - G(v_t^f)$.

Hiring as defined in Eq. 9 and firing as defined in Eq. 10 respond to aggregate shocks in the economy. Non-productivity shocks affect the marginal costs of production and wages. Due to sticky prices, expansionary fiscal policy will generate counter-cyclical price mark-up movements. The inverse of the price mark-up determines the marginal costs of production mc_t. The rise in marginal costs drives up the current and future value of a job and, as a result, hiring and employment in Eq. 9. Expansionary fiscal policy will equally, as it boosts hiring, dampen job destruction as defined in Eq. 10. In contrast to models that rely on exogenous separations only (Monacelli et al., 2010), firms in this model have an additional margin to adjust employment in response to expansionary shocks.

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 $(\tilde{J}_t(\varepsilon_t) - V_t + f)^{1-\gamma}(W_t(\varepsilon_t) - U_t)^{\gamma}$. The workers' bargaining power is denoted by γ. From the definition of the value of a match for the worker W_t and the value of unemployment U_t (for details see online Appendix A.2) follows the wage for each realization of the idiosyncratic shock ε_t as

$$\begin{aligned} w_t(\varepsilon_t) =& \gamma\Big(a_t mc_t - \varepsilon_t + E_t\Lambda_{t,t+1}\frac{\kappa}{q(\theta_{t+1})}\Big(\frac{1-\tau_{t+1}^p}{1-\tau_t^p} - (1-\eta_{t+1})\frac{1-\tau_{t+1}^n}{1-\tau_t^n}\Big)\Big) \\ &+ (1-\gamma)\frac{b}{1-\tau_t^n}. \end{aligned} \tag{11}$$

The individual wage is a weighted average of the intertemporal profits of the firm from the match and the reservation wage, i.e., the unemployment benefit scaled by labor taxes. Labor taxes drive a wedge between the value of working and not working. According to their bargaining weight γ, the workers earn a share of the firms' revenue of production plus a term representing the vacancy posting costs that the firm saves in the next period due to already having the worker in the firm. This latter term depends on the dynamics of profit and labor taxes, τ^p and τ^n.[7] The aggregate wage is the mean of individual wages weighted with the idiosyncratic shock distribution

$$w_t = \int_{-\infty}^{v_t^f} w_t(\varepsilon_t) g(\varepsilon|\varepsilon < v_t^f) d\varepsilon_t = \int_{-\infty}^{v_t^f} w_t(\varepsilon_t) \frac{g(\varepsilon)}{1-\phi_t^e} d\varepsilon_t. \tag{12}$$

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

$$E_0 \sum_{t=0}^{\infty} \Lambda_{t,t+1}(1-\tau_t^p) \Big[\frac{p_t(i)}{p_t} \tilde{y}_t(i) - mc_t \tilde{y}_t(i) - \frac{\Psi}{2} \Big(\frac{p_t(i)}{p_{t-1}(i)} - 1 \Big)^2 \tilde{y}_t \Big], \tag{13}$$

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 $\tilde{y}_t = \big(\int_0^1 \tilde{y}_t(i)^{\frac{\nu_t - 1}{\nu_t}} di \big)^{\frac{\nu_t}{\nu_t - 1}}$, 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 $\tilde{y}_t(i) = \Big(\frac{p_t(i)}{p_t} \Big)^{-\nu_t} \tilde{y}_t$ in individual prices. By maximizing Eq. 13 with respect to prices, subject to demand and imposing firm symmetry, optimal price setting follows as

$$\Psi(\pi_t - 1)\pi_t = (1-\nu_t) + \nu_t mc_t + E_t \Big[\Lambda_{t,t+1} \Psi(\pi_{t+1} - 1) \frac{\tilde{y}_{t+1}}{\tilde{y}_t} \frac{1-\tau_{t+1}^p}{1-\tau_t^p} \pi_{t+1} \Big]. \tag{14}$$

[7] With constant tax rates, Eq. 11 collapses to the typical Nash bargaining wage $w_t(\varepsilon_t) = \gamma(a_t mc_t - \varepsilon_t + E_t \Lambda_{t,t+1} \kappa \frac{\eta_{t+1}}{q(\theta_{t+1})}) + (1-\gamma) \frac{b}{1-\tau_t^n}$, where $E_t \kappa \frac{\eta_{t+1}}{q(\theta_{t+1})} = E_t \kappa \theta_{t+1} = E_t \kappa v_{t+1}/u_t$ represents the average vacancy posting cost per worker. With time-varying tax rates, Eq. 11 further accounts for the fact that expected changes in profit taxes affect the current value of the expected after tax saving of vacancy posting cost in the next period. Similarly, expected changes in labor taxes determine how the workers value their share of these profits as part of their wage income.

As in a standard Phillips curve, prices are set as a mark-up over marginal costs and depend on expected future prices. Fiscal stimulus can have expansionary effects on output because it reduces price mark-ups. Due to the labor market friction, real marginal costs of production mc differ from marginal costs in a perfectly competitive market. They encompass the long run value of a match.[8] 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 $\epsilon^\varphi \sim$ iid $N(0, \sigma_\varphi^2)$.[9]

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

$$g_t + bu_t + \frac{1 + i_{t-1}}{\pi_t} D_{t-1} = \tau_t^{ls} + \tau_t^n w_t n_t + \tau_t^c c_t + \Pi_t \tau_t^p + D_t. \tag{15}$$

Fiscal policy follows fiscal rules in the spirit of Leeper et al. (2010a) and Corsetti et al. (2012). 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. Households internalize the government behavior due to the rules and adjust consumption accordingly. Most importantly, as described by Corsetti et al. (2012), expected fiscal restraint in the future due to rules depresses long term real interest rates and may boost consumption in line with Eq. 4.

[8] See 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).

[9] This 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

$$\frac{g_t}{g} = \big(\frac{g_{t-1}}{g}\big)^{\rho_g} \big(\frac{D_{t-1}}{D}\big)^{-\psi_{g,d}} \big(\frac{y_t}{y}\big)^{-\psi_{g,y}} \exp(\epsilon_t^g). \tag{16}$$

Lump-sum transfers evolve as

$$\frac{\tau_t^{ls}}{\tau^{ls}} = \big(\frac{\tau_{t-1}^{ls}}{\tau^{ls}}\big)^{\rho_{\tau^{ls}}} \big(\frac{D_{t-1}}{D}\big)^{-\psi_{\tau^{ls}}} \big(\frac{y_t}{y}\big)^{-\psi_{\tau^{ls},y}} \exp(\epsilon_t^{\tau^{ls}}), \tag{17}$$

and rules for tax rates are given by

$$\frac{\tau_t^i}{\tau^i} = \big(\frac{\tau_{t-1}^i}{\tau^i}\big)^{\rho_{\tau^i}} \big(\frac{D_{t-1}}{D}\big)^{\psi_{\tau^i}} \big(\frac{y_t}{y}\big)^{\psi_{\tau^i,y}} \exp(\epsilon_t^{\tau^i}), \tag{18}$$

for $i = \{n, p, c\}$. The speed of adjustment of each fiscal instrument to government debt is determined by the $\psi_{\cdot,d}$ parameters. The $\psi_{\cdot,y}$ 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 $i = \{ls, n, p, c\}$ and are specified as iid $N(0, \sigma_j^2)$ for $j = \{g, ls, n, p, c\}$.

Monetary policy follows a Taylor (1993) rule

$$\frac{1+i_t}{1+i} = \Big(\frac{1+i_{t-1}}{1+i}\Big)^{\rho_i} \Big[\Big(\frac{\pi_t}{\pi}\Big)^{\xi_\pi} \Big(\frac{y_t}{y}\Big)^{\xi_y} \Big(\frac{u_t}{u}\Big)^{\xi_u}\Big]^{1-\rho_i} \exp(\epsilon_t^m). \tag{19}$$

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 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

To close the model, I impose goods and bond market clearing. From the household's budget constraint Eq. 2 and a balanced fiscal budget Eq. 15 then follows

$$c_t + g_t = w_t n_t + \Pi_t. \tag{20}$$

Aggregate real profits (before taxes) Π_t are defined by the sum of profits of intermediate firms and of the wholesale sector. Perfectly competitive retailers make zero profits. Intermediate firms receive rents due to the labor market friction. These rents are given by revenues net of wage payments, average profitability costs and vacancy posting costs

$$mc_t a_t n_t - w_t n_t - \frac{n_t}{1-\phi_t^e}\int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon_t - \kappa v_t. \tag{21}$$

Note that n_t is the number of employees after taking into account the endogenous separation risk. Dividing by $1-\phi^e$ yields the number of available workers before endogenous separations. Monopolistic competitors in the wholesale sector make real profits

$$\tilde{y}_t - mc_t a_t n_t - \frac{\Psi}{2}(\pi_t - 1)^2 \tilde{y}_t. \tag{22}$$

As a result, total real profits are

$$\Pi_t = \tilde{y}_t - w_t n_t - \frac{n_t}{1-\phi_t^e}\int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon_t - \kappa v_t - \frac{\Psi}{2}(\pi_t - 1)^2 \tilde{y}_t. \tag{23}$$

Inserting Eq. 23 in 20 gives the resource constraint as

$$c_t + g_t = \tilde{y}_t - \frac{n_t}{1-\phi_t^e}\int_{-\infty}^{v_t^f} \varepsilon_t g(\varepsilon) d\varepsilon_t - \kappa v_t - \frac{\Psi}{2}(\pi_t - 1)^2 \tilde{y}_t. \tag{24}$$

Private and public consumption equals total final goods production $\tilde{y}_t$ minus resource costs for aggregate profitability shocks, vacancy posting and price adjustment. The sum of private and public consumption defines output y_t excluding search and price adjustment costs as

$$y_t = c_t + g_t. \tag{25}$$

3 Estimation and calibration

This section discusses, first, the methods and data used for the estimation, second, the prior choice and identification of the model parameters, and, third, the results.

3.1 Data and measurement

As in An and Schorfheide (2007), I estimate the log-linearized model with Bayesian techniques on quarterly US data for GDP, inflation and interest rates.[10] 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.[11] Inflation and interest rates are demeaned. GDP, flow rates, spending, debt and tax rates are filtered with the one-sided HP filter of Stock and Watson (1999) (in logs).[12] 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^n}, ϵ^{τ^c}, ϵ^{τ^p}, shocks to lump-sum transfers, $\epsilon^{\tau^{ls}}$, preference shocks, ϵ^d, price-mark up shocks, ϵ^φ and shocks to the matching efficiency, ϵ^μ.

3.2 Discussion of priors and identification

Table 1 displays the steady state targets and the fixed parameters. The steady state targets of the model correspond to averages in the data as used in the estimation. 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. In line with averages in the time series data, steady state quarterly government spending is set to 20.8 percent of GDP and the average annual steady state stock of public debt is set to 32.0 percent of GDP. The steady state tax rates are also equal to their data counterparts.

[10]The mode of the posterior distribution is obtained with numerical maximization and the full posterior is explored with the Random Walk Metropolis Hastings algorithm. At the mode, I checked the gradient by inspecting the shape of slices of the likelihood and the posterior. Convergence of the Markov chain is checked by diagnostic tools such as CUSUM and trace plots (see Figure 11 in the online Appendix).

[11]The online Appendix B discusses data sources and the construction of effective tax rates in more detail. I proxy the profit tax using a series for a general tax on capital income in the data. The two series feature similar dynamics (see the discussion in the online Appendix B). The sample includes the Great Recession. The general results remain unchanged if the Great Recession period is excluded given that the sample is long with almost 50 years of data.

[12]As 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.

		Value
Discount factor	β	0.9944
Elasticity of substitution	ν	10
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^p	0.3907
Consumption tax rate	τ^c	0.0518

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

Unemployed workers find a job at an average rate of 79.4 percent. Employed workers are separated at an average rate of 9.8 percent. In line with den Haan et al. (2000), 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 $g(\varepsilon)$.[13] 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. 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.

The methods of Iskrev (2010) allow to check parameter identification, i.e., to determine for which model parameters the estimation contains no information.[14] Most

[13] To be precise, 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.

[14] See, 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.

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. 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 and the workers' bargaining power γ. A Beta prior with mean 0.5 and standard deviation 0.2 reflects that these parameters are bounded between zero and one. For the replacement rate $rr = b/w$, I specify a Beta prior with mean 0.4 and standard deviation 0.2.

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.[15] The prior mean for the output response is 0.125, which corresponds to a Taylor coefficient of 0.5 with annualized inflation. For the Taylor coefficient on unemployment, I follow studies that focus on the optimal Taylor response to unemployment.[16] A Normal prior with mean -0.2 and standard deviation 0.25 covers all parameter values found in this literature. Evidence on the average duration of a price contract varies between two and four quarters. I set a broad Normal prior centered at 100 with standard deviation $1000^{1/2}$ (Forni et al., 2009).[17]

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

[15] This relatively large number ensures that the model remains in determinancy regions (Smets and Wouters, 2003).

[16] Faia (2008) and Blanchard and Galí (2010) derive optimal Taylor coefficients in models with frictional labor markets from a set of simple policy rules that maximize household welfare. 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.

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

		Density	Mean	Std.dev.
Labor market				
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
Price setting, monetary policy, and preferences				
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
Fiscal policy				
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	$\psi_{\tau^n,y}$	Gamma	0.5	0.25
Feedback of output on profit tax	$\psi_{\tau^p,y}$	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
AR-coefficients of rules	ρ_k	Beta	0.5	0.2
Shock processes				
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: Parameters to be estimated and prior distributions. Quarterly calibration.

Normal prior that is centered at 0.15 with standard deviation 0.1.[18] The elasticities with respect to output follow Gamma distributions as in Leeper et al. (2010a). Note that the sign of the output parameters in the fiscal rules in Eq. 16 to 18 is set such that positive values from the Gamma prior imply counter-cyclical behavior of government spending

[18]Forni 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 applied here.

and transfers and pro-cyclical adjustment of tax rates. The prior mean of the spending and transfer elasticity for the systematic response to output is rather small, whereas profit and labor taxes respond stronger. 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 fiscal rules and shock processes, except for the monetary policy shock, follows Beta distributions with mean 0.5 and standard deviation 0.2 (Smets and Wouters, 2003).

3.3 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.[19] 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, to output with a modest coefficient of 0.10. However, monetary policy reacts strongly to unemployment (-0.40). This result provides empirical foundation for the theoretical arguments for introducing 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.

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.[20] 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. At the posterior mean, the implied value of the vacancy

[19]The online Appendix C collects plots of the prior and posterior distributions and CUSUM plots that illustrate the convergence of the Markov chain.

[20]Although the posterior mean is close to the prior, the standard deviation is reduced substantially compared to the prior.

			Posterior	
		Prior mean	Mean	90% interval
Price setting, monetary policy, and preferences				
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	$[1.09; 1.84]$
Labor market				
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	$[0.57; 0.68]$
Fiscal policy				
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^p}	0.15	0.0911	$[0.07; 0.12]$
Feedback of gvmt. debt on labor taxes	ψ_{τ^n}	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	$\psi_{\tau^p,y}$	0.75	0.2861	$[0.16; 0.41]$
Feedback of output on labor tax	$\psi_{\tau^n,y}$	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.

posting costs, κ, is 0.015 and of the scaling parameter of the logistic distribution, a_2, is 0.06. 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. 12). 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. Under flexible wages, Krause et al. (2008) argue that the labor market itself does not trigger persistence and volatility of the model. Instead, persistence and volatility originate from other model ingredients (e.g., strong nominal rigidities) and the exogenous shock processes.[21]

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).[22]

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).

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 are effectively white noise and have the largest standard deviations.[23] However, given that the absolute shock size is hard to

[21] Note 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.

[22] Leeper 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 transfers to debt is fixed at zero. Results are discussed in Section 4.3.

[23] The 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.

		Prior mean	Posterior Mean	Posterior 90% interval
Autoregressive parameters				
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^n}	0.50	0.6862	$[0.64; 0.73]$
Profit taxes	ρ_{τ^p}	0.50	0.7681	$[0.72; 0.81]$
Transfers	$\rho_{\tau^{ls}}$	0.50	0.0427	$[0.01; 0.08]$
Standard deviations				
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^p}	0.01	0.0201	$[0.02; 0.02]$
Labor taxes	σ_{τ^n}	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.

interpret, the relative importance of the different shocks is discussed in detail in the context of a structural variance decomposition in the online Appendix C.3.

Various statistics illustrate the fit of the estimated model (see online Appendix C for a detailed discussion). Simulated model standard error bands capture the auto- and

However, as revealed by the variance decomposition (see online Appendix D), 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.

cross-covariances of US data for the most part, in particular, for the fiscal and labor market variables. Besides, the model generates a Beveridge curve 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.

Model forecasts replicate the true data dynamics closely. The unemployment rate in the model is, for example, approximately four times as volatile as GDP. This finding illustrates that the model is not subject to the Shimer (2005) criticism on search and matching models. There are two reasons: First, the model features an endogenous separation margin. Second, model dynamics are triggered by several shocks in addition to productivity shocks.

4 The effects of fiscal policy

4.1 Fiscal multipliers

I evaluate the effects of discretionary fiscal policy using unemployment and output multipliers. Unemployment (output) multipliers report the percentage point reduction of unemployment (percentage change of GDP) in response to a one percent increase in the fiscal cost relative to GDP. For instance, the present value multiplier of government spending for unemployment at horizon k is defined as

$$\text{Present value multiplier}(k) = \frac{E_t \sum_{j=0}^{k} \beta^j (u_t - u)}{E_t \sum_{j=0}^{k} \beta^j (g_t - g)/y}. \tag{26}$$

For easier comparison, I report multipliers for expansionary fiscal policy, i.e., increases of expenditures and tax cuts.

Table 5 summarizes the estimated fiscal multipliers. The first rows of Table 5 represent the baseline scenario where all fiscal instruments follow fiscal rules. On impact, each fiscal expansion lowers unemployment and raises output. Generally, fiscal stimulus in a New Keynesian model with imperfect competition and price stickiness brings down the mark-ups and increases production and marginal costs (compare Eq. 14). In a model with a search and matching labor market, marginal costs of production reflect not only unit labor costs, but the long run value of a match. This long run value depends

	Spending multipliers		*Transfer multipliers*		*Labor tax multipliers*		*Consumption tax multipliers*	
Horizon	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment
	All instruments adjust (-3,315.70)							
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]
	Only transfers adjust, no fiscal rules (-3,328.63)							
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]
	Transfers do not adjust (-3,319.23)							
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]

Table 5: Estimated fiscal multipliers. Numbers show the posterior median and the 5 and 95 percent posterior intervals. 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).

also on aggregate labor market conditions rather then firm-specific characteristics alone (see Krause et al., 2008 or Faia et al., 2013 for details).

Generally, with labor market frictions, adjusting employment upward to meet rising demand is more costly compared to a model with a neoclassical labor market. Here, the firm has two adjustment margins for labor input: hiring and firing. Hiring is subject to vacancy posting costs, firings entail the loss of future profits of the existing match. Consequently, intermediate firms adjust both margins simultaneously in response to rising marginal costs (compare Eq. 9 and 10). The endogenous job destruction margin adds two features to the model: first, it reduces the sluggish adjustment of employment to aggregate shocks due to the matching function. As a result, the aggregate effects of the fiscal stimulus are larger compared to a model without this additional adjustment margin. Second, it aligns the model with the actual labor market adjustment in the data that is realized via job creation and destruction simultaneously. According to the Fujita and Ramey (2009) decomposition, 47 percent of the behavior of unemployment in the model is explained by the job finding rate, whereas 53 percent are driven by the separation rate.[24] In line with Eq. 12, wages rise with marginal costs. However, in contrast to a neoclassical labor market, labor supply does not increase after expansionary fiscal policy. The negative wealth effect crowds out consumption, but labor adjusts only along the extensive margin (see Monacelli et al. (2010)).[25]

The size of the multipliers varies depending on the fiscal instrument. Government spending turns out to be the most effective stabilizer of unemployment and output. Output multipliers are smaller than one as the government intervention crowds out private consumption (Section 4.2 shows that this finding holds in a model that facilitates private consumption crowding in). In the following, I discuss the effects of each fiscal instrument in turn.

[24] I apply the decomposition on simulated data from the estimated model using repeated draws from the posterior distributions of the parameters. In the US data, I find that 53 percent of the unemployment fluctuations are driven by the job-finding rate, whereas 48 percent are driven by the separation rate. These numbers fall in the one standard deviation interval of the model simulations and are very much in line with the findings of Fujita and Ramey (2009) themselves who also find that fluctuations in the separation rate explain between 40 to 50 percent of unemployment fluctuations. The exact numbers differ due to different samples and filtering.

[25] Empirical evidence emphasizing the predominant adjustment of labor along the extensive margin goes back to Hansen (1985). See Shimer (2010, Chap. 1) and Merkl and Wesselbaum (2011) for more recent evidence.

Government spending An increase in government spending by one percent of GDP decreases unemployment by 0.46 percentage points. Output increases by 0.47 percent. Figure 1 illustrates the responses of several key variables and highlights the transmission mechanism. In the figures, fiscal interventions are normalized to 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. The intuition for the positive effects of government spending is the following. 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 and price mark-ups fall. Profit maximizing monopolistic firms produce more consumption goods and demand more intermediate goods. To meet this additional demand, intermediate goods producers post more vacancies and fire fewer workers. As a result, the job-finding rate increases and the separation rate falls. Hiring and retaining additional workers drives up the costs of production. The unemployment rate falls, while wages rise. According to the Taylor rule, the monetary authority raises interest rates in response to the inflationary pressure and the deviation of output and unemployment from steady state. Due to strong interest rate smoothing, private consumption is crowded out in a moderate way.

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 three 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 in Corsetti et al. (2012). Fiscal consolidation is pursued mainly by adjusting alternative fiscal instruments instead of government spending. There is no consumption crowding in. Section 4.3 discusses the influence of the fiscal rules in more detail.

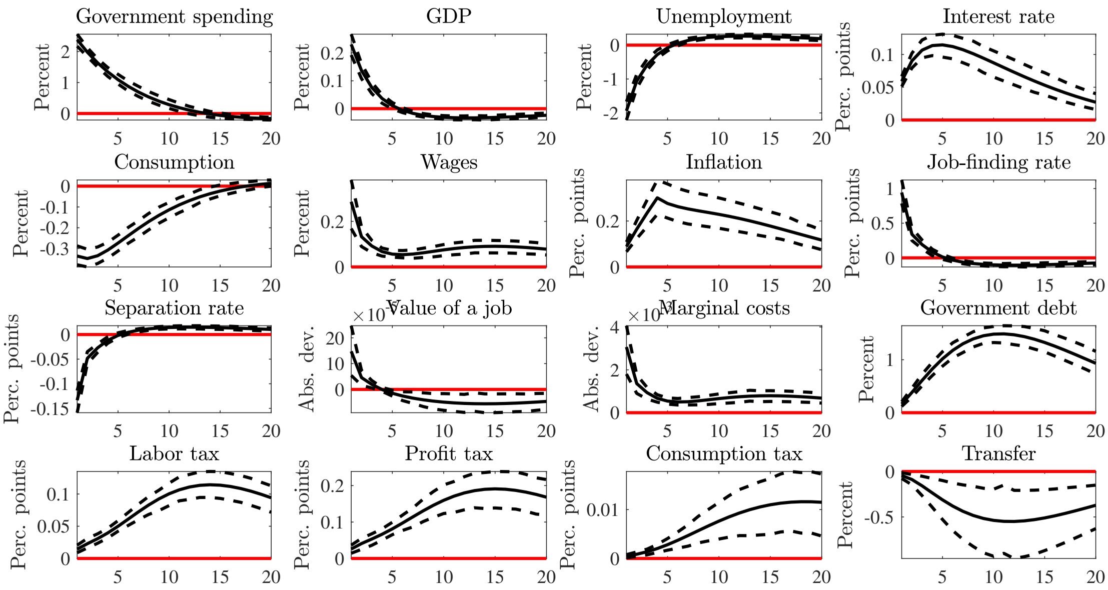

Figure 1: Estimated impulse responses to an increase in government spending (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

Transfers An increase in transfers has very small multipliers on impact (-0.03 for unemployment), and even small contractionary effects 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 2 shows that higher transfers raise government debt. As a result, fiscal policy has to be contractionary in the future. Public spending falls and tax rates rise with the peak approximately two years after the rise in transfers. Then, GDP falls below steady state. The small impact increase in consumption results from (expected) future real interest rates below steady state. This increase in private demand generates very small positive output (and negative unemployment) effects. 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 Ta-

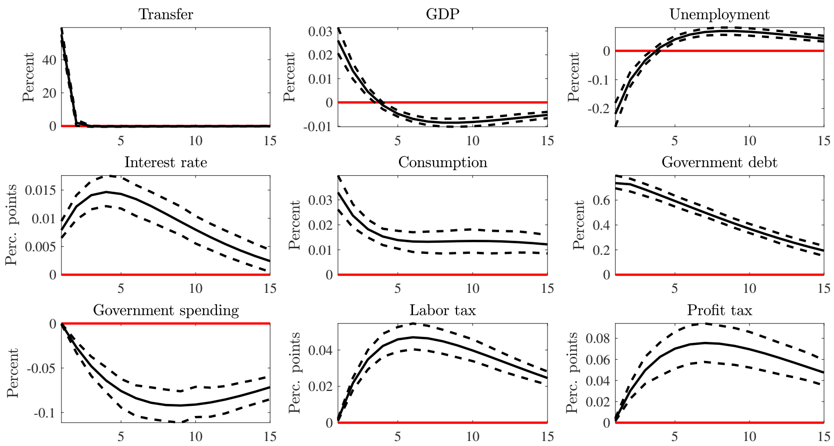

Figure 2: Estimated impulse responses to an increase in lump-sum transfers (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

ble 5). The impact unemployment multiplier is only -0.03. Figure 3 shows the 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. 11). In contrast to a neoclassical labor market, changes in the labor tax generate no direct effect on labor supply. 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 respond if the outside option of the workers changes (as the estimated workers' bargaining power is close to one, see Eq. 12). 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, but the effects on consumption are small.

Consumption tax cuts Multipliers for a cut in consumption taxes are larger than those for labor taxes. Cutting consumption taxes by one percent of GDP generates a

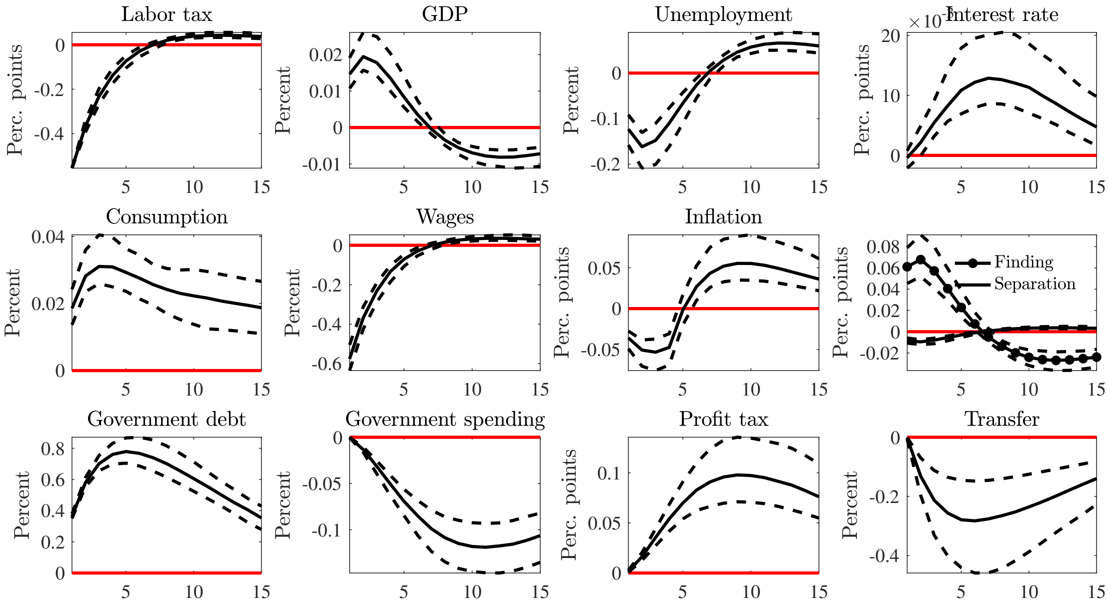

Figure 3: Estimated impulse responses to a cut in labor taxes (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

decrease of unemployment -0.36 percentage points. The corresponding output multiplier is 0.35. Figure 4 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. In the case of consumption taxes, part of the fiscal expansion is saved. Firms increase employment and GDP rises. Fiscal rules imply that spending, transfers and tax rates all adjust to rising debt levels. These contractionary policies result in GDP slightly below steady state from quarter seven after the shock onward. Again, lower future inflation and interest rates compared to an economy without fiscal rules bolsters consumption on impact.

The results demonstrate that fiscal policy can be effective in terms of stabilizing 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. 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 govern-

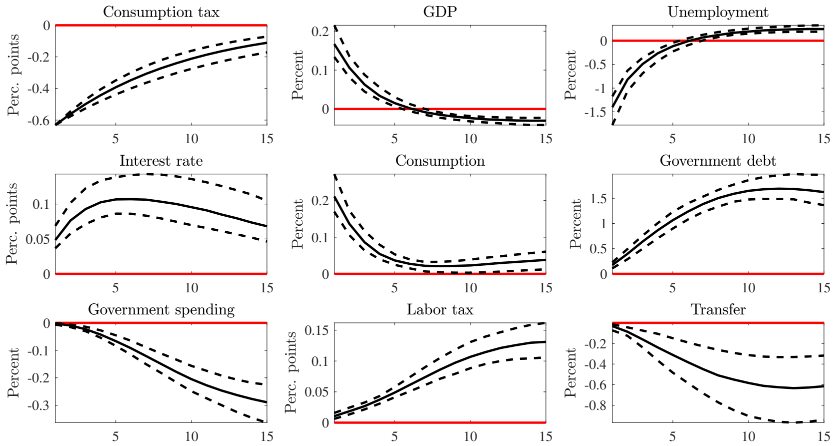

Figure 4: Estimated impulse responses to cut in consumption taxes (0.5 percent of GDP) in the US. The solid line shows the impulse responses at the posterior mean; the dashed lines at the 5 percent and 95 percent posterior intervals. The impulse horizon is measured in quarters.

ment stimulates demand by higher lump-sum transfers, the long run negative effects due to fiscal rules quickly offset the small short run positive effects. According to my model estimates, tax multipliers are always smaller than spending multipliers. This ranking corresponds to the impact output effects of spending and tax policy changes identified by Zubairy (2014) in a DSGE model without labor market frictions.

4.2 Fiscal expansions and private consumption

Even though the model is a standard model widely used for policy analysis, optimizing agents will always reduce private consumption in response to expansionary fiscal policy. In the empirical SVAR literature, however, this response is contended.[26] The DSGE literature has found different answers to this disagreement.[27] Yet, these approaches have been criticized for a lack of microeconomic foundation and empirical irrelevance (Kormilitsina and Zubairy, 2016). Here, I follow a different route to allow the model to generate a positive private consumption response: combining a comple-

[26]Some studies with narrative identification find either no or a slightly negative effect of government spending on private consumption (see, e.g., Ramey, 2011), whereas other studies applying short run restrictions find a significant increase in private consumption (e.g., Blanchard and Perotti, 2002, Fatás and Mihov, 2001, and Mountford and Uhlig, 2009).

[27]Deep 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, 2015).

	Multiplier	$b = 0.5$	$b = 0.75$	$b = 1$
$\sigma = 1$	Unemployment	-0.50	-0.7	-0.46
	Output	0.02	0.44	0.56
$\sigma = 2$	Unemployment	-1.09	-0.91	-0.67
	Output	0.55	0.90	0.92
$\sigma = 3$	Unemployment	-1.74	-1.01	-0.80
	Output	1.29	1.17	1.15

Table 6: Impact unemployment and 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.

mentarity in household's preferences and New Keynesian elements can generate private consumption crowding in in a general equilibrium model with a search and matching labor market.

In line with Monacelli et al. (2010), I modify the model towards households' preferences with a complementarity in consumption and leisure

$$E_0 \sum_{t=0}^{\infty} \beta^t d_t \frac{c_t^{1-\sigma}[1+(\sigma-1)bn_t]^{\sigma}-1}{1-\sigma}. \tag{27}$$

The parameter b now denotes the relative disutility of work 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 $\sigma = 1$.[28]

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. A simulation of the model at the prior mean illustrates that the range of multipliers that can be generated with this model modification for different values of σ and b covers values from close to zero to larger than unity (see Table 6). The size of the multipliers depends strongly on these two parameters. Output multipliers larger than one are

[28] As shown by Shimer (2010, Chap. 3), the above preferences are the result of a representative household maximizing the sum of utilities of its individual (employed and unemployed) household members. In line with the Monacelli et al. (2010) interpretation, the parameter b now is a preference parameter and hence is removed from the household's and the government's budget constraint.

Spending multipliers		*Transfer multipliers*		*Labor tax multipliers*		*Consumption tax multipliers*	
Unemployment	GDP	Unemployment	GDP	Unemployment	GDP	Unemployment	GDP
Standard model (-3,315.70)							
-0.464	0.466	-0.027	0.026	-0.030	0.030	-0.358	0.350
Model with complementarity in preferences (-3,324.47)							
0.234	-0.227	0.035	-0.034	0.045	-0.045	0.471	-0.458

Table 7: Impact fiscal multipliers across models with different preferences with full fiscal rules. Numbers show the posterior median and the 5 and 95 percent posterior intervals. 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).

indeed driven by private consumption crowding in.

I analyze whether there is a role for private consumption crowding in in the data by estimating this modified model. The prior range for the parameters b and σ covers all parameter constellations in Table 6. The posterior mean of the complementarity parameter σ is with 0.63, however, outside of the interesting region where rising employment boosts consumption. The posterior mean of the disutility of work parameter b is 0.93 (see online Appendix D for the detailed estimation output). In the estimated model, the propagation of government spending via consumption crowding in is absent. As Table 7 shows, the posterior means of the impact output multipliers are overall similar compared to the baseline model, except for government spending where the multiplier is even smaller than in the baseline model (0.23). The main reason for the latter finding is the complementarity parameter. The estimation rejects this alternative model specification. For this reason, the remaining analyses are restricted to the baseline model.

4.3 The influence of fiscal rules

This section analyzes the influence of fiscal rules on the multipliers (see Table 5 on page 23 for the results). I compare results where all fiscal instruments adjust to debt to two alternative specifications: one where lump-sum transfers do not adjust and one where only lump-sum transfers adjust to debt.[29] The specification without an adjust-

[29]These specifications are estimated as described in Section 3. The only difference is that the respective fiscal adjustment parameters are fixed at zero. Estimated parameters differ across the different

ment in transfers explores how results change if the only non-distortionary fiscal instrument is excluded from the fiscal rules. 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 the parameters for automatic stabilization are zero. In this specification, Ricardian equivalence holds.

Table 5 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.[30] Second, multipliers are smaller if fiscal policy does not follow fiscal rules. The consumption tax multiplier is reduced by two third. 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.[31]

To investigate this result in more detail, Figure 5 compares the model responses to a government spending shock in the estimated model with and without fiscal rules (dashed lines). With fiscal rules, government spending falls below steady state roughly three years after the initial shock. This depresses future production and as argued by Corsetti et al. (2012) the long term real interest rate. However, in the estimated model, the long term rate does not fall below steady state and hence consumption still declines on impact. Nevertheless, consumption falls less than in the model without fiscal rules. Whether the Corsetti et al. (2012) effect is large enough for consumption crowding in depends also on the interaction of monetary and fiscal policy. More aggressive monetary policy prevents consumption crowding in also in Corsetti et al. (2012).

Nevertheless, it is important to note that the short run benefit of enhanced multipliers is bought by negative effects in the future. The choice of the fiscal policy mix to consolidate debt trades off short run benefits versus medium run losses (in terms of

models. For example, the vacancy posting costs are larger in the model where only lump-sum transfers adjust to debt compared to the baseline models. This explains why the multipliers of GDP and unemployment differ by more in this specification.

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

[31]The impact multiplier of labor tax cuts even 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.

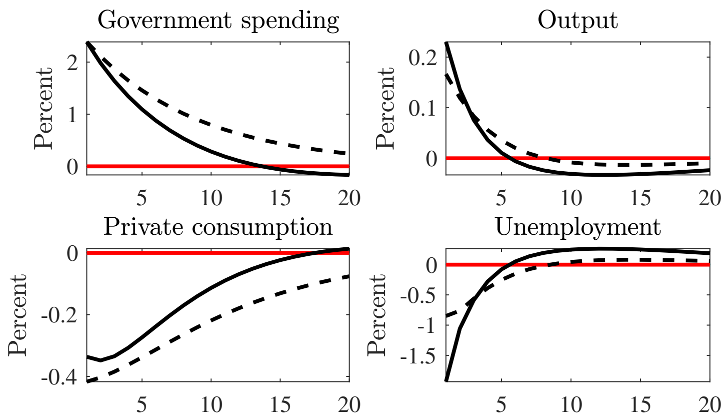

Figure 5: Comparison of impulse responses to a government spending shock with fiscal rules (solid lines) and without fiscal rules (dashed lines). The impact increase in government spending is normalized to 0.5 percent of GDP in both cases.

output and unemployment).[32] 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.

4.4 The results in perspective

A few comparable studies that analyze fiscal policy in the context of labor market frictions exist. 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 if one assumes a high value of non-work to work activities (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 assuming such a special parameterization.

Campolmi et al. (2011) allow for endogenous participation in a New Keynesian model augmented with search and matching frictions. They argue that output spending

[32]A normative analysis of the optimal fiscal policy mix under the possibility of spending reversals would be an interesting route for future research. Arseneau and Chugh (2012) find that labor market frictions matter for the optimal conduct of fiscal policy.

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.

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 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. 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.[33] 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. 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 depending on the identification. For the US, Hall (2010) concludes that most SVAR studies find positive output multipliers of government spending between 0.5

[33]The difference is essentially driven by two effects. Wages react less to labor tax cuts due to the high bargaining power and adjusting prices is relatively costly in 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.

and 1.[34] These studies do not explicitly focus on the labor market responses. Exceptions are Ravn and Simonelli (2007), Monacelli et al. (2010), and Rahn and Weber (2017). Monacelli et al. (2010) show that an increase in government spending (of 1 percent of GDP) stabilizes unemployment by 0.43 percentage points when cumulated. Evidence on the direct effect of tax policy on unemployment is scarce. For output, Mountford and Uhlig (2009) argue that tax multipliers can be very large, whereas Blanchard and Perotti (2002) find smaller tax than spending multipliers.

5 Conclusions

This paper studies the effects of fiscal policy on unemployment in a model with search and matching frictions, endogenous job separation, distortionary taxation and 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: raising government spending by one percent of GDP reduces unemployment by 0.46 percentage points. Likewise, consumption tax cuts are effective, but the multiplier is with 0.36 (in absolute terms) smaller than for government spending. In contrast, discretionary labor tax cuts have only very small expansionary effects on output and unemployment. In general, unemployment multipliers turn out to be sizable, output multipliers are always smaller than unity. The data prefer a model where fiscal policy crowds out private consumption.

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. These results are based on estimated fiscal rules from US data for the last decades. These rules abstract from regime changes in policy and are constant over time. It is an open question whether and how the results would change in extreme

[34] See 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 and at the zero lower bound (see, e.g., Auerbach and Gorodnichenko, 2012 for evidence from regime-switching SVARs and Eggertsson, 2011 for theoretical arguments). However, this discussion far from settled (Ramey and Zubairy, 2016).

situations such as an economy at the zero lower bound or with extreme debt levels as after the Great Recession. Ghosh et al. (2013) provide empirical evidence that fiscal rules may adjust in extreme debt situations. An analysis of the impact of such non-linearities on the effectiveness of policy is left for future research. 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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Online Appendix

A Model derivations

A.1 The intertemporal value of a job

The value of a match for the firm after the shock realization ε is known is

$$\tilde{J}_t(\varepsilon) = \Big(a_t mc_t - \varepsilon_t - w_t(\varepsilon_t)\Big)(1 - \tau_t^p) + E_t \Lambda_{t,t+1} J_{t+1}. \tag{28}$$

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

$$\begin{aligned} E_t J_{t+1} =& E_t(1 - \phi_{t+1}) \int_{-\infty}^{v_{t+1}^f} \frac{\big(a_{t+1} mc_{t+1} - \varepsilon_{t+1} - w_{t+1}(\varepsilon_{t+1})\big) g(\varepsilon)}{1 - \phi_{t+1}^e} d\varepsilon_{t+1} (1 - \tau_{t+1}^p) \\ & - E_t \Big[(1 - \phi^x) \phi_{t+1}^e V_{t+1} + \phi^x V_{t+1} + (1 - \phi_{t+1}) \Lambda_{t+1,t+2} J_{t+2} \Big]. \end{aligned} \tag{29}$$

The first term captures the expected (after tax) profits of the match in period $t + 1$, i.e., aggregate revenue minus expected idiosyncratic costs and expected wages, given that no separation occurs. Note that the conditional expected revenue depends on the density of ε conditional on not endogenously separating. This conditional density can be expressed as $g(\varepsilon | \varepsilon_{t+1} < v_{t+1}^f) = \frac{g(\varepsilon)}{G(v_{t+1}^f)} = \frac{g(\varepsilon)}{1 - \phi_{t+1}^e}$. Production is priced at marginal costs given that intermediate good producers sell on a perfectly competitive market. The second term represents the expected value of a vacancy in case of endogenous separation. 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.

A.2 The value of working and unemployment

The value of a match for the worker with shock realization ε is

$$W_t(\varepsilon_t) = w_t(\varepsilon_t)(1-\tau_t^n) + E_t\Lambda_{t,t+1}\Big[\phi_{t+1}U_{t+1} + (1-\phi_{t+1})\int_{-\infty}^{v_{t+1}^f} \frac{W_{t+1}(\varepsilon_{t+1})}{1-\phi_{t+1}^e} g(\varepsilon)d\varepsilon_{t+1}\Big] \tag{30}$$

and the value of an unemployed worker is

$$U_t = b + E_t\Lambda_{t,t+1}\Big[\eta_{t+1}(1-\phi_{t+1})\int_{-\infty}^{v_{t+1}^f} \frac{W_{t+1}(\varepsilon_{t+1})}{1-\phi_{t+1}^e} g(\varepsilon)d\varepsilon_{t+1} + \big(1-\eta_{t+1}(1-\phi_{t+1})\big)U_{t+1}\Big]. \tag{31}$$

B 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, 2015, Zubairy, 2014).

- Effective tax rates on labor, capital and consumption (see below). The profit tax in the model is represented by a general tax on capital income in the data. This approach is a short-cut given that the model has no capital. This short-cut allows me to use the standard and consistent computation of effective tax rates on income, consumption and capital that goes back to Mendoza et al. (1994). I checked the robustness of my results towards using a series for a profit tax in the estimation. I computed the effective profit tax from the US NIPA tables as proposed by Mertens and Montiel Olea (2013). The two series have a strong positive correlation of 0.88, although the profit tax has a lower mean (23.7 percent) compared to the capital tax (39.1 percent). The results on the fiscal multipliers are, however, robust towards using either the capital or the profit tax series for the estimation.

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., 2015 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 8 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 6 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 7 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.

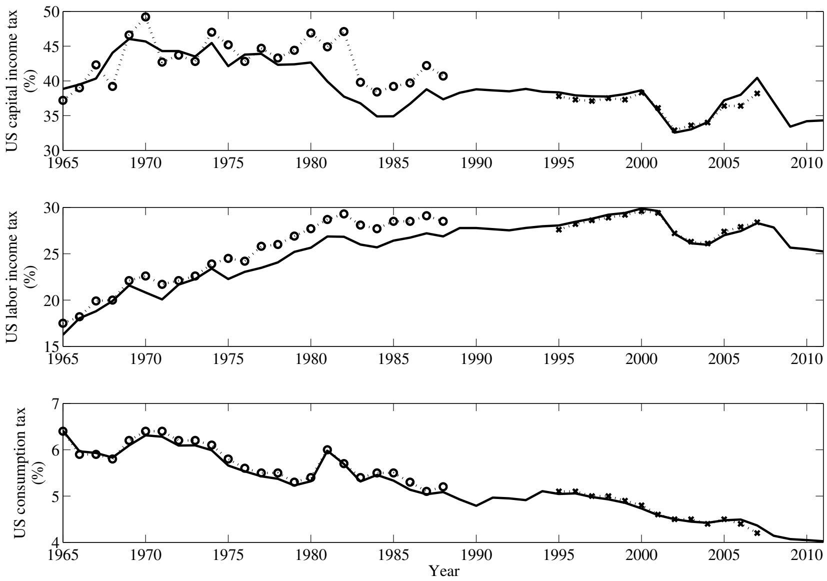

Figure 6: Annual effective tax rates. Comparison of data constructed here (solid lines), data of Mendoza et al., 1994 (lines marked by dots), and the data series computed by Trabandt and Uhlig, 2011 (lines marked by crosses).

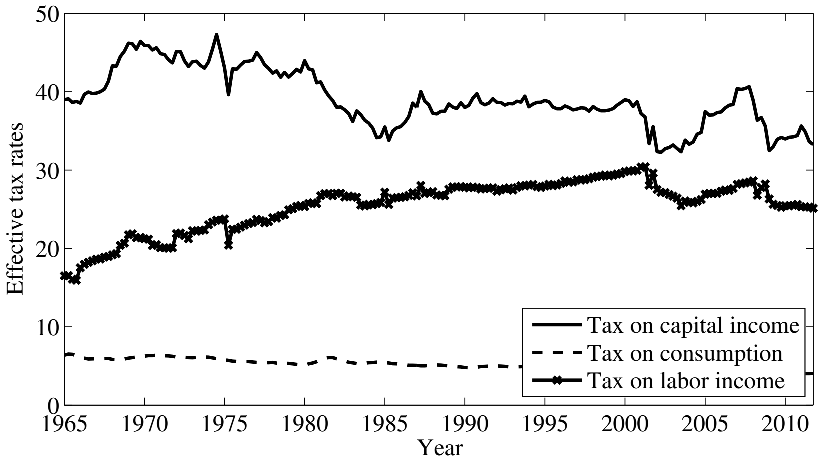

Figure 7: Quarterly effective tax rates in the US.

Variable	Description	Data source [quarterly indicator if interpolation is necessary]
Revenue statistics		
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]
National accounts		
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 8: 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*.

C Estimation output, model fit and variance decomposition

C.1 Prior and posterior distributions and convergence

Figure 8, 9 and 10 show the prior (dashed grey) and posterior distributions (solid black) of all estimated parameters as obtained in the baseline model. Figure 11 illustrates CUSUM plots that visualize the convergence of the Markov chains. The figures plot the cumulative mean minus the overall mean (Bauwens et al., 2000). A detailed discussion of the estimation results can be found in the main text in Section 3.3. Further details on the exact numbers are summarized in Table 3 and 4 in the main text, the prior distributions are given in Table 2 in the main text.

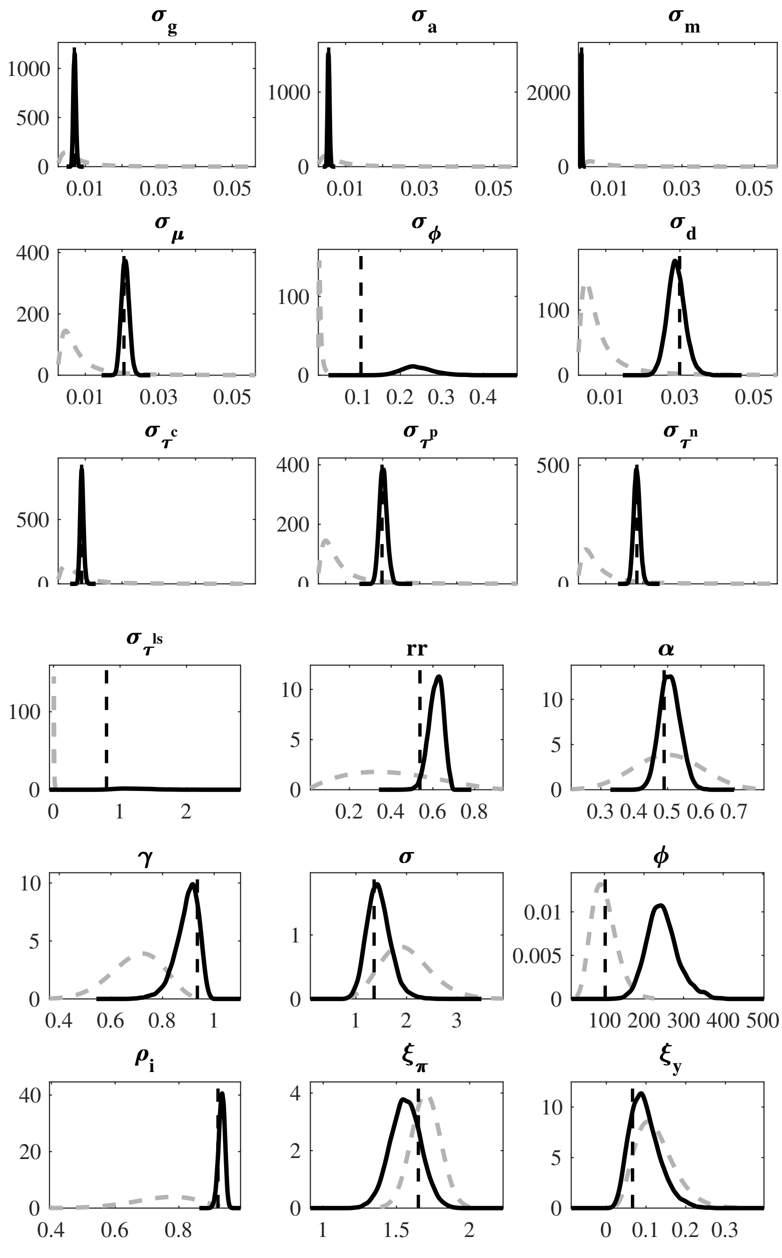

Figure 8: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation. The vertical lines mark the posterior mode.

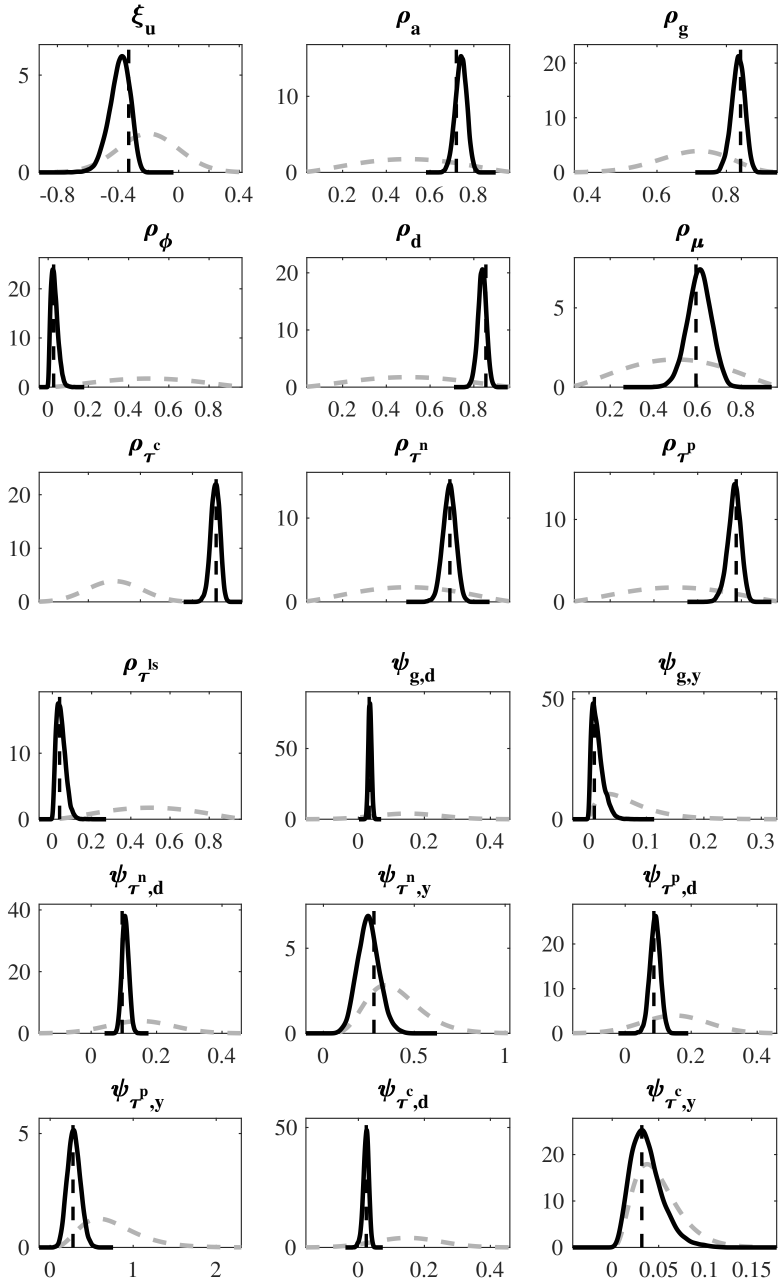

Figure 9: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation (ctd.). The vertical lines mark the posterior mode.

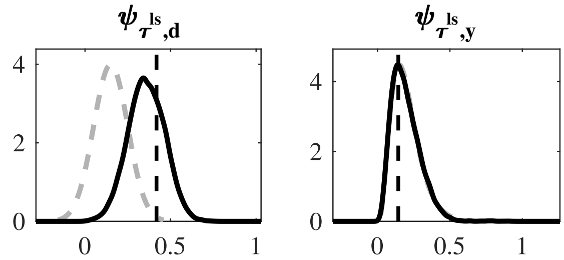

Figure 10: Prior (dashed grey) and posterior distributions (solid black) for baseline estimation (ctd.). The vertical lines mark the posterior mode.

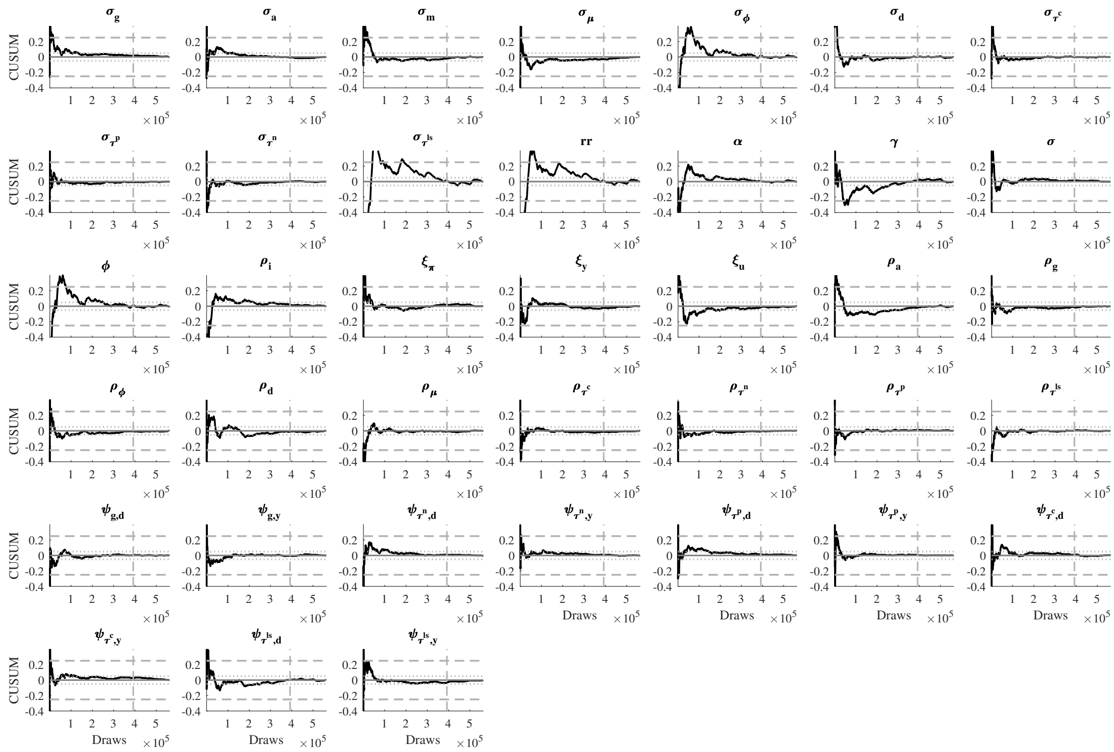

Figure 11: CUSUM charts for baseline estimation. The horizontal lines indicate 5 and 25 percent bands. The vertical lines indicate the burn-in of the Markov chain.

C.2 Model fit and properties

Figure 12 provides a visual representation of the auto- and cross-covariances of the model and the data. The fit is satisfactory 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. The one-step ahead Kalman forecast of the estimated model in Figure 13 matches the data series including the flow rates. The one-period ahead forecast of inflation is too volatile in the model compared to the data as inflation is purely foreward 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).

Table 9 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 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). Fiscal 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. 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. The 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

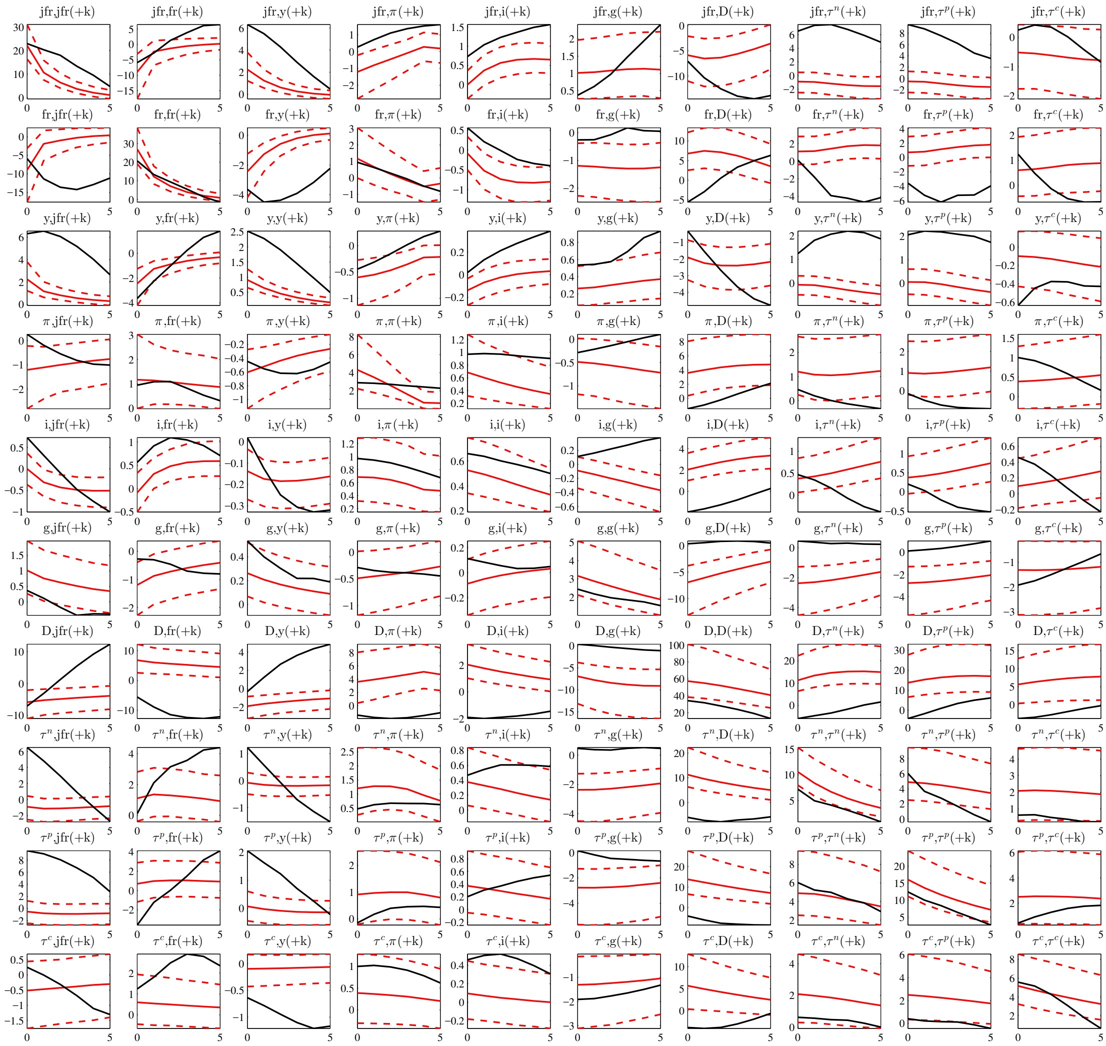

Figure 12: Auto- and cross-covariances at t and $t + k$ of US data (black solid line) and estimated model (red lines, dashed lines represent 5th and 95th percentiles, solid lines represent the posterior median). Model covariances are computed from simulated data as follows: I took 500 draws from the 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.

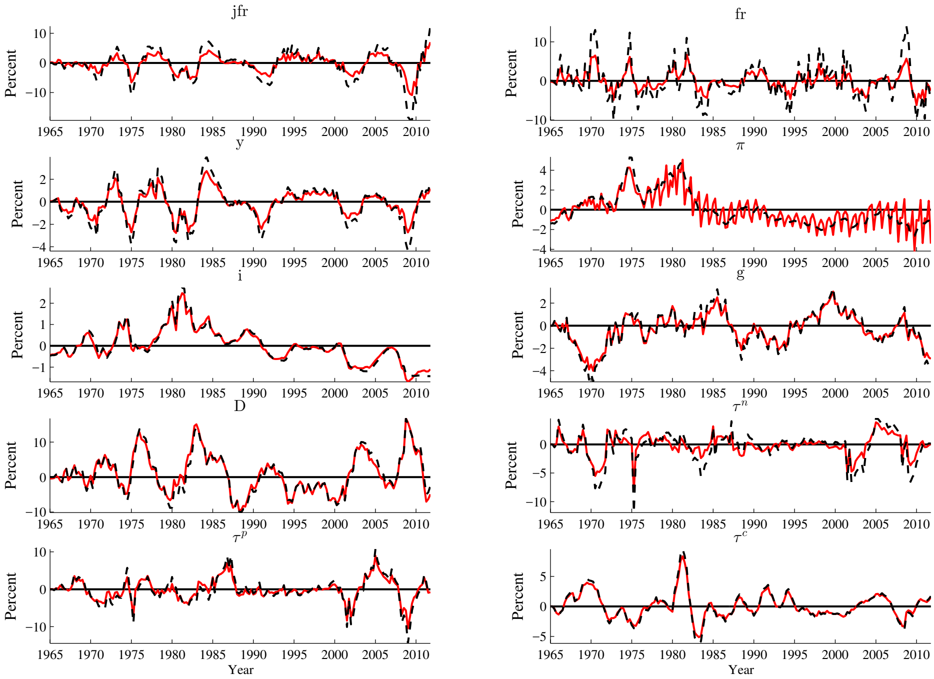

Figure 13: Comparison of US data (black dashed line) versus one-period ahead forecasts of observables of the estimated model (red solid lines). The plot shows deviations from steady state/trend. The one-period ahead forecast is obtained by Kalman filtering the state space representation of the estimated model at the posterior mean.

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. 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.

	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	-0.52	-0.20	-0.30
	[0.30; 0.69]	[-0.68; -0.28]	[-0.44; 0.07]	[-0.49; -0.09]
Productivity shocks	-0.47	0.47	-0.94	-0.89
	[-0.54; -0.38]	[0.38; 0.54]	[-0.96; -0.92]	[-0.94; -0.82]
Preference shocks	0.98	-0.98	0.32	0.15
	[0.97; 0.98]	[-0.98; -0.97]	[0.26; 0.39]	[-0.01; 0.42]
Monetary policy shocks	0.98	-0.98	-0.98	-0.15
	[0.97; 0.99]	[-0.99; -0.97]	[-0.99; -0.97]	[-0.50; 0.38]
Government spending shocks	0.98	-0.98	0.13	-0.04
	[0.97; 0.99]	[-0.99; -0.97]	[0.00; 0.23]	[-0.15; 0.08]

Table 9: 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.

C.3 Variance decomposition

The search and matching literature 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 10 illustrates the conditional forecast error variance decomposition of the estimated model. Productivity shocks explain only 15 percent of the dynamics of the 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). Nevertheless, productivity shocks 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. 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.

Figure 14 shows a historical variance decomposition of GDP and unemployment. In general, these figures confirm the earlier results obtained from the overall variance decomposition. Interestingly, preference shocks are an important driving force of GDP and in particular unemployment in the Great Recession. This finding is in line with Hall (2017) who argues that there is a connection between discounting and unemployment. The preference shock indeed stands in as a shock representing disturbances from financial markets in a model without explicit financial markets. Note that monetary policy shocks destabilize for example in the Great Recession. The reason for this finding is the following: The Taylor rule of monetary policy responds strongly to deviations from GDP and unemployment from steady state. For this reason, in the Great Recession, interest rates are decreased strongly via the Taylor rule until the zero lower bound binds. This binding constraint is captured in this (linear) model via positive monetary policy shocks.

	Productivity shock		Monetary shock		Spending shock		Mark-up shock		Preference shock		Matching shock		Transfer shock		Tax shocks	
Horizon	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval	Mean	90% interval
Variance decomposition of job creation																
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]
Variance decomposition of job destruction																
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]
Variance decomposition of unemployment																
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]
Variance decomposition of GDP																
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]
Variance decomposition of inflation																
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]
Variance decomposition of interest rates																
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 10: Posterior forecast error variance decomposition. The forecast horizon is measured in quarters.

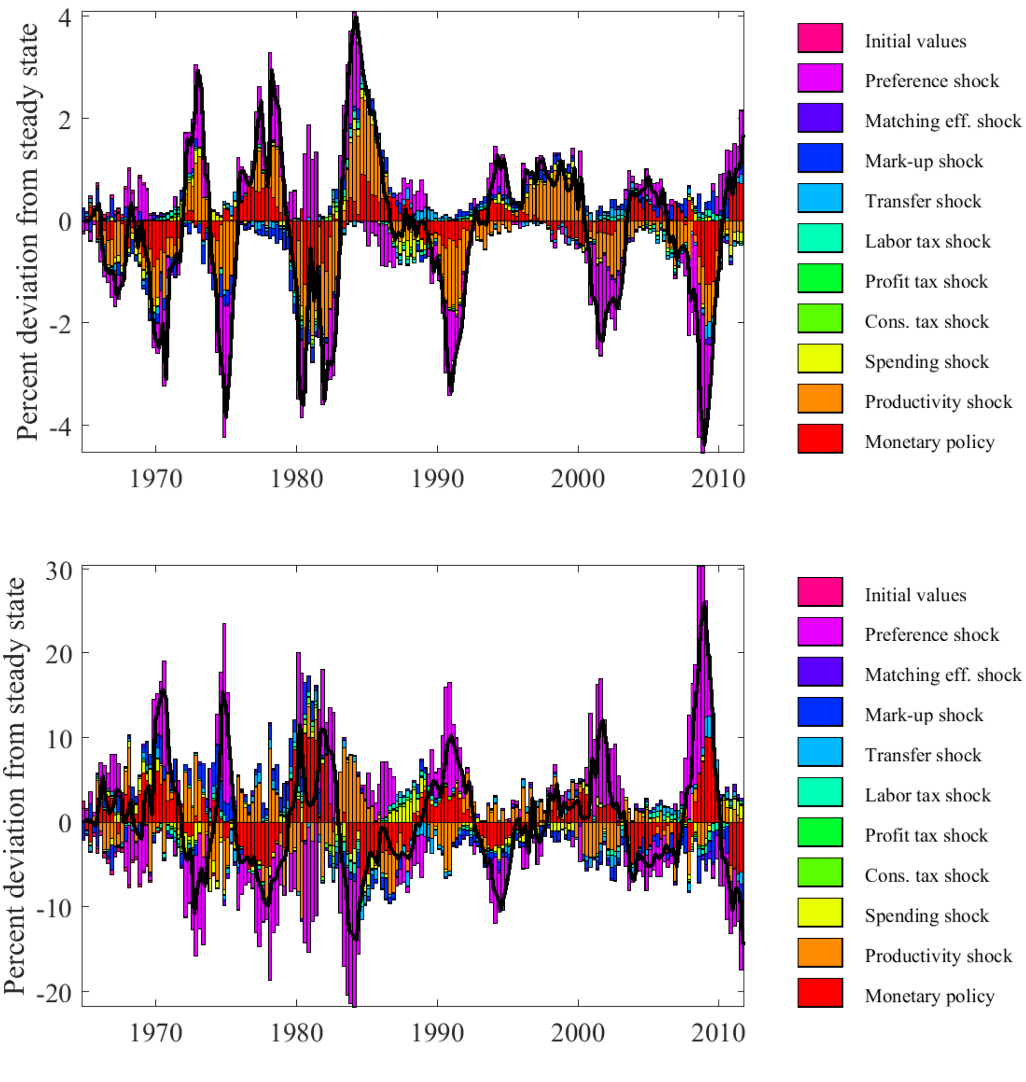

Figure 14: Historical variance decomposition of GDP (upper panel) and unemployment (lower panel).

In general, 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). Using estimated DSGE models, Gertler et al. (2008), Krause et al. (2008), Sala et al. (2012), and Furlanetto and Groshenny (2016) also find evidence for variation in labor market variables due to non-productivity shocks. Nevertheless, these studies do not analyze labor market flow rates.

D Estimation output for model with complementarity in preferences

Figure 15, 16 and 17 show the prior (dashed grey) and posterior distributions (solid black) of all estimated parameters as obtained in the model that allows for a complementarity in household preferences. The model is discussed in Section 4.2 of the main text. Figure 18 illustrates CUSUM plots that visualize the convergence of the Markov chains.

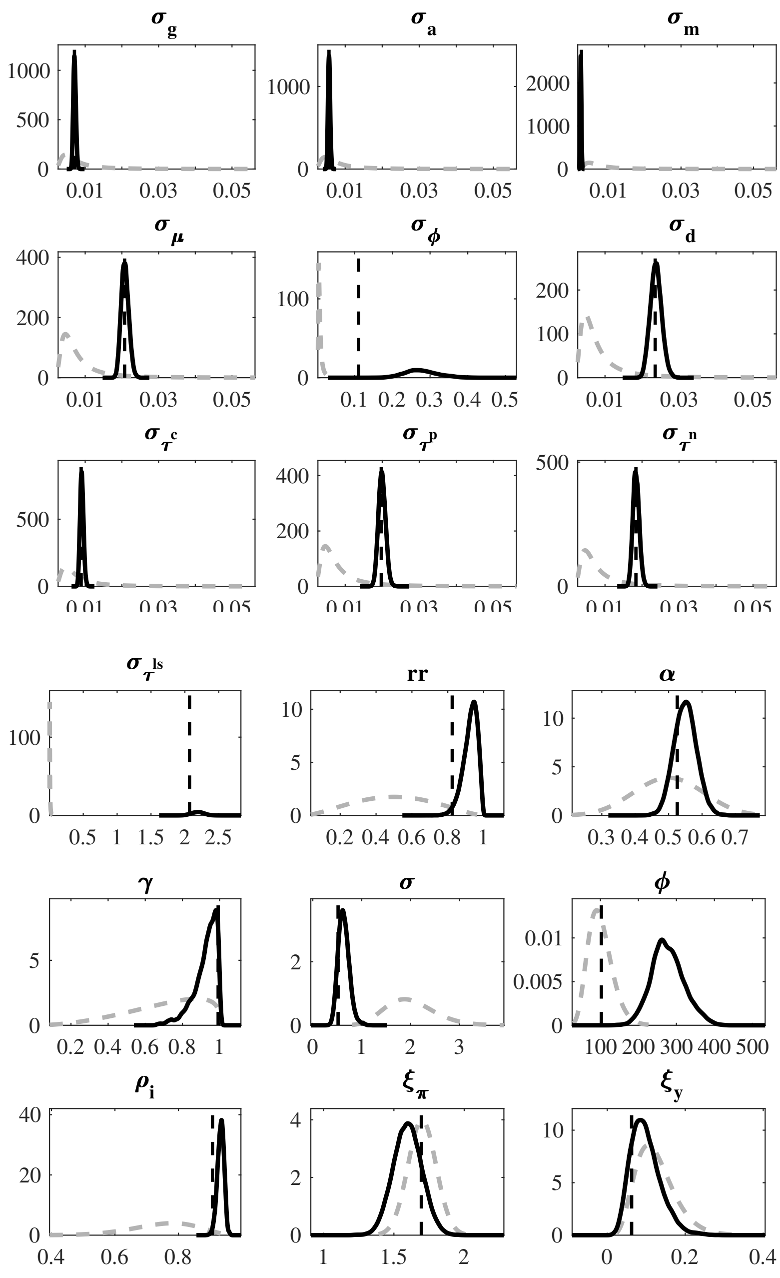

Figure 15: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences. The vertical lines mark the posterior mode.

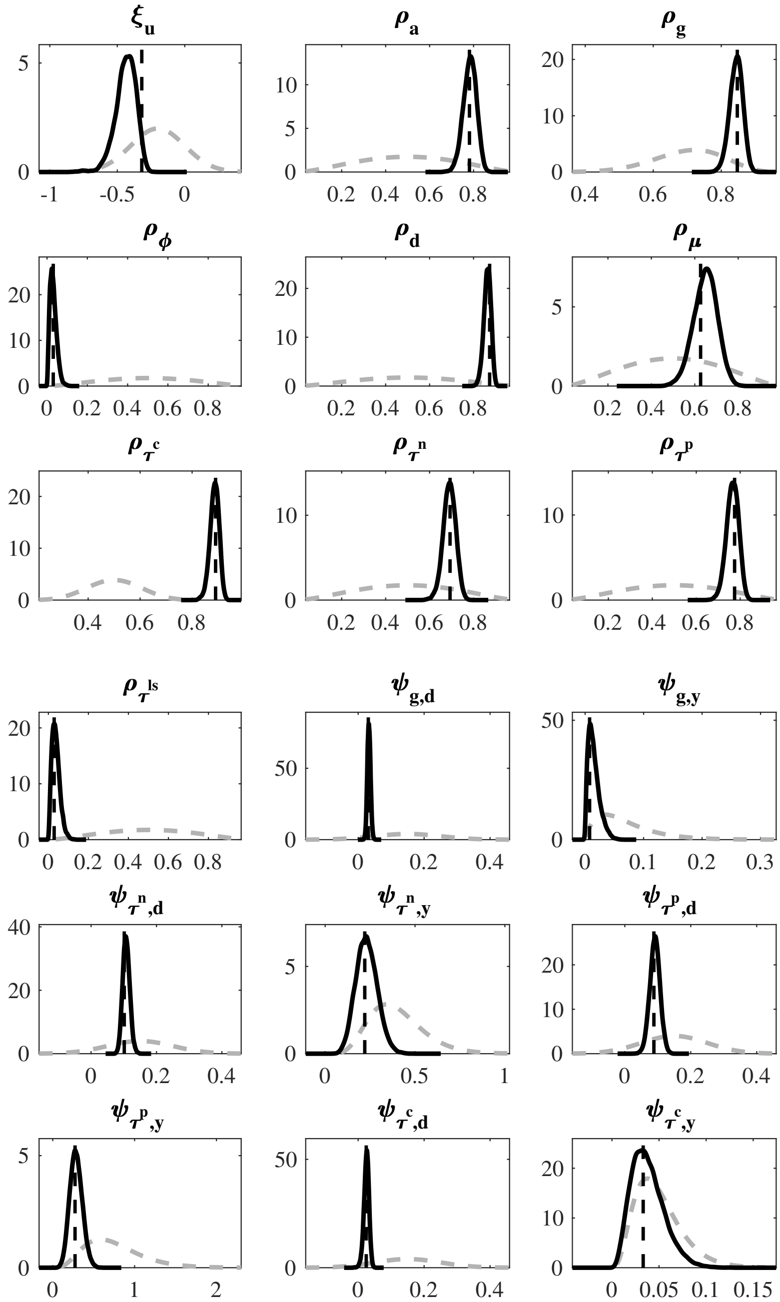

Figure 16: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences (ctd.). The vertical lines mark the posterior mode.

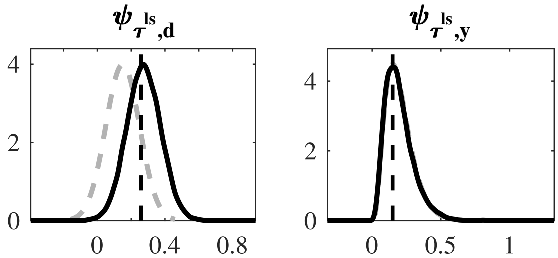

Figure 17: Prior (dashed grey) and posterior distributions (solid black) for model estimation with complementarity in preferences (ctd.). The vertical lines mark the posterior mode.

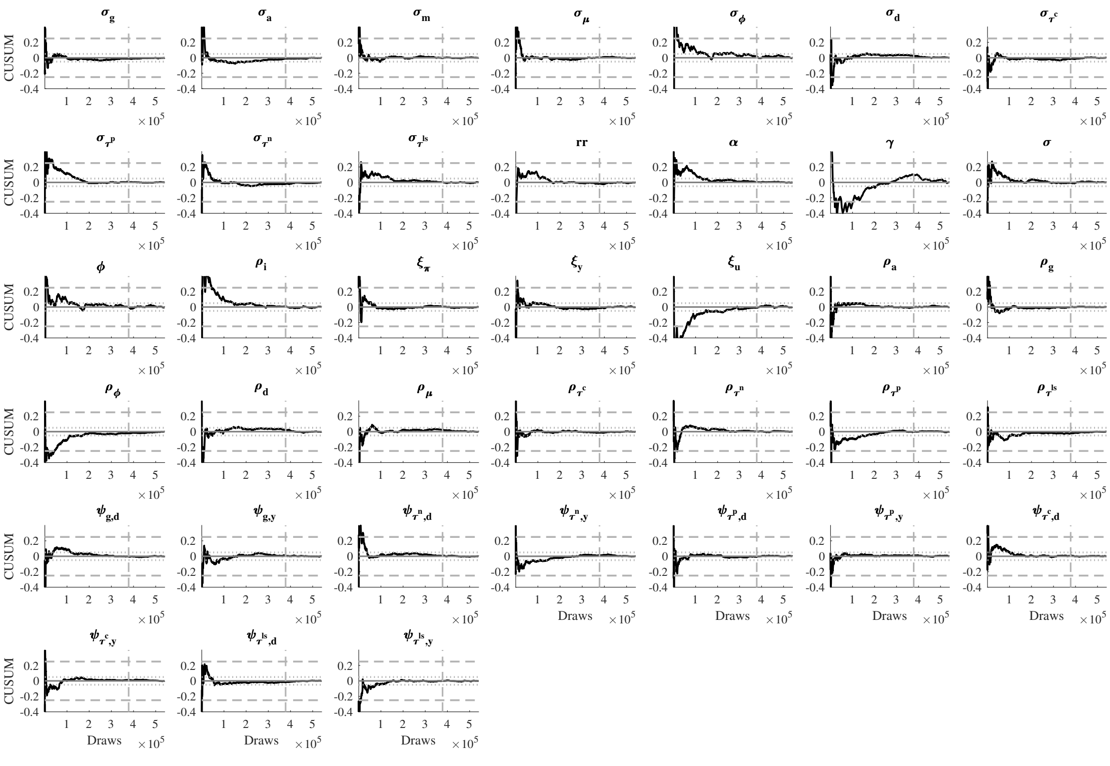

Figure 18: CUSUM charts for model estimation with complementarity in preferences. The horizontal lines indicate 5 and 25 percent bands. The vertical line indicates the burn-in of the Markov chain.

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