Fiscal News and Macroeconomic Volatility*

Benjamin Born Alexandra Peter Johannes Pfeifer

March 29, 2013

Abstract

This paper analyzes the contribution of anticipated capital and labor tax shocks to business cycle volatility in an estimated New Keynesian business cycle model. While fiscal policy accounts for about 15 percent of output variance at business cycle frequencies, this mostly derives from anticipated government spending shocks. Tax shocks, both anticipated and unanticipated, contribute little to the fluctuations of real variables. However, anticipated capital tax shocks do explain a sizable part of inflation fluctuations, accounting for up to 12 percent of its variance. In line with earlier studies, news shocks in total account for about 50 percent of output variance. Further decomposing this news effect, we find permanent total factor productivity news shocks to be most important. When looking at the federal level instead of total government, the importance of anticipated tax and spending shocks significantly increases, suggesting that fiscal policy at the subnational level typically counteracts the effects of federal fiscal policy shocks.

JEL-Classification: E32, E62, C11

Keywords: Anticipated Tax Shocks; Sources of Aggregate Fluctuations; Bayesian Estimation.

*Born: University of Mannheim, E-mail: born@uni-mannheim.de, Peter: International Monetary Fund, E-mail: apeter@imf.org, Pfeifer: University of Tübingen, E-mail: johannes.pfeifer@uni-tuebingen.de. We would like to thank Martin Flodén (the editor), two anonymous referees, Zeno Enders, Patrick Hürtgen, Gernot Müller, Jörn Tenhofen, Arnoud Stevens, Todd Walker, and seminar audiences in Bonn and Dortmund, as well as participants at the Doctoral Workshop on Dynamic Macroeconomics 2010, the 2nd Conference on Recent Developments in Macroeconomics, the 2010 Cologne Workshop on Macroeconomics, the 2010 Annual Meeting of the Verein für Socialpolitik, the 2012 SEEK/CEPR Workshop on News, Sentiment, and Confidence in Fluctuations, and the Spring Meeting of Young Economists 2012 for helpful comments and discussions. We are grateful to Martín Uribe for providing us with the relative price of investment data. All remaining errors are our own. The views of this paper are those of the authors and do not necessarily represent those of the IMF or IMF policy.

1 Introduction

The current paper analyzes the role of news about future fiscal policy ("fiscal news"), and in particular the anticipation of tax rate changes, for business cycle fluctuations. Recent macroeconomic research has increasingly shifted from explaining business cycle fluctuations through contemporaneous shocks to explaining them by anticipated, or news, shocks. Rational agents, anticipating future changes will already react today to these news (see, e.g., Beaudry and Portier, 2004, 2006; Jaimovich and Rebelo, 2009; Schmitt-Grohé and Uribe, 2012). However, most empirical studies on the effects of anticipated shocks on business cycles have focused on news about future productivity (see, e.g., Forni et al., 2011; Fujiwara et al., 2011; Khan and Tsoukalas, 2012).[1]

This is remarkable for two reasons. First, fiscal measures are usually publicly debated well in advance and often known before becoming effective, i.e., there are considerable decision and implementation lags. A tax bill typically takes about one year from the U.S. President's initial proposal to the law's enactment and another year until the tax change becomes effective (Mertens and Ravn, 2011; Yang, 2005). As a recent example, consider the *Patient Protection and Affordable Care Act* ("Obamacare"), whose core contents were debated for almost one year and whose financing provisions will only phase in gradually over time. Second, surprise fiscal policy shocks have long been discussed as a potential prominent driver of the business cycle (see e.g. Baxter and King, 1993; Cardia et al., 2003; Jones, 2002; McGrattan, 1994). McGrattan (1994) for example attributes one third of the U.S. business cycle variance to distortionary taxation, while McGrattan (2012) argues that changes in business taxation can explain one third of the output drop during the Great Depression.[2] This potential importance of fiscal policy shocks, combined with the fact that many fiscal policy measures are known well in advance, makes fiscal news a natural candidate for explaining aggregate fluctuations.

We add upon the previous literature by explicitly analyzing the business cycle variance contribution of fiscal news. For this purpose, we employ a New Keynesian Dynamic Stochastic General Equilibrium (DSGE) business cycle model featuring several real and nominal rigidities as well as various shocks identified as important drivers of the business cycle. We augment the model with a government sector featuring distortionary labor and capital taxes that follow fiscal rules with endogenous feedback to debt and current economic conditions. Our main focus lies on the effects of fiscal news, but we also control for anticipation in total factor productivity (TFP), investment-specific productivity, and the wage markup. The

[1]There is a prominent literature branch dealing with the importance of fiscal foresight. However, its focus has mostly been on analyzing single tax events (House and Shapiro, 2006; Parker, 1999; Poterba, 1988) or tracing out the consequences for econometric analyses (Leeper et al., forthcoming; Yang, 2005).

[2]Although Forni et al. (2009) find that unanticipated tax shocks contribute little to macroeconomic fluctuations of the Euro area, this could in principle be the result of ignoring fiscal foresight.

model is estimated by full information (Bayesian) methods using quarterly U.S. data from 1955 to 2006. Model-based estimation allows us to circumvent the issue of non-invertibility that can arise when estimating structural vector autoregressions (VARs) in the presence of anticipation effects (Fernández-Villaverde et al., 2007; Hansen and Sargent, 1991; Leeper et al., forthcoming).[3]

Computing forecast error variance decompositions, we find that for the U.S. total government fiscal foresight plays only a moderate role in explaining business cycles. With an unconditional variance share of 13 percent anticipated government spending shocks are the fiscal variable with the largest effect on output variance. In contrast, contemporaneous and anticipated labor and capital tax shocks are not important drivers of business cycles, together contributing only 2 percent to output fluctuations. Tax shocks, and particularly anticipated tax shocks, are only relevant for explaining the variance of inflation. Depending on the forecast horizon, anticipated capital tax shocks contribute 8 to 12 percent to its variance. Surprise capital tax shocks are responsible for another 4 percent. In contrast, the effects of labor tax shocks are negligible. Overall, these results are in line with the VAR evidence of Forni and Gambetti (2010) that 16 percent of output fluctuations are due to anticipated government spending shocks and the finding of Forni et al. (2009) for the EU that unanticipated tax shocks are a negligible factor for explaining business cycles. Also in line with previous studies considering either only surprise shocks (e.g. Smets and Wouters, 2007) or also news shocks (e.g. Schmitt-Grohé and Uribe, 2012), we find that technology shocks are an important driver of output fluctuations.

In our estimated model news shocks explain about 50 percent of the variance of output, with the main effect coming from news about TFP. This result conforms well with VAR evidence by Barsky and Sims (2011) and Kurmann and Otrok (forthcoming), who both find a similar fraction of output fluctuations explained by anticipated shocks.

The two papers most closely related to ours are recent contributions by Mertens and Ravn (2012) and Schmitt-Grohé and Uribe (2012). Mertens and Ravn (2012) use a VAR to analyze the business cycle contribution of narratively identified anticipated and unanticipated tax shocks.[4] They find that both types of tax shocks together explain 20 to 25 percent of output

[3]Non-invertibility means that the DGSE-model has a VARMA representation that cannot be inverted to yield a finite-order VAR in the observables. Hence, the true innovations do not perfectly map into the VAR residuals. Non-invertibility arises, e.g., when the information set of an econometrician is smaller than that of the forward-looking agents. It is important to note that this does not mean that VARs cannot be used to estimate news shocks at all. Sims (2012), for example, shows that in some cases it may be possible to recover the shocks using a structural VAR. By including enough lags and forward-looking variables, it may be possible to move the non-invertible root(s) close enough to unity so that the discrepancy between true structural errors and the estimated ones becomes small (see also Forni et al., 2011; Gambetti, 2012; Giannone and Reichlin, 2006).

[4]Mertens and Ravn (2012) classify the Romer and Romer (2010) tax shocks according to the time passed

variance, with anticipation accounting for the majority. The difference in our findings to Mertens and Ravn (2012) can be explained by the fact that their study focuses on legislated federal fiscal measures. When we estimate our baseline model on federal government data only, we find that fiscal foresight accounts for 37 percent of the unconditional output variance, with anticipated tax shocks being responsible for 15 percent. Moreover, Mertens and Ravn (2012) find that an anticipated tax cut generates a recession during the anticipation phase before the realization of the tax cut. Our baseline model estimated with total government data does not generate such an anticipatory recession, while the model estimated on federal government does. Those differences in results for using total vs. federal government data suggests that reactions at the subnational levels of government tend to counteract federal fiscal measures. Thus, considering the entire fiscal sector instead of the federal government only delivers a more representative picture of the average response to a fiscal shock as it does not rely on keeping the expenditures and revenues at the subnational level constant - something that seems not to happen in practice.

Schmitt-Grohé and Uribe (2012) evaluate the role of news about TFP, investment-specific technology, wage markup, and government spending shocks in an estimated RBC model with various real rigidities. In their setup, news shocks account for 41 percent of output fluctuations. But while they find government spending shocks to explain 10 percent of output variance, evenly distributed across surprise, one and two year anticipated shocks, they do not consider foresight about the financing side of the government budget constraint and do not allow for fiscal rules that contain endogenous feedback.

Our paper is also related to other DSGE-based papers focusing on the effects of anticipated technology shocks. Davis (2007), using a New Keynesian model, estimates news shocks to be responsible for 50 percent of output fluctuations. Fujiwara et al. (2011) extend the New Keynesian models of Smets and Wouters (2007) and Christiano et al. (2005) to include news about TFP. They estimate news shocks to explain 9 percent of the unconditional output variance. The paper of Khan and Tsoukalas (2012) uses the same basic New Keynesian model framework, but additionally allows for news about investment-specific technology growth. In their estimated model, both types of news shocks together account for less than 10 percent.

The outline of the paper is the following. Chapter 2 introduces the DSGE model with fiscal foresight, while chapter 3 presents the estimation approach and results. In chapter 4, we compute variance decompositions and impulse responses and consider the distinction between total and federal government. Chapter 5 concludes.

between the presidential signing of a bill and the tax changes becoming effective into anticipated and contemporaneous shocks.

2 A DSGE Model with Fiscal Foresight

We use a medium-scale DSGE model featuring various real and nominal frictions as well as a variety of shocks that have been identified as important drivers of the business cycle (see, e.g., Justiniano et al., 2010a; Smets and Wouters, 2007). We incorporate both contemporaneous and anticipated elements into the shock processes as in Schmitt-Grohé and Uribe (2012) and allow for non-stationary shocks. We first discuss the information structure of the shock processes in the next subsection before describing the model in detail.

2.1 Shock Structure

Our model features 10 sources of stochastic fluctuations. On the government side, we include shocks to labor and capital tax rates τ_t^n and τ_t^k, a shock to government spending g_t, and a monetary policy shock ξ_t^R. The technology shocks considered are shocks to stationary neutral productivity z_t, non-stationary productivity X_t, stationary investment-specific productivity z_t^I, and non-stationary investment-specific productivity A_t. In addition, the model includes a preference shock ξ_t^{pref} and a wage markup shock μ_t^w.

The monetary policy shock and the preference shock are assumed to only contain a contemporaneous, unanticipated component. For the other shocks, we follow the framework proposed by Schmitt-Grohé and Uribe (2012) and allow for both contemporaneous shocks and shocks that are anticipated 4 and 8 periods in advance. Anticipation horizons of 4 and 8 quarters fulfill the aim of capturing longer anticipation horizons while keeping the state space at a manageable level. This is crucial as each additional anticipation horizon is an additional state variable. While specifically choosing 4 and 8 quarters of anticipation might be seen as arbitrary, this assumption can be rationalized by the workings of the political system. Four quarters of anticipation are close to the average length of a tax bill from the President's proposal announcement to enactment (Yang, 2005). Eight quarters serves as a plausible upper bound for the anticipation of shocks to tax rates as Congressional elections take place every two years. We think this makes it very unlikely that people are able to correctly predict both the reigning majority and the tax laws being implemented by the next Congress. The same, of course, applies to spending bills. For reasons of symmetry, we then assume this anticipation structure for all shock processes, except for preferences and monetary policy, where a structural interpretation of anticipated shocks would be tenuous.

The general structure for shock $\epsilon^i,\ i \in \{\tau n, \tau k, g, z, x, zI, a, w\}$ is given by

$$\epsilon^i = \varepsilon_{i,t}^0 + \varepsilon_{i,t-4}^4 + \varepsilon_{i,t-8}^8 \ , \tag{1}$$

where $\varepsilon^j_{i,t-j},\ j \in \{0,4,8\}$ denotes a shock to variable i that becomes known in period $t-j$ and hits the economy j periods later. For example, $\varepsilon^4_{\tau n,t-4}$ denotes a four period anticipated shock to the labor tax rate that becomes known at time $t-4$ and becomes effective at time t. The shocks are assumed to have mean 0, standard deviation σ^j_i, to be serially uncorrelated, and to be uncorrelated across anticipation horizons, i.e. $E(\varepsilon^j_{i,t-j}) = 0$ and $E(\varepsilon^k_{i,t}\varepsilon^l_{i,t-j}) = (\sigma^k_i)^2$ for $j = 0,\ k = l$, and 0 otherwise. Moreover, they are uncorrelated across shock types $i_m, i_n \in i$, $E(\varepsilon^k_{i_m,t}\varepsilon^l_{i_n,t-j}) = 0\ \forall j,k,l$ and $i_m \neq i_n$. The only exception is that we allow for contemporaneous correlation between the labor and capital tax rate shocks at all anticipation horizons, i.e. $E(\varepsilon^j_{\tau k,t-j}\varepsilon^j_{\tau n,t-j}) = \sigma^j_{\tau k,\tau n}$. This assumption is due to the fact that in the construction of tax rates one part of proprietor's income is attributed to capital taxation and the other part is attributed to labor taxation. Moreover, many tax measures affect both the capital and the labor margin.

The assumed information structure implies that agents foresee future shocks to the extent of already known but not yet realized shocks $\varepsilon^m_{i,t-j},\ m > j$. The forward-looking behavior of rational optimizing agents leads them to react to anticipated shocks even before they are realized. By imposing a structural model on the data, this anticipatory behavior enables the econometrician to achieve identification.

2.2 Conceptualizing Tax Shocks

The tax shocks considered in the present work do not necessarily stem from actual changes in the labor and capital tax rates. Rather, they are interpreted as the probability weighted effect of tax actions under legislative debate or due to judicative decisions. They are the product of the likelihood of a tax change and of the size of this effect, as perceived by rational agents forming expectations about the future path of taxes. Hence, our definition is wider than the one considered by Mertens and Ravn (2012), who restrict their attention to the shocks directly deriving from the legislative process. Shocks deriving, e.g., from the SEC suing against the legality of a tax shelter would be excluded from their definition but not from ours.[5] Note that news shocks are distinct from pure uncertainty about future taxes. While the former are associated with an anticipated change in the mean of the tax rate, tax uncertainty shocks can be conceptualized as mean-preserving spreads.[6]

To fix ideas, consider the *Patient Protection and Affordable Care Act* of 2010 as an example. On June 9, 2009, a first draft of the health care bill was released. Latest at that time, people could anticipate that taxes were going to rise in order to finance the bill, if it ever

[5]This notion of tax shocks is consistent with the concept of "policy expectations" in McGrattan (2012).

[6]For an analysis of uncertainty about fiscal policy in the context of a business cycle model, see Born and Pfeifer (2011); Fernández-Villaverde et al. (2011).

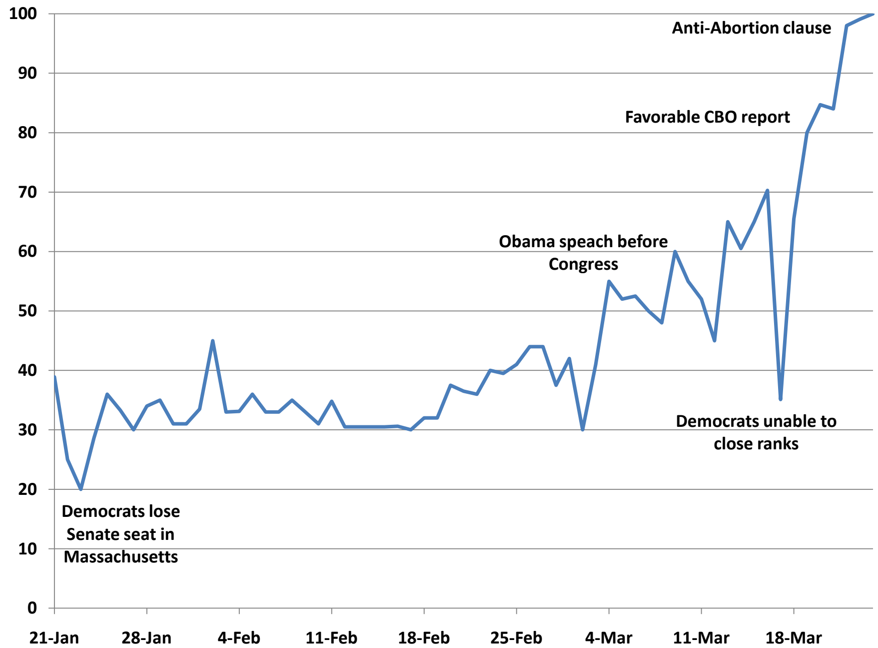

Figure 1: Intrade Daily Closing Prices:“Will ’Obamacare’ health care reform become law in the United States?”
Note: This contract will settle (expire) at 100 ($100.00), if a health care reform bill is passed into law before midnight ET 30 Jun 2010. It will settle (expire) at 0 ($0.00), if a health care reform bill is not passed into law. *Source:* intrade$^{\text{TM}}$(`http://www.intrade.com/`)

passed. However, both the size and the likelihood of such a change was largely unknown. The first point of uncertainty changed on July 13, 2009, when the Congressional Budget Office published official cost estimates: If passed, marginal income tax rates were going to increase by 22 percentage points for households between 100 percent and 400 percent of the poverty level. Taking these costs as given, households were experiencing tax shocks with changes in the likelihood of the passage of the bill. Intrade bets on the passage of the bill show that some people were constantly re-evaluating this likelihood. Figure 1 presents the closing prices of an Intrade betting contract that paid 100, if a health care reform bill was passed into law before mid-2010 and 0 if it was not passed. Hence, the closing price is a direct measure of the likelihood of a bill becoming law. There is a large variance in the probability of passing the bill that varies with the ebb and flow of the political process. These changes potentially act like a huge sequence of tax shocks for households. If one considers only the change in the likelihood from the time directly after the Massachusetts Senate election in January 2010 to the final vote of the bill, this amounts in expectations to a tax shock of $0.7 \times 22\% = 15.4\%$ during one quarter.[7]

[7]Unfortunately, due to the non-availability of data for the relative price of investment, our sample does not cover this series of events.

2.3 The Model

The model economy includes five sectors: the household sector with a large representative household, the labor market featuring a continuum of monopolistically competitive unions selling differentiated labor services to intermediate firms, the firm sector including a continuum of intermediate goods firms producing intermediate goods and a final good firm bundling the intermediate goods, and the government sector responsible for fiscal and monetary policy.

2.3.1 Household Sector

The economy is populated by a large representative household with a continuum of members. Household preferences are defined over per capita consumption C_t and per capita labor effort L_t, where each member consumes the same amount and works the same number of hours.[8] We follow Schmitt-Grohé and Uribe (2006) and assume that household members supply their labor uniformly to a continuum of unions $j \in [0,1]$. The unions are monopolistically competitive and supply differentiated labor services $L_t(j)$ to intermediate goods firms. Overall, total labor supply of the representative household is given by the integral over all labor markets j, i.e. $L_t = \int_0^1 L_t(j)dj$. We will discuss the labor market structure in detail below.

Following Jaimovich and Rebelo (2009), we assume a preference specification that allows to control the size of the wealth effect, but we additionally assume habits in consumption:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \xi_t^{pref} \frac{\left(C_t - \phi_c C_{t-1} - \gamma \frac{L_t^{1+\sigma_l}}{1+\sigma_l} S_t \right)^{1-\sigma_c} - 1}{1-\sigma_c} \, . \tag{2}$$

Here, the parameter $\phi_c \in [0,1]$ measures the degree of internal habit persistence, $\sigma_c \geq 0$ governs the intertemporal elasticity of substitution, $\sigma_l \geq 0$ is related to the Frisch elasticity of labor supply, and $\gamma \geq 0$ measures the relative disutility of labor effort.[9] The term

$$S_t = (C_t - \phi_c C_{t-1})^{\sigma_s} S_{t-1}^{1-\sigma_s} \tag{3}$$

makes the preferences non-separable in both consumption and work effort. This preference specification introduces the parameter $\sigma_s \in (0,1]$ that allows to govern the magnitude of the wealth effect on the labor supply. As special cases, the specification nests the preference class discussed by King et al. (1988), i.e. $\sigma_s = 1$, and the preferences proposed by Greenwood et al.

[8]Due to the symmetric equilibrium, the decisions of the household members are identical. Hence, we suppress the subscript denoting individual members.

[9]In a recent paper, Nutahara (2010) shows that it is important to distinguish between internal and external habits in a model with news shocks. He finds that internal habits are able to generate news-driven business cycles, whereas external habits are not.

(1988), i.e. $\sigma_s = 0$, where the latter case implies a zero wealth elasticity of labor supply. We assume the preference shock ξ_t^{pref} to follow an $AR(1)$-process in logs:

$$\log \xi_t^{pref} = \rho_{pref} \log \xi_{t-1}^{pref} + \varepsilon_t^{pref} \ . \tag{4}$$

The household faces the budget constraint

$$\begin{aligned} C_t + z_t^I A_t I_t + \frac{B_{t+1}}{P_t} = (1-\tau_t^n) \int_0^1 W_t(j) L_t(j) dj + \left(1-\tau_t^k\right) R_t^K u_t K_t + \Phi_t + T \\ + \left(1-\tau_t^k\right) \Xi_t + \left(1-\tau_t^k\right) (R_{t-1}-1) \frac{B_t}{P_t} + \frac{B_t}{P_t} \ . \end{aligned} \tag{5}$$

Besides labor income from supplying differentiated labor services $L_t(j)$ at the real wage $W_t(j)$, the household has capital income from renting out capital services $u_t K_t$ at the rental rate R_t^K, from receiving firm profits Ξ_t, and from investing in bonds B_{t+1}, which are in zero net supply. Both forms of income are taxed at their respective tax rates τ_t^n and τ_t^k. Only net returns of bonds are taxed, such that the term $\left(1-\tau_t^k\right)(R_{t-1}-1)\frac{B_t}{P_t} + \frac{B_t}{P_t}$ is the after-tax return. In addition, the households receive a fixed amount of lump sum transfers/pay a fixed amount of lump sum taxes T.[10]

The household spends its income on consumption C_t and investment $z_t^I A_t I_t$, where I_t denotes gross investment at the price of capital goods. We assume that the relative price of investment in terms of the consumption good is subject to two shocks, a stationary investment-specific productivity shock z_t^I and non-stationary investment-specific technological progress A_t (see Greenwood et al., 1997, 2000). The relative price of investment is equal to the technical rate of transformation between investment and consumption goods. Changes in this price do not affect the productivity of already installed capital, but do affect newly installed capital and become embodied in it. For the non-stationary investment-specific technology process, we assume a random walk with drift in its logarithm

$$\log A_t = \log A_{t-1} + \log \mu_t^a \ . \tag{6}$$

The drift term μ_t^a is subject to contemporaneous and anticipated shocks according to

$$\log\left(\frac{\mu_t^a}{\mu^a}\right) = \rho_a \log\left(\frac{\mu_{t-1}^a}{\mu^a}\right) + \varepsilon_{a,t}^0 + \varepsilon_{a,t-4}^4 + \varepsilon_{a,t-8}^8 \ . \tag{7}$$

[10]We calibrate the model to replicate the average debt to GDP ratio and the average tax rates on labor and capital income. The lump sum transfers T are then set to balance the budget in steady state. Government solvency is assured at any point in time by feedback from debt to tax rates and spending.

The stationary investment-specific technology shock z_t^I follows an $AR(1)$-process

$$\log z_t^I = \rho_{zI} \log z_{t-1}^I + \varepsilon_{zI,t}^0 + \varepsilon_{zI,t-4}^4 + \varepsilon_{zI,t-8}^8 \ . \tag{8}$$

Depreciation allowances are an important feature of the U.S. tax code, therefore, we also include them in our model. They are captured by the term Φ_t in equation (5) and have the form $\Phi_t = \tau_t^k \sum_{s=1}^{\infty} \delta_\tau (1-\delta_\tau)^{s-1} z_{t-s}^I A_{t-s} I_{t-s}$, where δ_τ is the depreciation rate for tax purposes.[11] Since depreciation allowances provide new investment with a tax shield at historical costs, they may be important in capturing the dynamics of investment following shocks (Christiano et al., 2011; Yang, 2005).

The household members own the capital stock K_t, whose law of motion is given by

$$K_{t+1} = \left[1 - \left(\delta_0 + \delta_1 (u_t - 1) + \frac{\delta_2}{2}(u_t - 1)^2\right)\right] K_t + \left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - \mu^I\right)^2\right] I_t \ . \tag{9}$$

Household members do not simply rent out capital, but capital services $u_t K_t$, where u_t denotes capital utilization. Thus, they decide about the intensity with which the existing capital stock is used. However, using capital with an intensity that is higher than normal is not costless, but leads to higher depreciation of the capital stock. This is captured by the increasing and convex function $\delta(u_t) = \delta_0 + \delta_1 (u_t - 1) + \delta_2/2 (u_t - 1)^2$, with $\delta_0, \delta_1, \delta_2 > 0$. Without loss of generality, capital utilization in steady state is normalized to 1. Following Christiano et al. (2005), we assume the presence of investment adjustment costs $S(I_t/I_{t-1}) = \kappa/2 \left(I_t/I_{t-1} - \mu^I\right)^2$ to dampen the volatility of investment over the business cycle. $\kappa > 0$ is a parameter governing the curvature of the investment adjustment costs and μ^I is the steady state growth rate of investment, which is equal to the steady state growth rate of capital. This specification assures that the investment adjustment costs are minimized and equal to 0 along the balanced growth path, i.e. $S = S' = 0$ and $S'' > 0$, where the primes denote derivatives.

The household maximizes its utility, equation (2), by choosing $C_t,\ L_t,\ S_t,\ B_{t+1},\ K_{t+1},\ u_t$, and I_t, subject to the budget constraint (5), the law of motion for capital (9), and the resource constraint for aggregate labor given by (10) below.

2.3.2 Labor Market

The labor market is characterized by differentiated labor services and staggered wage setting. To model these features without letting idiosyncratic wage risk affect the household members, and thus making aggregation intractable, we assume a continuum of unions $j,\ j \in [0,1]$. The

[11] Following Auerbach (1989), we allow the depreciation rate for tax purposes to differ from the physical depreciation rate.

household members supply their labor $L_t(j)$ equally to the unions, which are monopolistically competitive and supply differentiated labor $L_t(j)$ to intermediate firms at wage $W_t(j)$. Every period, a union j is able to re-optimize its wage with probability $(1-\theta_w)$, $0<\theta_w<1$. A union j that is not able to re-optimize indexes its nominal wage to the price level according to $W_t(j)\,P_t = (\Pi_{t-1})^{\chi_w}\Pi^{1-\chi_w}\mu_t^y W_{t-1}(j)\,P_{t-1}$, where the parameter $\chi_w \in [0,1]$ measures the degree of indexing, Π is steady state gross inflation, and μ_t^y is the gross growth rate of output (see ,e.g., Smets and Wouters, 2003). Thus, in the absence of price adjustment the wage still partly adapts to changes in productivity and inflation (Christiano et al., 2008), thereby assuring that no current wage contract will deviate arbitrarily far from the current optimal wage.

Household members supply the amount of labor services that is demanded at the current wage. Unions that can reset their wages choose the real wage that maximizes the expected utility of its members, taking into account the demand for its labor services $L_t(j) = (W_t(j)/W_t)^{-\eta_{w,t}}\,L_t^{comp}$, where L_t^{comp} is the aggregate demand for composite labor services, the respective resource constraint

$$L_t = L_t^{comp}\int_0^1 \left(\frac{W_t(j)}{W_t}\right)^{-\eta_{w,t}} dj \ , \tag{10}$$

and the aggregate wage level $W_t = \left(\int_0^1 W_t(j)^{1-\eta_{w,t}}\, dj\right)^{\frac{1}{1-\eta_{w,t}}}$. The time-varying substitution elasticity $\eta_{w,t}$ allows us to include a wage markup shock $\mu_t^w = (\eta_{w,t}-1)^{-1}$ that follows

$$\log\left(\frac{\mu_t^w}{\mu^w}\right) = \rho_w \log\left(\frac{\mu_{t-1}^w}{\mu^w}\right) + \varepsilon_{w,t}^0 + \varepsilon_{w,t-4}^4 + \varepsilon_{w,t-8}^8 \ . \tag{11}$$

Including a wage markup shock is motivated by the finding that this shock is important for explaining output fluctuations (see, e.g., Schmitt-Grohé and Uribe, 2012; Smets and Wouters, 2007).

2.3.3 Firm Sector

A continuum of monopolistically competitive intermediate goods firms i, $i \in [0,1]$, produces differentiated intermediate goods Y_{it} via a Cobb-Douglas production function, using capital services $u_{it}K_{it}$ and a composite labor bundle L_{it}^{comp}

$$Y_{it} = z_t\,(u_{it}K_{it})^{\alpha}\,(X_t L_{it}^{comp})^{1-\alpha} - \psi X_t^Y \ , \tag{12}$$

where α is the capital share, z_t is a stationary TFP shock, X_t is a non-stationary labor augmenting productivity process, and X_t^Y is the trend of output defined in Appendix B. The fixed cost of production ψ is set such that profits are 0 in steady state and there is no entry or exit (Christiano et al., 2005). The composite labor bundle is aggregated from differentiated labor inputs $L_{it}(j)$ with the Dixit-Stiglitz aggregator $L_{it}^{comp} = [\int_0^1 L_{it}(j)^{\frac{\eta_{w,t}-1}{\eta_{w,t}}} dj]^{\frac{\eta_{w,t}}{\eta_{w,t}-1}}$.

For the non-stationary labor augmenting productivity process X_t, we assume a random walk with drift in its logarithm

$$\log X_t = \log X_{t-1} + \log \mu_t^x. \tag{13}$$

The drift term μ_t^x is subject to contemporaneous and anticipated shocks according to

$$\log\left(\frac{\mu_t^x}{\mu^x}\right) = \rho_x \log\left(\frac{\mu_{t-1}^x}{\mu^x}\right) + \varepsilon_{x,t}^0 + \varepsilon_{x,t-4}^4 + \varepsilon_{x,t-8}^8. \tag{14}$$

Hence, in the deterministic steady state, the natural logarithm of the non-stationary component of the neutral technology shock grows with rate μ^x. The stationary technology shock z_t follows an $AR(1)$-process with persistence ρ_z

$$\log z_t = \rho_z \log z_{t-1} + \varepsilon_{z,t}^0 + \varepsilon_{z,t-4}^4 + \varepsilon_{z,t-8}^8. \tag{15}$$

We assume staggered price setting a la Calvo (1983) and Yun (1996). Each period, an intermediate goods firm i can re-optimize its price with probability $(1-\theta_p)$, $0 < \theta_p < 1$. If a firm i cannot re-optimize the price, its price is indexed to inflation $\Pi_t = \frac{P_t}{P_{t-1}}$ according to $P_{it+1} = (\Pi_t)^{\chi_p} (\Pi)^{1-\chi_p} P_{it}$, where $\chi_p \in [0,1]$ governs the degree of indexation. The intermediate goods firms maximize their discounted stream of profits subject to the demand from the final good producer, equation (17) below, applying the discount factor of their owners, the household members.

The intermediate goods are bundled by a competitive final good firm to a final good Y_t using a Dixit-Stiglitz aggregation technology with substitution elasticity η_p

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\eta_p-1}{\eta_p}} di\right)^{\frac{\eta_p}{\eta_p-1}}. \tag{16}$$

Expenditure minimization yields the optimal demand for intermediate good i as

$$Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta_p} Y_t \quad \forall\, i\ . \tag{17}$$

2.3.4 Government Sector

Government expenditures are financed by taxing profits and the returns to capital services at the rate τ_t^k and labor income at the rate τ_t^n. Following Leeper et al. (2010), we allow for endogeneity in the tax rules. Specifically, both labor and capital tax rates respond to lagged government debt to ensure fiscal solvency. In addition, following Kliem and Kriwoluzky (2012), we allow for an automatic stabilizing role of tax rates by having the labor tax rate respond contemporaneously to hours worked and the capital tax rate respond contemporaneously to investment:

$$\begin{aligned}\tau_t^n =& \left(1-\rho_{\tau n}\right)\tau^n + \rho_{\tau n}\tau_{t-1}^n + \phi_{nD}\log\left(\frac{B_t}{P_t}/\frac{B}{P}\right) + \phi_{nl}\log\left(L_t/L\right) \\ &+ \varepsilon_{\tau n,t}^0 + \varepsilon_{\tau n,t-4}^4 + \varepsilon_{\tau n,t-8}^8 \qquad (18)\\ \tau_t^k =& \left(1-\rho_{\tau k}\right)\tau^k + \rho_{\tau k}\tau_{t-1}^k + \phi_{kD}\log\left(\frac{B_t}{P_t}/\frac{B}{P}\right) + \phi_{kI}\log\left(z_t^I I_t/I\right) \\ &+ \varepsilon_{\tau k,t}^0 + \varepsilon_{\tau k,t-4}^4 + \varepsilon_{\tau k,t-8}^8\ , \qquad (19)\end{aligned}$$

where τ_t^n and τ_t^k are average tax rates, $\tau^k, \tau^n \in [0,1)$ are parameters determining the unconditional mean, $\rho_{\tau n}, \rho_{\tau k} \in [0,1)$ are the autoregressive parameters, and the ϕ's are the feedback semi-elasticities. Using average effective tax rates for capital and labor income may be problematic for several reasons. First, the U.S. tax code does not allow for a clean division between labor and capital taxation, which are theoretical constructs.[12] Second, using average effective tax rates may be particularly problematic for progressive labor income taxes, where marginal tax rates rather than effective tax rates influence peoples' behavior. Nevertheless, for comparability with the existing literature, we follow the path set forward by Mendoza et al. (1994), Jones (2002), and Leeper et al. (2010) and construct average effective tax rates for capital and labor income.[13] While this is clearly a simplifying assumption, it can be justified on grounds that dynamics of marginal and average tax rates are very similar (Mendoza et al., 1994).

In contrast to the other shocks in our model, the tax shocks $\varepsilon_{\tau j,t-i}^i, i \in \{0,4,8\}, j \in \{k,n\}$ are not assumed to be *i.i.d.* Instead, due to the problem of attributing proprietor's income to

[12] For example, the personal income tax applies to both sources of income.

[13] A referee pointed out to us that one could employ a mixed frequency Bayesian approach to estimate our quarterly model using the *annual* Barro and Sahasakul (1983) average marginal tax rates as extended by Barro and Redlick (2011). We still opt for using effective tax rates for the following reasons: i) It eases comparison to other studies, ii) the Barro and Sahasakul (1983) marginal tax rates focus on labor tax rates, making it hard to estimate a consistent measure of correlation between labor and capital tax rates, and iii) there is not much prior evidence on estimating fiscal feedback rules using mixed frequency data, while the evidence for quarterly effective tax rates (Kliem and Kriwoluzky, 2012) suggests that these rules can be consistently estimated and the parameters identified.

capital and labor taxation and due to the fact that many tax measures affect both capital and labor margins, we allow for correlation of the tax shocks to labor and capital at the individual time horizons, while keeping the assumption of no correlation across horizons.

Government spending G_t, which may be thought of as entering the utility function additively separable, displays a stochastic trend X_t^G and is assumed to respond to lagged government debt (ϕ_{gD}). Log deviations of government spending from its trend are then given by

$$\log\left(\frac{g_t}{g}\right) = \rho_g \log\left(\frac{g_{t-1}}{g}\right) + \phi_{gD}\log\left(\frac{B_t}{P_t}/\frac{B}{P}\right) + \epsilon^0_{g,t} + \epsilon^4_{g,t-4} + \epsilon^8_{g,t-8}\ , \tag{20}$$

where $g_t = \frac{G_t}{X_t^G}$ denotes detrended government spending and ρ_g is the persistence parameter.

The stochastic trend in G_t is assumed to be cointegrated with the trend in output. This assures that the output share of government spending G_t/Y_t is stationary, while at the same time allowing the trend in G_t to be smoother than the one in Y_t. The degree of smoothness is governed by the parameter ρ_{xg}. In particular,

$$X_t^G = \left(X_{t-1}^G\right)^{\rho_{xg}}\left(X_{t-1}^Y\right)^{1-\rho_{xg}}\ . \tag{21}$$

The structure for our fiscal policy processes implies that the same autocorrelation coefficients govern the endogenous responses of anticipated and surprise shocks. However, by allowing for an endogenous response of tax rates and government spending to debt and business cycle conditions, fiscal foresight can in principle affect the policy variable gradually through its effect on the rest of the system and thus in a different way than the surprise shock does.

Lump sum transfers T are set to balance the budget in steady state, given $B/P, \tau^n$, and τ^k. Thus, the government budget constraint is given by

$$G_t + T + \Phi_t + R_{t-1}\frac{B_t}{P_t} = \tau_t^n W_t L_t^{comp} + \tau_t^k\left(R_t^K u_t K_t + \Xi_t + (R_{t-1}-1)\frac{B_t}{P_t}\right) + \frac{B_{t+1}}{P_t}\ . \tag{22}$$

We close the model by assuming that the central bank follows a Taylor rule that reacts to inflation and output growth:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left(\left(\frac{\Pi_t}{\Pi}\right)^{\phi_{R_\Pi}}\left(\frac{Y_t}{Y_{t-1}}\frac{1}{\mu^y}\right)^{\phi_{R_Y}}\right)^{1-\rho_R}\exp\left(\xi_t^R\right), \tag{23}$$

where ρ_R is a smoothing parameter introduced to capture the empirical evidence of gradual movements in interest rates (see, e.g., Clarida et al., 2000). The parameters ϕ_{R_Y} and ϕ_{R_Π} capture the responsiveness of the nominal interest rate to deviations of inflation and of output growth from their steady state values. We assume that the central bank responds to changes

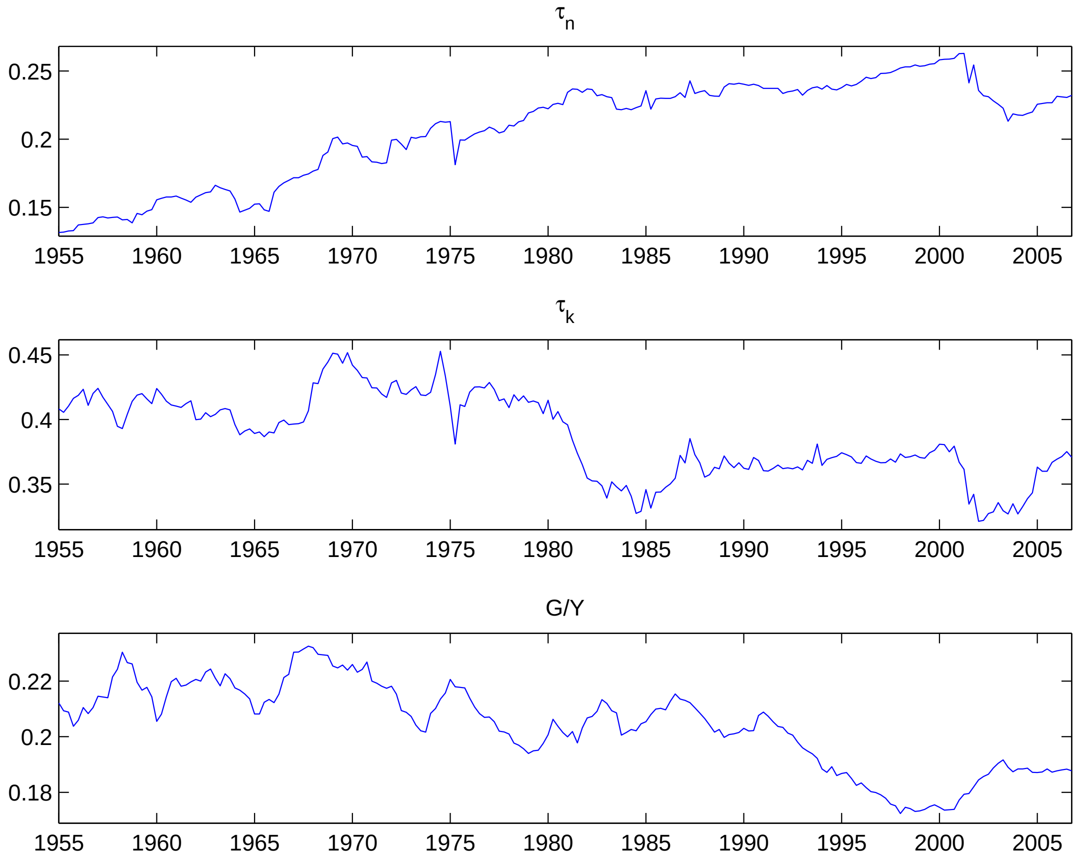

Figure 2: Evolution of the tax rates and the government spending to GDP ratio.

in output rather than its level. This conforms better with empirical evidence and avoids the need to define a measure of trend growth that the central bank can observe (see Lubik and Schorfheide, 2007). ξ_t^R is the *i.i.d.* monetary policy shock.

3 Model Estimation

We use a Bayesian approach as described in An and Schorfheide (2007) and Fernández-Villaverde (2010). Specifically, we use the Kalman filter to obtain the likelihood from the state-space representation of the model solution and the *Tailored Randomized Block Metropolis-Hastings (TaRB-MH)* algorithm (Chib and Ramamurthy, 2010) to maximize the posterior likelihood.[14]

3.1 Data

We use quarterly U.S. data from 1955:Q1 until 2006:Q4 and include twelve observable time series: the growth rates of per capita GDP, consumption, investment, wages and government expenditure, all in real terms, the logarithm of the level of per capita hours worked, the growth rates of the relative price of investment and of total factor productivity, the log difference of the GDP deflator, and the federal funds rate. Since our main objective are the effects of tax shocks, we also include capital and labor tax rates.[15] Figure 2 displays the evolution of the tax rates and the government spending to GDP ratio over our sample. All three series show a large persistence. Tests against the null hypothesis of a unit root in both tax rates are borderline significant, while they cannot reject the null of a unit root in the government spending to GDP ratio. As there are theoretical reasons to believe that both the tax rates and the government spending to GDP ratio do not contain unit roots, we treat them as stationary. However, to account for the relatively persistent deviations from the unconditional mean, we allow the trend in G_t to be smoother than the one in Y_t.[16]

3.2 Fixed Parameters

Prior to estimation, we fix a number of parameters to match sample means (see Table 1). The curvature of the utility function σ_c is set to 2. This value is consistent with most DSGE models. The discount factor β is fixed at 0.99. We set the parameter that governs the disutility of labor effort γ such that labor effort in steady state is 20 percent. We assume an annual physical depreciation rate of 10 percent, which corresponds to a δ_0 of 0.025 per quarter. Following Auerbach (1989) and Mertens and Ravn (2011), we set the depreciation rate for tax purposes δ_τ to twice the rate of physical depreciation, i.e. 0.05. The depreciation parameter δ_1 is fixed to set the steady state capacity utilization to 1 (Christiano et al., 2005). The parameter α is 0.3253, which matches the capital share in output over our sample, and the fixed cost parameter ψ is set to ensure zero profits in steady state. We assume a steady state price and wage markup of 11 percent and thus set η_p and η_w to 10.

The steady state gross growth rates of per capita output μ^y and of the relative price of investment μ^a are set to their sample means of $1 + 0.45\%$ and $1 - 0.43\%$. The parameters τ^k and τ^n, which determine the unconditional mean of the tax rates, equal the post-war sample means of 0.387 and 0.207. We set the steady state ratio of government spending to

[14] We used a t-distribution with 10 degrees of freedom as proposal density. The posterior distribution was computed from a 12,500 draw Monte Carlo Markov Chain.

[15] Detailed data sources and the observation equation that describes how the empirical time series are matched to the corresponding model variables can be found in Appendices C and D.

[16] We think that the government spending to GDP ratio actually displays mean reversion. Since the end of our sample in 2006Q4, it has returned to about 20.5 in 2010 and is thus close to its unconditional mean.

output G/Y to 0.2038, which also corresponds to the sample mean. We fix the debt to GDP ratio B/Y such that debt to annual GDP is equal to the average gross federal debt to GDP ratio over our sample of 50 percent. The lump sum transfers in steady state, T, were set to -0.0145 in order to balance the budget in steady state, given the steady state tax rates, the government spending share in GDP, the debt to GDP ratio, and the steady state interest rate on government debt. Finally, the steady state inflation rate corresponds to the average sample mean of 1.0089, i.e. annual inflation of 3.6 percent.

3.3 Priors

To avoid the common problem of the estimated model overpredicting the model variances, we follow Christiano et al. (2011) and use endogenous priors (see also Del Negro and Schorfheide, 2008). The procedure is motivated by sequential Bayesian learning. Starting from independent initial priors on the parameters that are unrelated to the data under consideration, we use the standard deviations observed in a "pre-sample" to update those initial priors. Thus, we use the product of the initial priors and the pre-sample likelihood of the standard deviations of the observables as the new prior.[17] Due to the absence of available data for a pre-sample, we follow Christiano et al. (2011) and use the actual sample to compute the standard deviations of the observables.

Table 2 presents the initial prior distributions. Where available, we use prior values that are standard in the literature (e.g. Smets and Wouters, 2007) and independent of the underlying data. The autoregressive parameters of the tax processes, $\rho_{\tau n}$ and $\rho_{\tau k}$, are assumed to follow a beta distribution with mean 0.7 and standard deviation 0.2. For the autocorrelation between the tax shocks, we assume a modified beta distribution centered around 0, covering the interval [-1,1], with standard deviation 0.3. The other autoregressive parameters, $\rho_i,\ i \in \{pref, g, z, x, zI, a, w\}$, are assumed to follow a beta distribution with mean 0.5 and standard deviation 0.2. We assume the standard deviations of the shocks to follow inverse-gamma distributions with prior mean 0.1 and standard deviation 2. The only exception are the measurement errors, for which we assume a uniform prior with an upper bound equal to one quarter of the series' variance. The feedback parameters in the tax rules and the government spending rule (ϕ_{nD}, ϕ_{nl}, ϕ_{kD}, ϕ_{kI}, and ϕ_{gD}) are assumed to follow standard normal distributions. For the parameters of the Taylor-rule, ϕ_{R_Π} and ϕ_{R_Y}, we impose gamma distributions with a prior mean of 1.5 and 0.5, respectively, while the interest rate smoothing parameter ρ_R has the same prior distribution as the persistence parameters of the shock processes. The habit parameter ϕ_c is assumed to be beta distributed with a

[17]For more information, see the technical appendix of Christiano et al. (2011).

prior mean of 0.7, which is standard in the literature. Following Justiniano et al. (2010b), the parameter determining the Frisch elasticity of labor supply σ_l is assumed to follow a gamma distribution with a prior mean of 2 and a standard deviation of 0.75. The prior distribution for the parameter governing the wealth elasticity of labor supply σ_s is a beta distribution with mean 0.5 and standard deviation 0.2. We impose an inverse-gamma distribution with prior mean of 0.5 and standard deviation of 0.15 for δ_2/δ_1, the elasticity of marginal depreciation with respect to capacity utilization. The parameters governing the indexation of prices and wages, χ_p and χ_w, each are beta distributed with mean 0.5 and standard deviation 0.2. For the Calvo parameters θ_w and θ_p we assume a beta distribution with a prior mean of 0.5, which corresponds to price and wage contracts having an average length of half a year (Smets and Wouters, 2007). Finally, we follow the literature (e.g. Justiniano et al., 2010a; Smets and Wouters, 2007) and impose a gamma prior with mean 4 for the parameter controlling investment adjustment costs κ.

3.4 Posterior Distribution

The last four columns of Table 2 display the mean, the standard deviation, and the 90%-posterior intervals for each of the estimated parameters. Most estimated parameters and shock processes are in line with previous studies on the determinants of business cycle fluctuations, both with those using only contemporaneous shocks (e.g. Justiniano et al., 2010a; Smets and Wouters, 2007) as well as those including contemporaneous and anticipated shocks (Fujiwara et al., 2011; Khan and Tsoukalas, 2012; Schmitt-Grohé and Uribe, 2012).

However, some estimates deserve further comment. We find a considerable degree of internal habits with $\phi_c = 0.94$, which is close to the estimate obtained by Schmitt-Grohé and Uribe (2012). The posterior mean of the parameter governing the wealth elasticity ($\sigma_s = 0.05$) implies a relatively low wealth elasticity of labor supply and, thus, preferences that are close to the ones proposed by Greenwood et al. (1988).[18] Schmitt-Grohé and Uribe (2012) find an even lower wealth elasticity of almost zero. Khan and Tsoukalas (2012), on the other hand, estimate the wealth elasticity of labor to be quite high at 0.62. A possible explanation for these differing estimates is the inclusion of government spending as an observable. Increases in government spending may entail positive consumption responses (Blanchard and Perotti, 2002; Galí et al., 2007), a behavior which can be explained by a New-Keynesian model with a low wealth elasticity (Monacelli and Perotti, 2008). Even in studies finding a negative consumption response (see, e.g., Ramey, 2011), this negative response tends to be relatively small or hardly distinguishable from 0, also suggesting the presence of a low wealth effect.

[18] Note, however, that in the presence of habits, even a value of $\sigma_s = 0$ still implies the presence of a wealth effect, see Monacelli and Perotti (2008).

Including government spending as an observable restricts the parameter governing the wealth elasticity to a low value. In our model, this happens, although the consumption response to a government spending shock is estimated to be negative. On the other hand, without the observable government spending as in Khan and Tsoukalas (2012), this parameter remains mostly unrestricted with regard to the effects of government spending on consumption.[19]

Turning to the nominal rigidities in our model, we find that prices and wages are on average adjusted about every 2.5 and 3.5 quarters, respectively. The degree of price indexation is low ($\chi_p = 0.01$) and in a similar range as in Justiniano et al. (2011). Wages, on the other hand, are indexed to inflation with a higher proportion than prices ($\chi_w = 0.6$), which corresponds well with the estimates in Smets and Wouters (2007).

The parameters of the Taylor rule are in line with previous estimates (e.g. Clarida et al., 2000). They imply a high degree of interest rate smoothing ($\rho_R = 0.83$), a strong response to inflation ($\phi_{R_\Pi} = 2.27$), and a moderate value for the standard deviation of the monetary policy shock ($\sigma_R = 0.386\%$). The response of monetary policy to output growth ϕ_{Ry} is estimated to be very small. This small estimate seems to be due to the endogenous feedback of the fiscal rules that captures most of the policy feedback to economic conditions.[20]

Most shocks are estimated to be highly persistent, with $AR(1)$-coefficients ranging from 0.94 for the labor tax rate to 0.98 for government spending shocks.[21] The notable exception is the preference shock, which has the lowest autocorrelation with 0.09, a value close to the ones found in, e.g., Khan and Tsoukalas (2012) and Schmitt-Grohé and Uribe (2012). In contrast, the non-stationary productivity component with a serial correlation of 0.62 and the capital tax shock with 0.77 exhibit only a moderate degree of persistence. In particular, the autocorrelation of the non-stationary TFP shock is consistent with the moderate values commonly found in the literature (e.g. Justiniano et al., 2011; Khan and Tsoukalas, 2012).

Our estimation results show that there is considerable correlation between the tax shocks. We find a significant positive contemporaneous correlation of the surprise shocks of 0.52. There is also some evidence for correlation of the anticipated shocks, albeit the 90%-interval contains 0 in both cases. We also find highly statistically significant feedback from both debt and current economic conditions to the tax rates. In terms of economic significance, while both debt feedback and current economic conditions play a role in satisfying the government's intertemporal budget constraint, the feedback from debt is relatively weak. In contrast, current economic conditions play a stronger role, potentially via the positive effect of progressive

[19] A small wealth effect also helps in explaining the empirical behavior of labor market variables (Galí et al., 2011).

[20] Compare the working paper version Born et al. (2011), which featured no endogenous feedback, but a considerable estimated output response of monetary policy.

[21] The high persistence of the labor tax rate has, for example, been documented in Cardia et al. (2003).

taxation on government spending.

Government spending and labor taxes act to stabilize debt with parameters $\phi_{gD} = -0.003$ and $\phi_{nD} = 0.003$, respectively. The negative estimated value of $\phi_{kD} = -0.002$ implies that capital taxes decrease if debt increases. This potentially reflects the sometimes held belief of policy makers in self-financing capital tax cuts, i.e. being on the wrong side of the Laffer curve. Both tax rates also show a sizable stabilizing reaction to business cycle conditions with estimated values of $\phi_{nl} = 0.021$ and $\phi_{kI} = 0.019$.

Table 3 compares some empirical moments of the data to the corresponding moments from the model. Overall, the model is able to replicate the sample moments fairly well, both for the growth rates of the national accounts variables and of the fiscal variables. Moreover, the correlations with output growth and the autocorrelations are well-matched. The only exception is the growth rate of wages, which is slightly procyclical in the model and acyclical in the data and exhibits an overly high autocorrelation in the model. Looking at the fiscal variables, we find that both spending and tax rates are well matched in their cyclicality, with government spending being slightly procyclical and tax rates acyclical in both the data and the model. The autocorrelation of government spending growth rates is close to 0, while taxes are highly autocorrelated. The model is mostly able to replicate these findings. Only the autocorrelation of capital taxes is a bit lower than in the data, but still high at 0.83.

4 Business Cycle Effects of Fiscal News

We are now in a position to analyze the dynamic effects of fiscal news. To better understand the dynamic effects of news shocks, we analyze their transmission into the economy in Section 4.1. Given the estimated deep parameters of the model, we then compute forecast error variance decompositions to trace out the shocks' contributions to business cycle volatility (Section 4.2). In Section 4.3, we discuss the shocks' dynamic effects and variance contributions in a model re-estimated on federal government data.

4.1 Impulse Responses

In this subsection, we analyze the impulse responses to anticipated and surprise capital and labor tax shocks as well as government spending shocks.

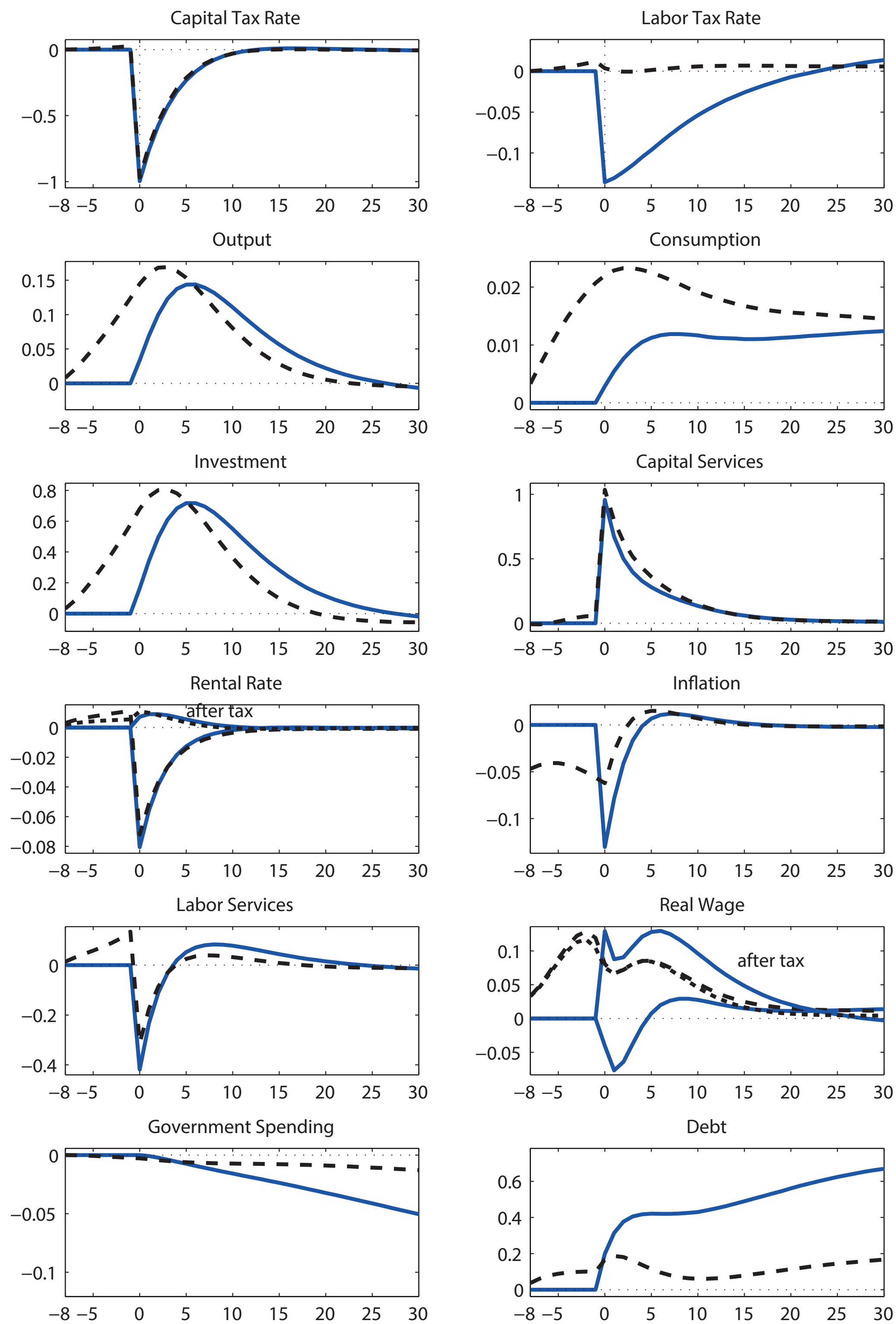

Figure 3: Impulse responses to unanticipated and anticipated capital tax shocks.
Notes: solid line: impulse responses to an unanticipated 1 percentage point cut of the capital tax rate τ_t^k; dashed line (short-dashed for after-tax measures): impulse responses to an eight period anticipated 1 percentage point cut of the capital tax rate τ_t^k that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are semi-elasticities and measured in percentage deviations from steady state, with the exception of inflation and the rental rate, which are measured as percentage point deviations from steady state.

4.1.1 Capital Tax Rate Shocks

Figure 3 shows the median impulse responses to an unanticipated (solid line) and an eight period anticipated (dashed line) one percentage point cut of the capital tax rate.[22] The top left panel shows the impulse response for the capital tax rate that is shocked. In order to deal with the correlation of the tax shocks, we use a Cholesky ordering with capital taxes ordered first, i.e. capital taxes do not react to labor tax shocks contemporaneously except for the endogenous feedback through the effect on investment.[23]

The actual response of the capital tax rate is very similar comparing the surprise and anticipated tax shocks. This is partly due to the way anticipation is modeled. The only difference between the two cases is the different endogenous feedback resulting from the different time at which it is known that a tax shock will happen at $t = 0$. Because in the case of the anticipated shock the future realization of the tax shock is already known at $t = -8$, agents immediately respond to this information and the fiscal rules will respond to this reaction. However, the endogenous feedback in the fiscal rules is relatively weak and distributed over a prolonged period of time. Therefore, the immediate impact on the tax rates is muted, implying that the response of the capital tax rate to the unanticipated capital tax shock looks similar to the anticipated one. As a result, for both shocks, the capital tax rate decreases and returns to steady state relatively quickly as there is only a moderate autocorrelation of 0.76.

Due to the correlation between capital and labor tax shocks and the endogenous feedback from debt and hours worked on the labor tax, the labor tax rate also reacts to a capital tax shock. During the anticipation phase the labor tax reaction is quite weak. However, after the shock realization, the two impulse response functions of the labor tax rate differ to a large extent. The response to the surprise capital shock is considerably larger than the response to the anticipated one, because the two surprise tax shocks are highly correlated. In contrast, the anticipated capital tax shock is only weakly correlated with the anticipated labor tax shock.

Let us now first consider the responses of the other variables to a surprise 1 percentage point decrease in the capital tax rate (solid line). This surprise tax cut acts expansionary and on impact leads to an increase in output, investment, and consumption. While investment reacts strongest to the tax cut, the consumption response is more persistent due to the strong

[22] For both shocks, this roughly corresponds to a one standard deviation shock as $\sigma^0_{\tau k} = 0.929\%$ and $\sigma^8_{\tau k} = 1.078\%$.

[23] Results are robust to changing the Cholesky ordering. When ordering the labor tax rate first, the capital tax shock does not affect the labor tax rate except through the endogenous feedback. As a result, the total effective shock size decreases and the IRFs are quantitatively smaller, but remain qualitatively unaltered. For detailed results, see the online appendix.

consumption habits . The effect on output is only moderate due to the relatively low estimated persistence of the shock process. An initial 1 percentage point decrease in the capital tax rate leads to a peak output response of 0.15 percent.

Due to the temporary nature of the tax cut and capital being predetermined for one period, households immediately ramp up capacity utilization to make optimal use of the short period of lower taxes. At the same time, they increase the capital stock through investment to allow reducing capital utilization at a later point and to better smooth consumption over time. This increase in investment is driven by an increase in the after-tax real rental rate of capital, which increases due to the tax cut. The before-tax rental rate, on the other hand, decreases due to the increase in capital services. Given the agents relatively high estimated Frisch elasticity, they would like to increase their labor supply, when the after-tax real wage increases. However, the increase in labor is delayed by two quarters as output and labor are demand-determined and output only slowly approaches the flex-price output as prices and wages gradually adjust. Thus, during the first two quarters after the shock firms substitute capital for labor services to increase output and only after that labor also increases.

As could be expected, a negative capital tax shock acts like a positive supply shock and lowers inflation. Due to the minimal output response coefficient in the Taylor Rule, the policy rate closely follows the inflation rate (impulse responses not shown here). Finally, because both tax rates fall with only a partially offsetting increase in the tax base (we are not on the wrong side of the Laffer curve), government debt increases and only slowly returns back to steady state. Most of the stabilization effect on debt derives from the response of government spending, which persistently falls below steady state and only returns to steady state as debt recedes.

The impulse responses for the eight period anticipated tax shock generally look very similar to the surprise shock, with a few notable differences. Most importantly, agents have more time to adjust and already react during the anticipation phase. Hence, the impulse responses are more drawn out. Reacting immediately to an anticipated tax shock is optimal for the agents, because the estimated degrees of consumption habits, capital adjustment costs, capital utilization, and nominal rigidities imply that large abrupt changes in important choice variables are welfare reducing and must be avoided. This can first be seen from the fact that agents now initially substitute labor services for capital services, leading to an immediate increase in the former and a tiny decrease below steady state for the latter. Only when the higher labor input increases the marginal product of capital, do capital services also start to increase. The higher production, resulting from the increase in labor services and the resources saved through the initially lower depreciation associated with lower capacity utilization, allows to increase consumption during the anticipation phase, while at the same time increasing the capital stock. This higher physical capital stock will then be used more heavily as soon as the shock realizes.

Second, as a result of these more gradual and hence more resource-saving responses, the peak responses of almost all variables are higher than for the case of a comparable surprise tax cut and generally occur earlier relative to the shock realization at $t = 0$. The notable exceptions are labor services and the real wage as well as debt and government spending, which show lower peak responses. The reason for these lower responses is not a different transmission mechanism, but that capital and labor tax shocks are only weakly correlated at the anticipation horizon of 8 quarters. This weak correlation implies that labor taxes actually increase due to endogenous feedback instead of decreasing as for the surprise shock. As a result, the debt buildup after the anticipated capital tax shock is lower, leading to a smaller decrease in government spending. This implies a smaller wealth effect on the labor supply, which together with the smaller direct impact of labor taxes on the labor margin also dampens the labor and wage response.

Note that for the baseline model at the median impulse response functions, we do not find an investment-driven slump during the anticipation phase of a tax cut as in Mertens and Ravn (2012) and Leeper et al. (forthcoming). Thus, our results are more in line with Mountford and Uhlig (2009), even after accounting for foresight (Leeper et al., 2012). The reason is the interplay of depreciation allowances,[24] the effect of nominal rigidities and monetary policy on real interest rates, and capital adjustment costs. In the face of a known future capital tax cut, depreciation allowances ceteris paribus lower the incentive to invest, because new investment is now associated with a lower tax shield. However, in contrast to the results of Mertens and Ravn (2011), this incentive to disinvest is estimated to be relatively mild in our baseline model. Nevertheless, we cannot exclude the possibility of such an announcement recession as the negative output response is contained in the highest posterior density intervals of the output response (not shown for clarity of the figure). The reason is that at the posterior mean the parameter changes required to generate such behavior are relatively small. For example, each of the following parameter changes in itself is sufficient to make output drop following an 8 quarter anticipated capital tax shock: increasing the depreciation rate for tax purposes from 5 to 8 percent (leads to a larger tax shield), decreasing the capital adjustment cost parameter κ to 1.5 (leads to lower costs to adjust tax shield),[25] decreasing the Calvo parameter θ_p to 0.4, or decreasing the inflation feedback parameter in the Taylor rule to 1.7

[24]Depreciation allowances are the crucial component in the theoretical model of Mertens and Ravn (2011). Without them, their model is not able to generate the impulse responses that are able to replicate the VAR-based responses of Mertens and Ravn (2012).

[25]For the crucial role of low investment adjustment costs to generate decreases in investment following an anticipated tax cut, see also Auerbach (1989) and Leeper et al. (2012).

(both lead to a lower effect of inflation on the real rental rate). Changing those parameters even further increases the size of the anticipatory recession.[26]

The difference to the results of Mertens and Ravn (2011, 2012) can also be explained in part by the different measure of government used. Employing the Romer and Romer (2010) tax shocks, their studies focus on the federal level of government. When we use only federal government spending and taxes in the estimation of our model, we are also able to generate a recessionary dip in output in anticipation of a capital tax cut (see Figure 6 and the discussion in the next two subsections).

4.1.2 Labor Tax Rate Shocks

Figure 4 displays the impulse responses to one percentage point surprise (solid line) and anticipated (dashed line) labor tax shocks.[27] The surprise labor tax cut acts like a positive supply shock. Inflation decreases while output, investment, and consumption go up. The labor tax decrease leads to a budget deficit and increases debt persistently, which feeds back to a small but persistent decrease in government spending via the fiscal rule. Due to capital taxes being ordered first in our Cholesky decomposition, capital taxes do not react to labor tax shocks except through the endogenous feedback.[28] As capital taxes respond more strongly to current investment than to debt, the capital tax rate increases. The decrease in labor taxes benefits both firms, which now pay a lower before-tax real wage, and households, which receive higher wages after taxes. Correspondingly, labor services increase significantly. In addition, the decrease in labor taxes and the increase in capital taxes combined with output gradually expanding towards the flex-price output induces firms to use more labor services instead of capital services. The decrease in capital services stems from a drop in capacity utilization, which overcompensates the increase in the capital stock driven by consumption smoothing. Only when the initial burst of deflation starts subsiding do markups return to their steady state value and do capital services catch up and finally rise above steady state.

The anticipated labor tax shock also acts expansionary, but already upon announcement. As explained above, agents have more time to adjust and save resource and utility costs associated with abruptly changing their behavior. Therefore, the impulse responses are more drawn out and have a higher peak than for the surprise shock. Due to the smaller relative change in labor and capital taxation, both labor and capital services increase during the

[26]Moreover, in an estimated real version of the model, the announcement of a future capital tax cut is sufficient to generate an investment-driven slump through the incentive to reduce the tax shield via the depreciation allowances. For detailed results of two estimated real version of the model and a comparison to our baseline monetary model, see the online appendix.

[27]The two shocks have standard deviations of 0.227% and 0.049%, respectively and have been scaled up to both have a size of one percentage point.

[28]Again, the results are robust to changing the Cholesky ordering. For details, see the online appendix.

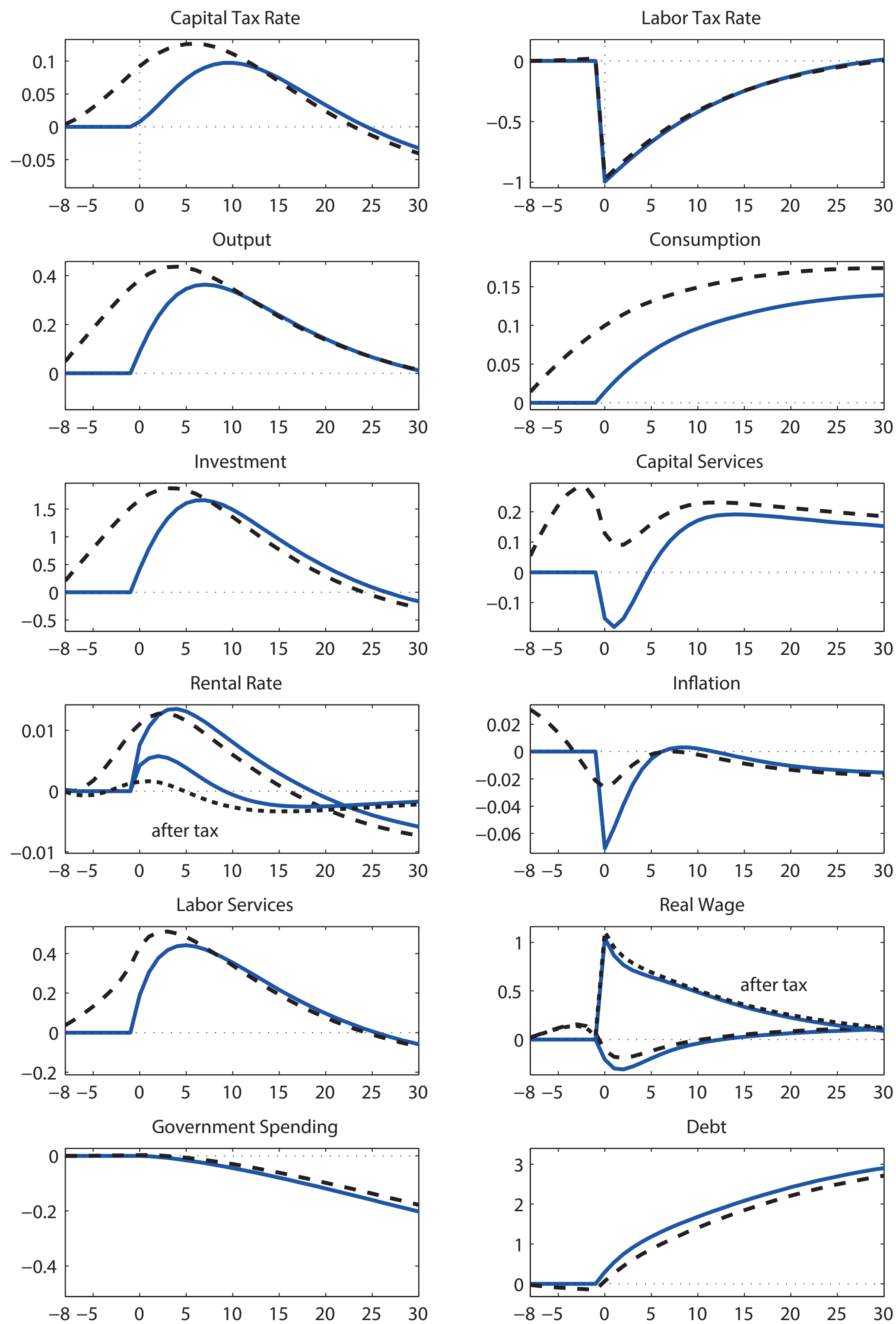

Figure 4: Impulse responses to unanticipated and anticipated labor tax shocks.
Notes: solid line: impulse responses to an unanticipated 1 percentage point cut of the labor tax rate τ_t^n; dashed line (short-dashed for after-tax measures): impulse responses to an eight period anticipated 1 percentage point cut of the labor tax rate τ_t^n that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are semi-elasticities and measured in percentage deviations from steady state, with the exception of inflation and the rental rate, which are measured as percentage point deviations from steady state.

anticipation phase without much substitution taking place. This changes upon realization of the labor tax cut, when firms switch from capital to labor, with both inputs still being well above steady state.

Initially, due to agents wanting to expand the future capital stock and to consume more immediately due to consumption smoothing, inflation slightly increases and then slowly subsides when the production factors capital and labor expand. Inflation only picks up when the labor tax shock realizes, before subsiding again.

4.1.3 Government Spending Shocks

Figure 5 displays the impulse responses to one percent surprise (solid line) and anticipated (dashed line) increases in government spending.[29] The bottom row shows that the government spending shocks are both relatively persistent and lead to a significant deterioration of the government budget, resulting in a large and persistent buildup of debt. This debt buildup via the feedback embedded in the fiscal rule somewhat dampens the persistence in government spending, which would be even larger otherwise. The fiscal feedback is also responsible for the behavior of the capital and the labor tax rate. The former falls due to the increase in debt and the decrease of investment that results from a crowding out effect. In contrast, labor taxes rise due to the debt feedback and the positive feedback from the increase in labor services.

First, consider the surprise government spending shock. As would be expected, it acts like a standard demand shock, driving up output and inflation, and crowding out investment and consumption. As households tap into the capital stock to produce the additional government consumption while keeping up private consumption, they ramp up capacity utilization so that capital services increase. At the same time, households start working more, with an additional incentive to increase labor supply stemming from the higher marginal product of labor due to the increase in capital services. When capital services return to their steady state, this substitution effect dissipates and the wealth effect on labor supply, which was estimated to be small, starts to dominate. As a result, the real wage drops below steady state. The responses to the surprise government shock are similar to the responses to a spending "news"-shock in Ramey (2011).[30] As in her study, spending, output, hours and labor income taxes rise, while consumption and investment fall. Moreover, the implied peak multiplier in her study is between 1.1 and 1.2, while it is about 0.9 in our baseline model.

[29]The two shocks have standard deviations of 0.033% and 1.602%, respectively, and have been scaled to have a size of one percent each.

[30]Although the Ramey (2011)-shocks are expected changes in defense spending, spending actually starts rising one quarter after the announcement. Thus, the spending "news"-variable more closely corresponds to a surprise shock in our framework.

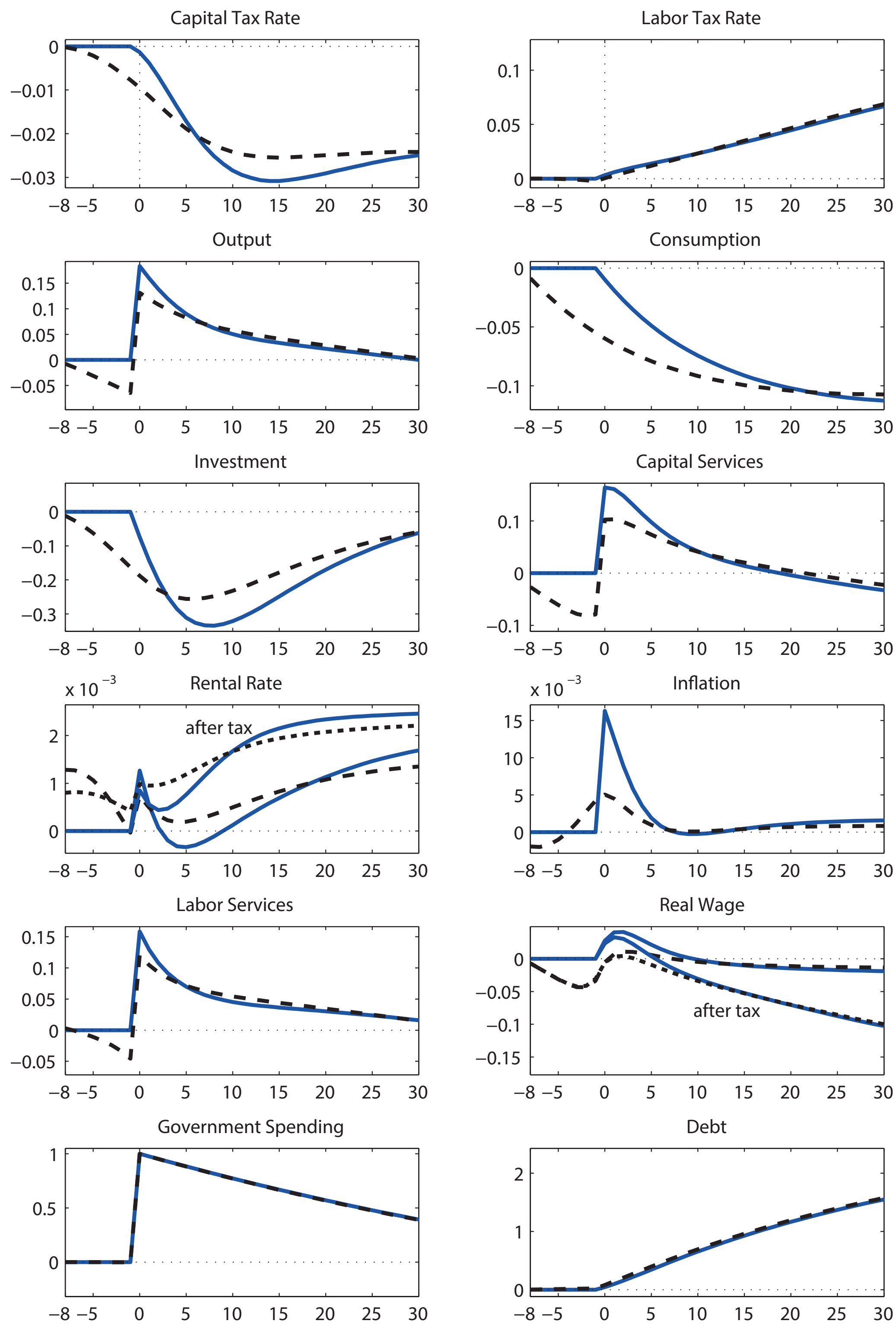

Figure 5: Impulse responses to unanticipated and anticipated government spending shocks. *Notes*: solid line: impulse responses to an unanticipated 1 percent increase in government spending g_t; dashed line (short-dashed for after-tax measures): impulse responses to an eight period anticipated 1 percent increase in government spending g_t that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are elasticities and measured in percentage deviations from steady state, with the exception of inflation and the rental rate, which are measured as percentage point deviations from steady state.

Second, for the anticipated government spending shock, agents again have more time to adjust. Due to strong consumption habits, consumption starts falling immediately. Moreover, to save investment adjustment costs, households gradually reduce investment in order for it to be low when the government spending shock realizes and disinvestment is needed most. At the same time, capacity utilization u_t and thus capital depreciation $\delta(u_t)$ falls during the anticipation phase. The resulting resource savings from the lower capital depreciation rate temporarily overcompensate the disinvestment in capital so that the physical capital stock actually rises while capital services fall (the impulse responses for capacity utilization and capital stock are omitted for brevity). The lower capital services also depress the real wage via their effect on the marginal product of labor. This substitution effect overcompensates the wealth effect on the labor supply. The larger capital stock that is built up during the anticipation phase is used up when the shock actually realizes. In this case, households still disinvest, but ramp up capital utilization, so that capital services now rise. This increases the depreciation of the capital stock, which starts to fall. The increase in capital services upon realization of the shock is similar to the response of the surprise shock and thus also triggers a similar response of the real wage and, correspondingly, of labor services.

4.2 Variance Decomposition

We use our DSGE-based estimation approach to analyze the quantitative importance of the different anticipated and surprise shocks for explaining business cycles. To this end, we compute conditional and unconditional forecast error variance decompositions for the growth rates of output, consumption, investment, hours, wages, the federal funds rate, inflation, labor and capital tax rates, and government spending (see Table 4).[31] We find that fiscal foresight plays a moderate role in explaining business cycle fluctuations. Specifically, using full information Bayesian estimation and accounting for different kinds of shocks, we find that anticipated government spending is the fiscal variable with the largest effect on output variance. It is responsible for 13 percent of output variance, which is close to the 16 percent found by Forni and Gambetti (2010), who use a factor VAR to deal with fiscal foresight and also consider total government data. However, this value is somewhat larger than the 6 percent found by Schmitt-Grohé and Uribe (2012) in their RBC-DSGE model without endogenous fiscal feedback.[32]

[31] For ease of exposition we have combined the two anticipated shock components into one and left out the anticipated stationary investment-specific shocks that contribute less than 0.1 percent to the variance of the variables.

[32] Estimating a version of the Schmitt-Grohé and Uribe (2012) model with fiscal feedback and including an anticipated preference shock as in their model, we find that only surprise spending shocks matter with a contribution to output variance of about 12 percent. When adding a nominal block, the model moments of

We find that capital tax shocks and, in particular, news about capital taxes explain less than 2 percent of output growth fluctuations in our baseline model, while news about labor tax shocks do not matter at all. This compares to an output variance contribution of tax shocks of about 20 to 27 percent in the VAR study of Mertens and Ravn (2012). However, their study uses the Romer and Romer (2010) tax shocks and is thus focused on the federal level. When we estimated our baseline model on federal fiscal data only, tax shocks account for 24 percent of output fluctuations (see the results and discussion in Section 4.3).

Regarding the evidence on the effects of news shocks on the business cycles, our finding that about 50 percent of the variance of output growth can be attributed to anticipated shocks is on the upper end of estimates found in Forni et al. (2011), Barsky and Sims (2011), and Kurmann and Otrok (forthcoming). The news shocks that matter most are news about non-stationary technology, which account for 13 to 22 percent of the variance of output and consumption. With a variance share of 19-22 percent, news about stationary TFP is especially important in explaining the variability of investment growth. But it also contributes significantly to the variance of output (12-15 percent). Using a factor model, Forni et al. (2011) find that around 20 percent of output volatility is explained by technology and 10 percent by news about technology, while Barsky and Sims (2011), in a VAR, attribute 10 to 40 percent to news shocks. Kurmann and Otrok (forthcoming) study the term-structure of interest rates in a VAR and find that non-stationary TFP news, the only news shocks they consider, account for about 50 percent of output volatility.

Fujiwara et al. (2011) and Khan and Tsoukalas (2012), using an estimated DSGE model with nominal rigidities, find a technology news contribution to output variance of 8.5 and 1.6 percent, respectively, while Schmitt-Grohé and Uribe (2012) in the context of a real model find that news about technology account for about 10 percent of output variance. Our own estimate of a technology news contribution of 33 percent is closer to the monetary DGSE model of Davis (2007) with 20-50 percent of output variance attributed to technology news and the 50 percent in the VAR of Kurmann and Otrok (forthcoming).

Allowing anticipation not only for TFP but also for other shocks leads to a higher relative contribution of news shocks. Whereas the contribution of anticipated shocks in the study by Fujiwara et al. (2011) ranges from 4 percent (to the variance of investment) to 15 percent (to inflation volatility), we find contributions of anticipated shocks (combining all shocks) between 29 percent (consumption volatility) and 60 percent (variance of the nominal interest rate). This difference to Fujiwara et al. (2011) is mostly due to the fact that Fujiwara et al.

the fiscal and technological variables move closer to the empirical data, while at the same time the importance of the anticipated government spending shock increases at the cost of the surprise one. This better model fit suggests the importance of nominal rigidities and the interaction of fiscal policy with monetary policy to account for the empirically observed data. For more details, see the online appendix.

(2011) assume the presence of a deterministic linear trend and thus do not allow for changes in trend growth. In contrast, most of the importance of TFP news shocks in our model is driven by the non-stationary, i.e. trend, shock. The difference to the results in Khan and Tsoukalas (2012) seems to be due to our different specification of the investment specific technology shocks (see below), as in their study the contemporaneous investment specific technology shock accounts for 68 percent and 87 percent of output and investment variability, thus hardly leaving room for other shocks at all.[33]

Turning to the role of unanticipated shocks, we see that while the investment-specific technology shock has been identified as an important driver of business cycles by previous studies (Davis, 2007; Fisher, 2006; Justiniano et al., 2010a), it is of lesser importance in our case and contributes a smaller fraction to fluctuations than TFP shocks. The contributions of non-stationary investment-specific productivity vary between 2.3 percent (e.g. output) and 6 percent (inflation), whereas stationary investment-specific technology explains less than 1 percent. The difference to the previous studies' finding of a high contribution of investment-specific technology stems from our decision to include the relative price of investment as an observable. Recent studies, which include the relative price of investment as an observable, find similarly small contributions of investment-specific technology (Justiniano et al., 2011; Schmitt-Grohé and Uribe, 2012).[34] However, we have to stress that both the stationary as well as the non-stationary investment-specific productivity shock pertain to the relative price of investment and are, accordingly, mapped to this observable.[35] Thus, our stationary investment-specific technology shock is not directly comparable to the stationary investment-specific technology shock in Schmitt-Grohé and Uribe (2012), which is rather a marginal efficiency of investment (MEI) shock as in Justiniano et al. (2011). This could explain the differing results regarding the effects of this particular shock for output with 20 percent in their case vs. less than 1 percent in our model. Following the criticism of Chari et al. (2009), we abstain from including this additional type of disturbance, as it has no clear structural interpretation (apart from maybe being related to financial disturbances) in our one-sector model and its inclusion would not be disciplined by observable data.[36]

[33]A further confounding factor is that Khan and Tsoukalas (2012) do not use TFP as an observable, while we do.

[34]Models that do not use the relative price of investment as an observable variable usually imply wrong moments for this series (Justiniano et al., 2011). When this problem is eliminated, the variance contribution of investment-specific technology shocks tends to disappear.

[35]The observation equation in Appendix C shows the exact mapping.

[36]For details on the importance of measurement error, see the online appendix. Measurement error explains about 3-10 percent of the variance of wages, corroborating recent work by Justiniano et al. (2013), who stress the importance of accounting for measurement error in wages. Also not surprisingly, given the construction of labor and capital tax rates, measurement error is an important contributor to their variance, explaining 20-30 at short and 1-5 percent at long horizons.

4.3 Fiscal Policy at the Federal Level

One could argue that nationwide shocks have different implications than state level shocks. To better judge the effect of fiscal policy measures at the federal level, like e.g. stimulus packages, holding the revenues and expenditures at the subnational level constant (something that might theoretically be done by giving appropriate transfers to the states), we have re-estimated our model with fiscal data from the federal level only.

The importance of fiscal foresight increases considerably as can be seen from Table 5. Fiscal foresight now explains 37 percent of the unconditional variance of output. Particularly important is foresight about government spending (22 percent of output variance), followed by anticipated labor tax rates (11 percent), and capital taxes (4 percent). While in our baseline model surprise and anticipated labor tax shocks did not play a big role in explaining the variance of the variables considered, they are now an important driver of variability. This is mostly due to three changes in the estimated parameter values (see the last column of Table 2). First, labor tax shocks are estimated to be a lot more persistent at 0.998 compared to 0.94. This together with the second element, the lower Frisch elasticity of labor supply ($\sigma_l = 2.598$ compared to 0.786 in the baseline model), implies more persistent responses of the labor supply. Third, the feedback of capital taxes to investment is estimated to be negative ($\phi_{kI} = -0.009$). Due to those three parameter changes, an investment increase after a decrease in labor taxes leads to a rise in labor and thereby the marginal product of capital. A decrease in capital taxation further propels this boom. This generates a very strong amplification mechanism as shown in the impulse responses discussed below.

If we consider the model estimated on federal fiscal data instead of total government data, the impulse responses to both surprise and anticipated government spending shocks hardly change neither quantitatively nor qualitatively. Therefore, Figure 6 only shows impulse responses for capital and labor tax shocks. For the labor tax shock, the impulse responses change quantitatively for both surprise and anticipated shocks, but are very similar qualitatively. The main difference relates to capital taxes and explains the quantitative differences: because capital taxes are estimated to decrease when investment increases, the boom in investment, consumption, and output generated by the labor tax cut is further propelled as capital taxes decrease. In contrast, for the model with total government, an endogenous capital tax increase dampened the output effect. Moreover, due to the stronger boom, the effect on government debt is lower and even turns negative after 12 quarters for the surprise shock and 4 quarters after announcement for the anticipated shock. Via feedback, this lower debt build-up compared to the total government case relatively quickly leads to an additional increase in government spending and thus output. As a result, the labor tax decrease has a very large multiplier with a peak output response of about 3 percent.

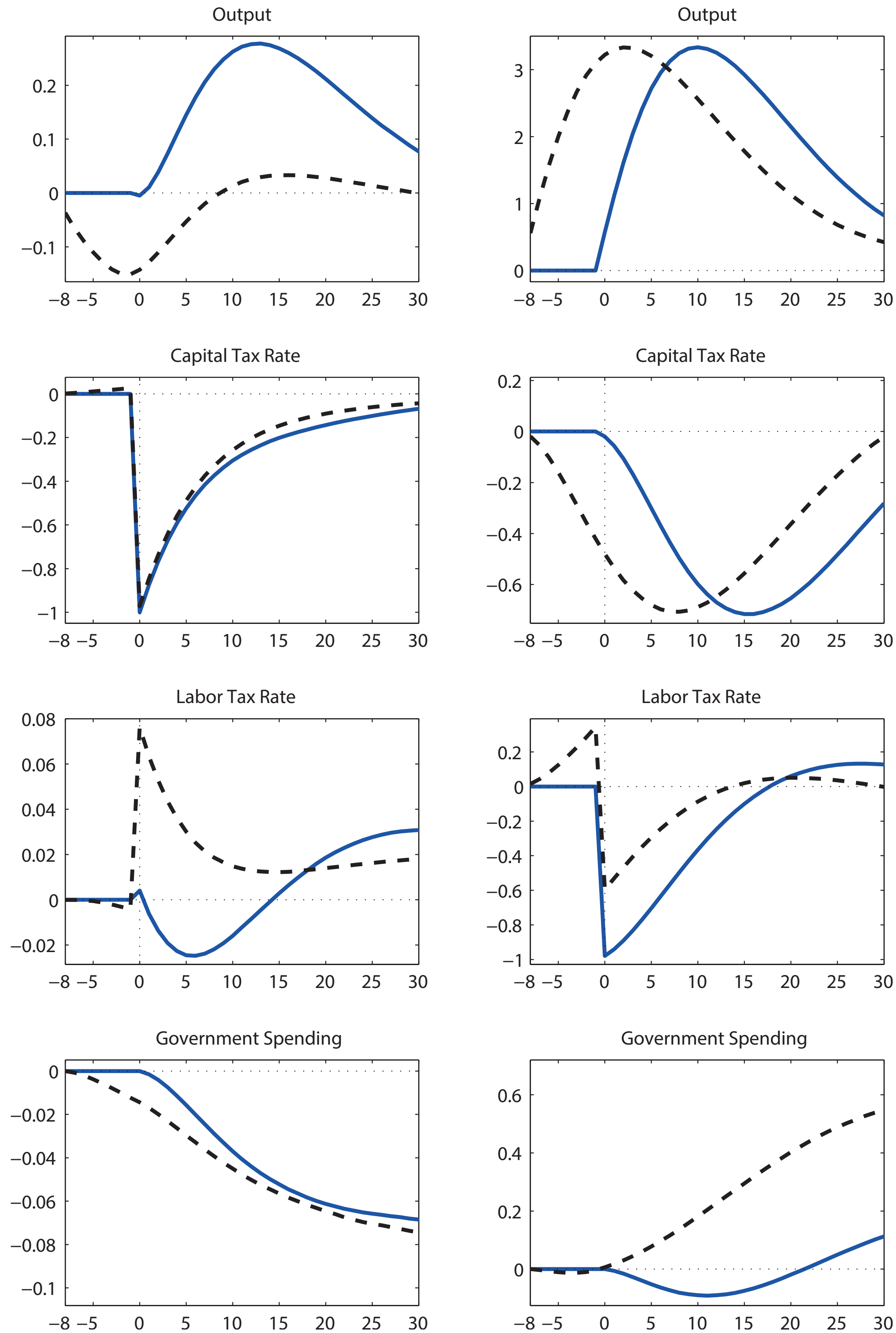

Figure 6: Impulse responses to unanticipated and anticipated capital tax shocks (left panel) and labor tax shocks (right panel), using federal government data only.

Notes: solid line: impulse responses to an unanticipated 1 percent increase in the respective tax rate; dashed line: impulse responses to an eight period anticipated 1 percent increase in the respective tax rate that becomes known at $t = -8$ and effective at $t = 0$. All impulse responses are semi-elasticities and measured in percentage deviations from steady state.

For the surprise capital tax shock, the impulse responses are both qualitatively and quantitatively similar to the baseline responses. However, for the anticipated capital tax shock the responses differ strongly from the baseline case. Due to an estimated negative correlation of the anticipated labor and capital tax shocks, the anticipated decrease in capital taxes is associated with the expectation of an increase in labor taxes. Paired with the lower estimated value of the Frisch elasticity compared to the general government case, people start decreasing their labor supply immediately, leading to a drop in investment and thus generating an investment-driven anticipatory recession. Moreover, due to the persistent increase in government debt and the high persistence of the labor tax rate, the tax burden on labor stays high for a long time, creating a short-lived boom after the capital tax cut realizes.

This increased importance of fiscal policy in a model estimated on federal government data suggests that fiscal changes at the subnational level tend to counteract the ones at the federal level (as also suggested by the change in the estimated fiscal rules visible from the last column of Table 2). A case in point might be the recent Great Recession, where countercyclical fiscal stimulus at the federal level was counteracted by tightening at the state level due to balanced budget rules. Thus, focusing on federal level shocks might only deliver a partial picture of the effect of discretionary fiscal stimulus measures, as it takes as given constant subnational fiscal policy. Given recent experience during the Great Recession, this seems to be an unjustified assumption. Thus, one could argue that only analyzing total government delivers a full picture of the average response of the U.S. economy to fiscal policy shocks.

5 Conclusion

In this paper, we analyzed the contribution of fiscal foresight about labor and capital tax rates and government spending to business cycle volatility in an estimated New Keynesian DSGE model featuring fiscal rules with endogenous feedback. Computing forecast error variance decompositions, we found that fiscal foresight only plays a limited role for business cycle fluctuations. Anticipated government spending shocks accounted for 13 percent of output growth volatility, while both surprise and anticipated tax shocks hardly affected the volatility of real variables. The importance of tax shocks was mostly confined to inflation, where anticipated capital tax shocks were responsible for 8 to 12 percent of the total variance.

Our results show that accounting for fiscal foresight only slightly alters the qualitative importance of traditional business cycle factors like technology shocks (see, e.g., Schmitt-Grohé and Uribe, 2012; Smets and Wouters, 2007). In particular, we find anticipated permanent TFP shocks to be the most important driver of business cycles. When estimating the model on federal government data only, fiscal policy shocks become considerably more important, accounting for more than one third of business cycle fluctuations. This effect is driven by anticipated government spending and labor tax shocks. However, this assumes that subnational spending and revenues stay constant and are not affected by federal decisions, something that appears unlikely to hold in practice. Thus, we think the results for total government are more representative of the typical response of the economy to fiscal shocks.

Structural estimation always runs the risk of misspecifying the underlying model structure. In future work, it might be worthwhile to explore the effects of a more detailed modeling of the U.S. tax code as suggested by McGrattan (2012). However, given the non-linear modeling and filtering required in this case and the typically large state space of models with anticipation effects, estimating the effects of fiscal news in such a model will be an extremely challenging computational task. Finally, the role of the information structure assumed in the present work should be further scrutinized as the particular choice of information structures may matter (Leeper and Walker, 2011).

A Tables

Table 1: Parameters fixed prior to estimation

Parameter	Value	Target/Motivation (matched to quarterly data)
σ_c	2	Common in RBC models
γ	0.00064	Set labor effort in steady state to 20%
β	0.99	Common in RBC models
δ_0	0.025	Annual physical depreciation of 10%
δ_1	0.0484	Set capacity utilization $u = 1$ in steady state
δ_τ	0.05	Twice the rate of physical depreciation δ_0 (Auerbach, 1989)
α	0.3253	Match capital share in output
ψ	0.055	Set profits to zero
η_p	10	Set price markup to 11% in steady state
η_w	10	Set wage markup to 11% in steady state
μ^y	1.0045	Match average sample growth rate of per capita output
μ^a	0.9957	Match average sample growth rate of relative price of investment
τ^n	0.207	Match average sample labor tax rate
τ^k	0.387	Match average sample capital tax rate
G/Y	0.2038	Match average sample mean
B/Y	2	Match average sample gross federal debt to GDP ratio of 50%
T	-0.0145	Balance government budget in steady state
Π	1.0089	Match average sample mean

Table 2: Prior and Posterior Distributions

Parameter	Prior distribution			Posterior distribution				Federal
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent	Mean
				Preference and Technology Parameters				
χ_w	Beta	0.50	0.20	0.583	0.087	0.439	0.728	0.661
χ_p	Beta	0.50	0.20	0.005	0.003	0.001	0.011	0.004
θ_p	Beta	0.50	0.20	0.715	0.010	0.699	0.731	0.881
θ_w	Beta	0.50	0.20	0.622	0.020	0.588	0.653	0.486
σ_l	Gamma	2.00	0.75	0.786	0.110	0.610	0.969	2.598
σ_s	Beta	0.50	0.20	0.047	0.004	0.041	0.054	0.020
κ	Gamma	4.00	1.50	4.069	0.198	3.737	4.394	3.901
δ_2/δ_1	Inv.-Gamma	0.50	0.15	0.110	0.005	0.102	0.118	0.090
ϕ_c	Beta	0.70	0.10	0.939	0.006	0.928	0.948	0.864

Table 2: Prior and Posterior Distributions - Continued

Parameter	Prior distribution			Posterior distribution				Federal
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent	Mean
				Preference Shock				
ρ_{pref}	Beta	0.50	0.20	0.085	0.032	0.034	0.139	0.106
σ_{pref}	Inv.-Gamma	0.10	2.00	12.277	1.219	10.211	14.315	5.488
				Wage Markup Shock				
ρ_w	Beta	0.50	0.20	0.964	0.005	0.956	0.972	0.988
σ_w	Inv.-Gamma	0.10	2.00	15.128	1.180	13.161	17.123	0.031
σ_w^4	Inv.-Gamma	0.10	2.00	0.033	0.019	0.025	0.066	7.786
σ_w^8	Inv.-Gamma	0.10	2.00	12.309	1.415	10.018	14.650	0.031
				Stationary Technology Shock				
ρ_z	Beta	0.50	0.20	0.952	0.004	0.945	0.959	0.908
σ_z	Inv.-Gamma	0.10	2.00	0.458	0.030	0.408	0.505	0.553
σ_z^4	Inv.-Gamma	0.10	2.00	0.543	0.028	0.494	0.587	0.128
σ_z^8	Inv.-Gamma	0.10	2.00	0.505	0.030	0.458	0.554	0.502
				Non-Stationary Technology Shock				
ρ_x	Beta	0.50	0.20	0.623	0.023	0.583	0.658	0.455
σ_x	Inv.-Gamma	0.10	2.00	0.402	0.029	0.355	0.450	0.588
σ_x^4	Inv.-Gamma	0.10	2.00	0.394	0.028	0.346	0.439	0.591
σ_x^8	Inv.-Gamma	0.10	2.00	0.329	0.030	0.281	0.378	0.245
				Stationary Investment-Specific Productivity Shock				
ρ_{zI}	Beta	0.50	0.20	0.967	0.004	0.960	0.973	0.998
σ_{zI}	Inv.-Gamma	0.10	2.00	0.357	0.021	0.324	0.393	0.354
σ_{zI}^4	Inv.-Gamma	0.10	2.00	0.040	0.032	0.022	0.116	0.083
σ_{zI}^8	Inv.-Gamma	0.10	2.00	0.032	0.013	0.025	0.057	0.031
				Non-Stationary Investment-Specific Productivity Shock				
ρ_a	Beta	0.50	0.20	0.843	0.010	0.826	0.859	0.955
σ_a	Inv.-Gamma	0.10	2.00	0.199	0.012	0.180	0.219	0.086
σ_a^4	Inv.-Gamma	0.10	2.00	0.158	0.013	0.137	0.180	0.065
σ_a^8	Inv.-Gamma	0.10	2.00	0.166	0.011	0.148	0.185	0.092

Table 2: Prior and Posterior Distributions - Continued

Parameter	Prior distribution			Posterior distribution				Federal
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent	Mean
				Government Spending Shock				
ρ_g	Beta	0.50	0.20	0.976	0.002	0.973	0.980	0.960
ρ_{xg}	Beta	0.50	0.20	0.931	0.011	0.913	0.949	0.826
σ_g	Inv.-Gamma	0.10	2.00	0.033	0.017	0.025	0.060	0.030
σ_g^4	Inv.-Gamma	0.10	2.00	0.033	0.021	0.024	0.067	0.033
σ_g^8	Inv.-Gamma	0.10	2.00	1.602	0.023	1.563	1.640	2.404
ϕ_{gD}	Normal	0.00	1.00	-0.003	0.000	-0.004	-0.003	-0.009
				Labor Tax Shock				
$\rho_{\tau n}$	Beta	0.70	0.20	0.936	0.012	0.914	0.953	0.998
$\sigma_{\tau n}$	Inv.-Gamma	0.10	2.00	0.227	0.061	0.132	0.335	0.174
$\sigma_{\tau n}^4$	Inv.-Gamma	0.10	2.00	0.213	0.104	0.025	0.333	0.215
$\sigma_{\tau n}^8$	Inv.-Gamma	0.10	2.00	0.049	0.064	0.024	0.243	0.270
ϕ_{nD}	Normal	0.00	1.00	0.003	0.001	0.002	0.004	0.001
ϕ_{nl}	Normal	0.00	1.00	0.021	0.004	0.015	0.028	0.028
				Capital Tax Shock				
$\rho_{\tau k}$	Beta	0.70	0.20	0.765	0.024	0.724	0.802	0.875
$\sigma_{\tau k}$	Inv.-Gamma	0.10	2.00	0.929	0.079	0.796	1.055	1.060
$\sigma_{\tau k}^4$	Inv.-Gamma	0.10	2.00	0.898	0.091	0.739	1.043	1.173
$\sigma_{\tau k}^8$	Inv.-Gamma	0.10	2.00	1.078	0.080	0.938	1.206	1.298
ϕ_{kD}	Normal	0.00	1.00	-0.002	0.001	-0.003	-0.001	-0.001
ϕ_{kI}	Normal	0.00	1.00	0.019	0.003	0.015	0.023	-0.009
				Tax Shock Correlations				
$\{\varepsilon_{\tau k}, \varepsilon_{\tau n}\}$	Beta*	0.00	0.30	0.517	0.122	0.316	0.715	-0.103
$\{\varepsilon_{\tau k}^4, \varepsilon_{\tau n}^4\}$	Beta*	0.00	0.30	-0.165	0.149	-0.392	0.083	-0.727
$\{\varepsilon_{\tau k}^8, \varepsilon_{\tau n}^8\}$	Beta*	0.00	0.30	0.055	0.212	-0.292	0.408	-0.456
				Monetary Policy				
ρ_R	Beta	0.50	0.20	0.828	0.007	0.815	0.840	0.864
σ_R	Inv.-Gamma	0.10	2.00	0.386	0.019	0.358	0.420	0.317
ϕ_{R_Π}	Gamma	1.50	3.00	2.265	0.041	2.202	2.335	2.392
ϕ_{R_Y}	Gamma	0.50	3.00	0.000	0.000	0.000	0.000	0.000

Table 2: Prior and Posterior Distributions - Continued

Parameter	Prior distribution			Posterior distribution				Federal
	Distribution	Mean	Std. Dev.	Mean	Std. Dev.	5 Percent	95 Percent	Mean
				Measurement Error				
σ_y^{me}	Uniform	0.01	0.01	0.000	0.000	0.000	0.000	0.000
σ_w^{me}	Uniform	0.07	0.04	0.142	0.000	0.142	0.142	0.142
$\sigma_{\tau n}^{me}$	Uniform	0.46	0.26	0.234	0.024	0.193	0.272	0.318
$\sigma_{\tau k}^{me}$	Uniform	0.40	0.23	0.792	0.000	0.792	0.792	0.792

Notes: The standard deviations of the shocks and measurement errors have been transformed into percentages by multiplying with 100. Beta* indicates that the correlations follow a beta-distribution stretched to the interval [-1,1].

Table 3: Model and Data Moments

	Model	Data	Model	Data	Model	Data
	$\rho(x_t, y_t)$		$\sigma(x_t)$		$\rho(x_t, x_{t-1})$	
$\Delta\log(Y_t)$	1.000	1.000	0.903	0.907	0.721	0.276
$\Delta\log(C_t)$	0.649	0.507	0.578	0.504	0.517	0.221
$\Delta\log\left(z_t^I A_t I_t\right)$	0.834	0.691	3.300	2.272	0.869	0.527
$\log\left(\frac{L_t}{L}\right)$	0.122	0.053	5.392	4.015	0.965	0.978
$\Delta\log(G_t)$	0.427	0.252	1.673	1.125	0.060	0.061
$\Delta\log\left(z_t^I A_t\right)$	-0.143	-0.036	0.670	0.408	0.594	0.493
τ_t^n	0.008	-0.058	4.433	3.641	0.994	0.991
τ_t^k	0.023	-0.132	3.686	3.173	0.834	0.968
$\Delta\log(W_t)$	0.524	-0.043	0.805	0.573	0.554	0.087
$\Delta\log(TFP_t)$	0.371	0.075	1.047	0.848	0.164	-0.075
$\log(R_t)$	-0.090	-0.183	1.222	0.809	0.951	0.959
$\log(\Pi_t)$	0.000	-0.263	0.753	0.578	0.836	0.854

Notes: Time series x_t are the growth rates of output ($\Delta\log(Y_t)$, denoted by y_t in the first column), consumption ($\Delta\log(C_t)$), investment ($\Delta\log\left(z_t^I A_t I_t\right)$), percentage deviations of hours worked from steady state ($\log\left(\frac{L_t}{L}\right)$), the growth rates of government spending ($\Delta\log(G_t)$) and investment-specific technology ($\Delta\log\left(z_t^I A_t\right)$), the level of labor and capital taxes (τ_t^n and τ_t^k), the growth rates of wages ($\Delta\log(W_t)$) and TFP ($\Delta\log(TFP_t)$), the level of the net nominal interest rate ($\log(R_t)$), and the level of net inflation ($\log(\Pi_t)$). Model moments are computed at the posterior median of the parameters.

Table 4: Variance Decomposition (in %):

	Pref./Wage Markup			Technology							Policy						
	ξ^{pref}	ε_w^0	$\varepsilon_w^{4,8}$	ε_z^0	$\varepsilon_z^{4,8}$	ε_x^0	$\varepsilon_x^{4,8}$	ε_{zI}^0	ε_a^0	$\varepsilon_a^{4,8}$	ξ^R	ε_g^0	$\varepsilon_g^{4,8}$	$\varepsilon_{\tau n}^0$	$\varepsilon_{\tau n}^{4,8}$	$\varepsilon_{\tau k}^0$	$\varepsilon_{\tau k}^{4,8}$
4 periods																	
GDP	11.6	9.1	1.7	13.7	15.3	28.2	12.7	0.7	0.7	1.0	3.4	0.0	0.2	0.4	0.0	0.3	0.6
Cons.	69.1	0.9	0.5	1.1	2.2	10.1	13.2	0.0	0.9	1.4	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Invest.	2.1	12.2	1.7	18.8	19.2	24.4	7.6	1.3	0.8	3.9	5.8	0.0	0.0	0.6	0.0	0.6	0.9
Hours	1.2	27.4	0.8	8.8	11.2	1.0	9.5	0.2	6.6	12.6	8.7	0.0	0.0	1.6	0.0	9.4	1.0
Infl.	1.0	3.6	0.8	8.1	2.7	2.2	6.0	0.1	4.6	22.3	35.1	0.0	0.0	0.3	0.0	5.0	7.9
Cap. Tax	0.1	0.3	0.0	0.5	0.5	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	68.6	0.0
Lab. Tax	0.0	0.4	0.0	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.0	77.0	0.0	0.2	0.0
Gov. Spend.	0.0	0.0	0.0	0.0	0.0	73.0	0.0	0.0	3.9	0.0	0.2	22.7	0.0	0.0	0.0	0.0	0.0
16 periods																	
GDP	6.6	5.8	2.2	8.4	13.1	21.1	19.4	0.5	2.3	3.2	2.1	0.0	13.6	0.3	0.0	0.2	0.9
Cons.	53.0	1.3	0.8	1.5	3.3	15.3	21.2	0.0	1.2	1.7	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Invest.	1.7	9.6	2.9	14.5	20.4	19.8	13.7	1.0	2.5	6.3	4.5	0.0	0.2	0.5	0.0	0.5	1.8
Hours	0.8	37.0	17.8	3.7	7.7	6.3	6.5	0.3	2.1	7.1	2.2	0.0	1.6	1.5	0.0	2.1	3.2
Infl.	0.8	3.1	1.0	6.9	4.8	2.5	6.2	0.6	4.5	22.1	30.4	0.0	0.1	0.2	0.0	4.3	12.3
Cap. Tax	0.4	3.0	1.3	4.3	8.0	4.0	2.7	0.2	0.2	0.4	0.3	0.0	0.1	0.1	0.0	19.9	47.3
Lab. Tax	0.1	9.2	2.8	0.1	0.7	0.3	0.3	0.0	0.6	2.2	0.3	0.0	0.3	71.4	0.8	0.1	0.1
Gov. Spend.	0.0	0.0	0.0	0.0	0.0	1.3	1.5	0.0	0.2	0.1	0.0	0.1	96.7	0.0	0.0	0.0	0.0
Uncond. Variance																	
GDP	6.2	5.8	2.4	8.6	14.3	19.9	18.8	0.5	2.3	4.1	2.0	0.0	13.0	0.2	0.0	0.5	1.1
Cons.	49.9	1.4	0.9	1.7	3.6	16.0	22.4	0.0	1.3	1.9	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Invest.	1.7	9.3	3.5	14.2	22.5	18.4	13.2	0.9	2.2	6.6	3.8	0.0	0.2	0.4	0.0	0.9	2.0
Hours	0.8	22.6	16.3	2.5	5.5	7.1	13.1	0.3	5.5	13.7	1.3	0.0	7.2	1.3	0.0	1.2	1.5
Infl.	1.4	4.3	2.1	8.9	12.4	2.4	5.2	0.7	5.7	23.4	20.7	0.0	0.1	0.4	0.0	3.5	8.4
Cap. Tax	0.6	3.6	2.7	5.1	12.5	6.1	8.6	0.4	2.8	6.1	0.3	0.0	2.1	0.3	0.0	12.8	30.8
Lab. Tax	0.3	11.9	8.3	6.2	14.4	10.2	15.1	0.4	0.4	0.9	1.3	0.0	25.8	2.7	0.0	0.9	0.1
Gov. Spend.	0.0	0.1	0.1	0.0	0.1	1.8	3.0	0.0	0.3	0.6	0.0	0.1	93.9	0.0	0.0	0.0	0.0

Notes: Variance decompositions are performed at the posterior median. ε_i^0 represents contemporaneous shock components; $\varepsilon_i^{4,8}$ represents the sum of the 4 and 8 quarter anticipated shock components. For ease of exposition, we have combined the two anticipated shock components into one and left out the anticipated stationary investment-specific shocks that contribute less than 0.01 percent to the variance of the variables. Due to space constraints, we also do not show the shocks' variance contributions to wages and the interest rate.

Table 5: Variance Decomposition, Federal Government Only (in %):

	Pref./Wage Markup			Technology							Policy						
	ξ^{pref}	ε_w^0	$\varepsilon_w^{4,8}$	ε_z^0	$\varepsilon_z^{4,8}$	ε_x^0	$\varepsilon_x^{4,8}$	ε_{zI}^0	ε_a^0	$\varepsilon_a^{4,8}$	ξ^R	ε_g^0	$\varepsilon_g^{4,8}$	$\varepsilon_{\tau n}^0$	$\varepsilon_{\tau n}^{4,8}$	$\varepsilon_{\tau k}^0$	$\varepsilon_{\tau k}^{4,8}$
4 periods																	
GDP	10.5	0.0	3.4	10.4	7.4	17.8	6.2	0.7	1.4	1.5	7.1	0.0	1.1	7.8	22.5	0.8	0.8
Cons.	47.3	0.0	0.2	2.8	1.8	15.5	12.8	0.4	3.0	5.8	0.2	0.0	0.8	2.0	5.8	0.3	1.0
Invest.	0.6	0.0	5.1	11.3	8.2	5.6	1.2	1.1	7.6	11.1	11.8	0.0	0.7	8.6	24.6	0.9	0.7
Hours	1.1	0.0	3.4	10.4	5.2	3.4	4.7	0.5	10.7	10.0	8.1	0.0	0.6	8.7	17.1	13.0	2.5
Infl.	0.4	0.0	4.5	7.8	4.7	1.4	0.2	0.0	5.7	16.5	7.2	0.0	0.6	4.7	12.6	6.0	27.3
Cap. Tax	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	82.3	0.0
Lab. Tax	0.1	0.0	0.2	1.0	0.3	0.4	0.3	0.0	1.0	0.8	0.7	0.0	0.0	49.8	1.1	1.2	0.2
Gov. Spend.	0.0	0.0	0.0	0.0	0.0	97.0	0.0	0.0	0.9	0.0	0.1	1.8	0.0	0.0	0.0	0.0	0.0
16 periods																	
GDP	6.0	0.0	2.6	7.1	5.2	13.2	7.1	0.5	2.0	1.7	5.3	0.0	24.1	5.4	15.8	1.2	2.2
Cons.	41.3	0.0	0.2	2.9	1.9	17.6	15.0	0.5	3.1	6.0	0.2	0.0	0.9	2.2	6.3	0.4	1.1
Invest.	0.5	0.0	5.2	10.7	8.1	5.2	1.6	0.9	6.8	9.6	11.7	0.0	0.7	8.1	23.6	2.3	4.1
Hours	0.5	0.0	10.5	4.2	4.3	2.8	1.7	0.1	3.9	6.8	2.4	0.0	1.9	13.5	37.2	3.8	5.9
Infl.	0.4	0.0	4.4	7.1	4.9	1.2	0.2	0.0	5.9	17.4	6.6	0.0	0.6	4.8	13.3	5.4	27.2
Cap. Tax	0.0	0.0	0.3	0.8	0.7	0.0	0.0	0.0	0.3	0.6	0.1	0.0	0.1	0.7	2.1	25.0	66.0
Lab. Tax	0.1	0.0	11.8	0.7	4.0	0.4	0.3	0.1	6.2	9.6	1.5	0.0	0.3	24.0	26.9	1.2	0.9
Gov. Spend.	0.0	0.0	0.0	0.0	0.0	2.3	2.5	0.0	0.2	0.1	0.0	0.0	94.9	0.0	0.0	0.0	0.0
Uncond. Variance																	
GDP	5.6	0.0	3.9	8.1	6.1	12.5	6.7	0.5	2.4	3.4	5.0	0.0	22.4	6.2	11.0	1.7	3.8
Cons.	41.4	0.0	0.4	3.0	2.0	17.7	15.1	0.5	3.7	7.4	0.2	0.0	1.0	2.3	4.0	0.5	0.4
Invest.	0.6	0.0	7.2	11.6	9.2	5.3	1.7	0.7	6.4	11.3	9.6	0.0	0.7	8.8	15.7	2.8	7.5
Hours	0.4	0.0	12.1	3.5	3.6	4.6	4.2	1.5	6.2	12.5	2.1	0.0	7.4	8.8	15.4	2.7	14.1
Infl.	0.4	0.0	5.9	7.9	5.4	3.2	2.7	0.2	9.5	24.9	7.2	0.0	0.7	5.4	9.2	6.3	10.5
Cap. Tax	0.1	0.0	5.3	1.9	1.5	2.3	2.0	0.1	1.1	3.0	0.3	0.0	0.8	1.6	2.8	22.6	51.6
Lab. Tax	0.2	0.0	7.9	3.4	3.1	2.5	2.5	6.5	15.1	31.8	0.7	0.0	14.2	2.7	3.4	0.4	2.4
Gov. Spend.	0.0	0.0	0.1	0.0	0.0	2.3	2.7	0.0	0.5	0.8	0.0	0.0	93.4	0.0	0.0	0.0	0.0

Notes: See the notes to Table 4.

B Stationary Equilibrium

In order to derive a state-space representation of the model, the model presented in the main text is solved by using a first-order perturbation method. However, due to the two integrated processes A_t and X_t, which grow with rates

$$\mu_t^a = \frac{A_t}{A_{t-1}}, \quad \mu_t^x = \frac{X_t}{X_{t-1}}, \tag{24}$$

the model has to be detrended first in order to induce stationarity and to have a well-defined steady state. Y_t, C_t and W_t inherit the trend $X_t^Y = A^{\frac{\alpha}{\alpha-1}} X_t$, which corresponds to a growth rate of

$$\mu_t^y = (\mu_t^a)^{\frac{\alpha}{\alpha-1}} \mu_t^x. \tag{25}$$

K_t and I_t inherit the trend $X_t^K = A^{\frac{1}{\alpha-1}} X_t$ and thus grow with

$$\mu_t^k = \mu_t^I = (\mu_t^a)^{\frac{1}{\alpha-1}} \mu_t^x. \tag{26}$$

G_t inherits $X_t^G = \left(X_{t-1}^G\right)^{\rho_{xg}} \left(X_{t-1}^Y\right)^{1-\rho_{xg}}$ due to the assumed cointegrated trend with output. It hence grows with rate

$$x_t^g = \frac{(x_{t-1}^g)^{\rho_{xg}}}{\mu_t^y}. \tag{27}$$

The detrending is performed by dividing the trending model variables by their respective trend. For the estimation of our structural model, these stationary model variables are matched to the data presented in Appendix D.

C Observation Equation

The observation equation describes how the empirical times series are matched to the corresponding model variables:[37]

$$
OBS_t = \begin{bmatrix} \Delta\log(Y_t) \\ \Delta\log(C_t) \\ \Delta\log\left(z_t^I A_t I_t\right) \\ \log\left(\frac{L_t}{L}\right) \\ \Delta\log(G_t) \\ \Delta\log\left(z_t^I A_t\right) \\ \tau_t^k \\ \tau_t^n \\ \Delta\log(TFP_t) \\ \Delta\log(W_t) \\ \log\left(\frac{R_t}{R}\right) \\ \log\left(\frac{\Pi_t}{\Pi}\right) \end{bmatrix} \times 100 = - \begin{bmatrix} \log(\mu^y) \\ \log(\mu^y) \\ \log(\mu^y) \\ 0 \\ \log(\mu^y) \\ \log(\mu^a) \\ 0 \\ 0 \\ (1-\alpha)\log(\mu^x) \\ \log(\mu^y) \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} + \hat{\mu}_t^y \\ \hat{c}_t - \hat{c}_{t-1} + \hat{\mu}_t^y \\ \hat{i}_t - \hat{i}_{t-1} + \hat{z}_t^I - \hat{z}_{t-1}^I + \hat{\mu}_t^y \\ \hat{L}_t \\ \hat{g}_t - \hat{g}_{t-1} + \hat{x}_t^g - \hat{x}_{t-1}^g + \hat{\mu}_t^y \\ \hat{\mu}_t^a + \hat{z}_t^I - \hat{z}_{t-1}^I \\ \tau_t^k \\ \tau_t^n \\ \hat{z}_t - \hat{z}_{t-1} + (1-\alpha)\hat{\mu}_t^x \\ \hat{w}_t + \hat{w}_{t-1} + \hat{\mu}^y \\ \hat{R}_t \\ \hat{\Pi}_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{y,t}^{me} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \varepsilon_{\tau k,t}^{me} \\ \varepsilon_{\tau n,t}^{me} \\ 0 \\ \varepsilon_{w,t}^{me} \\ 0 \\ 0 \end{bmatrix},
$$

where Δ denotes the temporal difference operator, L denotes the steady state of hours worked, μ^y is the steady state growth rate of output[38], μ^a is the steady state growth rate of the relative price of investment, $TFP_t = z_t X_t^{1-\alpha}$ is total factor productivity, and R is the steady state interest rate. The hats above the variables denote log deviations from steady state. Due to potential mismeasurement of tax rates and wages, we follow Sargent (1989) and Ireland (2004) allow for measurement error in those variables. Moreover, to avoid stochastic singularity of the model, we allow for measurement error in output.

[37]The equation for L_t follows from

$$\log L_t = \log\left(L_t \frac{L}{L}\right) \approx \hat{L}_t + \log L \ .$$

The equation for government spending follows from

$$\log\frac{G_t}{G_{t-1}} = \log\frac{g_t X_t^g}{g_{t-1}X_{t-1}^g} = \log\frac{g_t x_t^g X_t^Y}{g_{t-1}x_{t-1}^g X_{t-1}^Y} = \log\frac{g_t x_t^g}{g_{t-1}x_{t-1}^g}\mu_t^y \ .$$

Note that the presence of x^g also implies that there is no perfect linear restriction between the GDP components following from the resource constraint. Hence, we do not need to add additional measurement error.

[38]This is also the growth rate of the individual components of GDP along the balanced growth path.

D Data construction

Unless otherwise noted, all data are from the Bureau of Economic Analysis (BEA)'s NIPA Tables and available in quarterly frequency from 1955Q1 until 2006Q4.

Capital and labor tax rates. Our approach to calculate average tax rates closely follows Mendoza et al. (1994), Jones (2002), and Leeper et al. (2010). We first compute the average personal income tax rate

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

where IT is personal current tax revenues (Table 3.1 line 3), W is wage and salary accruals (Table 1.12 line 3), PRI is proprietor's income (Table 1.12 line 9), and $CI \equiv PRI/2 + RI + CP + NI$ is capital income. Here, RI is rental income (Table 1.12 line 12), CP is corporate profits (Table 1.12 line 13), and NI denotes the net interest income (Table 1.12 line 18).

The average labor and capital income tax rates can then be computed as

$$\tau^n = \frac{\tau^p(W + PRI/2) + CSI}{EC + PRI/2} \ ,$$

where CSI denotes contributions for government social insurance (Table 3.1 line 7), and EC is compensation of employees (Table 1.12 line 2), and

$$\tau^k = \frac{\tau^p CI + CT + PT}{CI + PT} \ ,$$

where CT is taxes on corporate income (Table 3.1 line 5), and PT is property taxes (Table 3.3 line 8).

Government spending. Government spending is the sum of government consumption (Table 3.1 line 16) and government investment (Table 3.1 line 35) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

Total factor productivity (TFP). The TFP series is taken from Fernald (2012), who closely follows Basu et al. (2006) and provides a quarterly series that is adjusted for capital and labor utilization.

Relative price of investment. The relative price of investment is taken from Schmitt-Grohé and Uribe (2011). They base their calculations on Fisher (2006).

Output. Nominal GDP (Table 1.1.5 line 1) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

Investment. Sum of Residential fixed investment (Table 1.1.5 line 12) and nonresidential fixed investment (Table 1.1.5 line 9) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

Consumption. Sum of personal consumption expenditures for nondurable goods (Table 1.1.5 line 5) and services (Table 1.1.5 line 6) divided by the GDP deflator (Table 1.1.4 line 1) and the civilian noninstitutional population (BLS, Series LNU00000000Q).

Real wage. Hourly compensation in the nonfarm business sector (BLS, Series PRS85006103) divided by the GDP deflator (Table 1.1.4 line 1).

Inflation. Computed as the log-difference of the GDP deflator (Table 1.1.4 line 1).

Nominal interest rate. Geometric mean of the effective Federal Funds Rate (St.Louis FED - FRED Database, Series FEDFUNDS).

Hours worked. Nonfarm business hours worked (BLS, Series PRS85006033) divided by the civilian noninstitutional population (BLS, Series LNU00000000Q)

Debt. Gross Federal Debt (St.Louis FED - FRED Database, Series FYGFD).

References

An, Sungbae, Schorfheide, Frank, 2007. Bayesian Analysis of DSGE Models. Econometric Reviews 26, 113–172.

Auerbach, Alan J., 1989. Tax Reform and Adjustment Costs: The Impact on Investment and Market Value. International Economic Review 30, 939–962.

Barro, Robert J., Redlick, Charles J., 2011. Macroeconomic Effects from Government Purchases and Taxes. Quarterly Journal of Economics 126 (1), 51–102.

Barro, Robert J, Sahasakul, Chaipat, 1983. Measuring the Average Marginal Tax Rate from the Individual Income Tax. Journal of Business 56, 419–52.

Barsky, Robert B., Sims, Eric, 2011. News Shocks and Business Cycles. Journal of Monetary Economics 58, 273–289.

Basu, Susanto, Fernald, John G., Kimball, Miles S., 2006. Are Technology Improvements Contractionary? American Economic Review 96, 1418–1448.

Baxter, Marianne, King, Robert G, 1993. Fiscal Policy in General Equilibrium. American Economic Review 83, 315–34.

Beaudry, Paul, Portier, Franck, 2004. An Exploration into Pigou's Theory of Cycles. Journal of Monetary Economics 51, 1183–1216.

— 2006. Stock Prices, News, and Economic Fluctuations. American Economic Review 96, 1293–1307.

Blanchard, Olivier J., Perotti, Roberto, 2002. An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. Quarterly Journal of Economics 117, 1329–1368.

Born, Benjamin, Pfeifer, Johannes, 2011. Policy Risk and the Business Cycle. Bonn Econ Discussion Papers 06/2011.

Born, Benjamin, Peter, Alexandra, Pfeifer, Johannes, 2011. Fiscal News and Macroeconomic Volatility. Bonn Econ Discussion Papers 08/2011.

Calvo, Guillermo A., 1983. Staggered Prices in a Utility-Maximizing Framework. Journal of Monetary Economics 12, 383–398.

Cardia, Emanuela, Kozhaya, Norma, Ruge-Murcia, Francisco J., 2003. Distortionary Taxation and Labor Supply. Journal of Money, Credit and Banking 35, 350–73.

Chari, V. V., Kehoe, Patrick J., McGrattan, Ellen R., 2009. New Keynesian Models: Not Yet Useful for Policy Analysis. American Economic Journal: Macroeconomics 1, 242–266.

Chib, Siddharta, Ramamurthy, Srikanth, 2010. Tailored Randomized Block MCMC Methods with Application to DSGE Models. Journal of Econometrics 155, 19–38.

Christiano, Lawrence J., Eichenbaum, Martin, Evans, Charles L., 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. Journal of Political Economy 113, 1–45.

Christiano, Lawrence J., Ilut, Cosmin, Motto, Roberto, Rostagno, Massimo, 2008. Monetary Policy and Stock Market Boom-Bust Cycles. ECB Working Paper Series 955.

Christiano, Lawrence J., Trabandt, Mathias, Walentin, Karl, 2011. Introducing Financial Frictions and Unemployment Into a Small Open Economy Model. Journal of Economic Dynamics and Control 35, 1999–2041.

Clarida, Richard, Galí, Jordi, Gertler, Mark, 2000. Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. Quarterly Journal of Economics 115, 147–180.

Davis, Joshua M., 2007. News and the Term Structure in General Equilibrium. Mimeo.

Del Negro, Marco, Schorfheide, Frank, 2008. Forming Priors for DSGE Models (and how it Affects the Assessment of Nominal Rigidities). Journal of Monetary Economics 55, 1191–1208.

Fernald, John, 2012. A Quarterly, Utilization-Adjusted Series on Total Factor Productivity. Federal Reserve Bank of San Francisco Working Paper 2012-19.

Fernández-Villaverde, Jesús, 2010. The Econometrics of DSGE Models. SERIEs 1, 3–49.

Fernández-Villaverde, Jesús, Rubio-Ramírez, Juan F., Sargent, Thomas J., Watson, Mark W., 2007. ABCs (and Ds) of Understanding VARs. American Economic Review 97, 1021–1026.

Fernández-Villaverde, Jesús, Guerrón-Quintana, Pablo A., Kuester, Keith, Rubio-Ramírez, Juan, 2011. Fiscal Volatility Shocks and Economic Activity. NBER Working Papers 17317.

Fisher, Jonas D.M., 2006. The Dynamic Effects of Neutral and Investment Specific Technology Shocks. Journal of Political Economy 114, 413–451.

Forni, Lorenzo, Monteforte, Libero, Sessa, Luca, 2009. The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area. Journal of Public Economics 93, 559–585.

Forni, Mario, Gambetti, Luca, 2010. Fiscal Foresight and the Effects of Goverment Spending. CEPR Discussion Papers 7840.

Forni, Mario, Gambetti, Luca, Sala, Luca, 2011. No News in Business Cycles. CEPR Discussion Papers 8274.

Fujiwara, Ippei, Hirose, Yasuo, Shintani, Mototsugu, 2011. Can News Be a Major Source of Aggregate Fluctuations? A Bayesian DSGE Approach. Journal of Money, Credit and Banking 43, 1–29.

Galí, Jordi, López-Salido, J. David, Vallés, Javier, 2007. Understanding the Effects of Government Spending on Consumption. Journal of the European Economic Association 5, 227–270.

Galí, Jordi, Smets, Frank, Wouters, Rafael, 2011. Unemployment in an Estimated New Keynesian Model, in: NBER Macroeconomics Annual 2011, Volume 26.

Gambetti, Luca, 2012. Government Spending News and Shocks. Mimeo, Universitat Autonoma de Barcelona.

Giannone, Domenico, Reichlin, Lucrezia, 2006. Does Information Help Recovering Structural Shocks From Past Observations? Journal of the European Economic Association 4, 455–465.

Greenwood, Jeremy, Hercowitz, Zvi, Huffman, Gregory W., 1988. Investment, Capacity Utilization, and the Real Business Cycle. American Economic Review 78, 402–17.

Greenwood, Jeremy, Hercowitz, Zvi, Krusell, Per, 1997. Long-Run Implications of Investment-Specific Technological Change. American Economic Review 87, 342–362.

— 2000. The Role of Investment-Specific Technological Change in the Business Cycle. European Economic Review 44, 91–115.

Hansen, Lars Peter, Sargent, Thomas J., 1991. Two Difficulties in Interpreting Vector Autoregressions, in: Rational Expectations Econometrics, ed. by Robert Lucas, Thomas Sargent, pp. 77–119.

House, Christopher L., Shapiro, Matthew D., 2006. Phased-In Tax Cuts and Economic Activity. American Economic Review 96, 1835–1849.

Ireland, Peter N., 2004. A Method for Taking Models to the Data. Journal of Economic Dynamics and Control 28, 1205–1226.

Jaimovich, Nir, Rebelo, Sergio, 2009. Can News about the Future Drive the Business Cycle? American Economic Review 99, 1097–1118.

Jones, John Bailey, 2002. Has Fiscal Policy Helped Stabilize the Postwar U.S. Economy? Journal of Monetary Economics 49, 709–746.

Justiniano, Alejandro, Primiceri, Giorgio E., Tambalotti, Andrea, 2010a. Investment Shocks and Business Cycles. Journal of Monetary Economics 57, 132 –145.

— 2010b. Investment Shocks and Business Cycles, Online Appendix. Available at `http://faculty.wcas.northwestern.edu/~gep575/samm_OnlineAppendix5_gt.pdf` (accessed February 28th, 2010).

— 2011. Investment Shocks and the Relative Price of Investment. Review of Economic Dynamics 14, 102–121.

— 2013. Is There a Trade-off Between Inflation and Output Stabilization? American Economic Journal: Macroeconomics 5, 1–31.

Khan, Hashmat, Tsoukalas, John, 2012. The Quantitative Importance of News Shocks in Estimated DSGE Models. Journal of Money, Credit and Banking 44, 1535–1561.

King, Robert G., Plosser, Charles I., Rebelo, Sergio T., 1988. Production, Growth and Business Cycles: I. The Basic Neoclassical Model. Journal of Monetary Economics 21, 195–232.

Kliem, Martin, Kriwoluzky, Alexander, 2012. Toward a Taylor Rule for Fiscal Policy. Mimeo, University of Bonn.

Kurmann, André, Otrok, Christopher, forthcoming. News Shocks and the Slope of the Term Structure of Interest Rates. American Economic Review.

Leeper, Eric M., Walker, Todd B., 2011. Information Flows and News Driven Business Cycles. Review of Economic Dynamics 14, 55–71.

Leeper, Eric M., Plante, Michael, Traum, Nora, 2010. Dynamics of Fiscal Financing in the United States. Journal of Econometrics 156, 304–321.

Leeper, Eric M., Walker, Todd B., Yang, Shu-Chun Susan, 2012. Fiscal Foresight and Information Flows. Technical Appendix.

— forthcoming. Fiscal Foresight and Information Flows. Econometrica.

Lubik, Thomas A., Schorfheide, Frank, 2007. Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation. Journal of Monetary Economics 54, 1069–1087.

McGrattan, Ellen R., 1994. The Macroeconomic Effects of Distortionary Taxation. Journal of Monetary Economics 33, 573–601.

— 2012. Capital Taxation During the U.S. Great Depression. Quarterly Journal of Economics 127, 1515–1550.

Mendoza, Enrique G., Razin, Assaf, Tesar, Linda L., 1994. Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption. Journal of Monetary Economics 34, 297–323.

Mertens, Karel, Ravn, Morten O., 2011. Understanding the Aggregate Effects of Anticipated and Unanticipated Tax Policy Shocks. Review of Economic Dynamics 14, 27–54.

Mertens, Karel, Ravn, Morten O., 2012. Empirical Evidence on the Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks. American Economic Journal: Economic Policy 4, 145–181.

Monacelli, Tommaso, Perotti, Roberto, 2008. Fiscal Policy, Wealth Effects, and Markups. NBER Working Papers 14584.

Mountford, Andrew, Uhlig, Harald, 2009. What Are the Effects of Fiscal Policy Shocks? Journal of Applied Econometrics 24, 960–992.

Nutahara, Kengo, 2010. Internal and External Habits and News-Driven Business Cycles. Economics Letters 107, 300–303.

Parker, Jonathan A., 1999. The Reaction of Household Consumption to Predictable Changes in Social Security Taxes. American Economic Review 89, 959–973.

Poterba, James M., 1988. Are Consumers Forward Looking? Evidence from Fiscal Experiments. American Economic Review 78, 413–418.

Ramey, Valerie A., 2011. Identifying Government Spending Shocks: It's all in the Timing. Quarterly Journal of Economics 126, 1–50.

Romer, Christina D., Romer, David H., 2010. The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks. American Economic Review 100, 763–801.

Sargent, Thomas J, 1989. Two Models of Measurements and the Investment Accelerator. Journal of Political Economy 97, 251–87.

Schmitt-Grohé, Stephanie, Uribe, Martín, 2006. Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model, in: NBER Macroeconomics Annual 2005, Volume 20, pp. 383–462.

— 2011. Business Cycles With A Common Trend in Neutral and Investment-Specific Productivity. Review of Economic Dynamics 14, 122–135.

— 2012. What's News in Business Cycles. Econometrica 80, 2733–2764.

Sims, Eric, 2012. Non-Invertibilities and Structural VARs. Advances in Econometrics 28, 81–135.

Smets, Frank, Wouters, Raf, 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. Journal of the European Economic Association 1, 1123–1175.

Smets, Frank, Wouters, Rafael, 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. American Economic Review 97, 586–606.

Yang, Shu-Chun Susan, 2005. Quantifying Tax Effects Under Policy Foresight. Journal of Monetary Economics 52, 1557–1568.

Yun, Tack, 1996. Nominal Price Rigidity, Money Supply Endogeneity, and Business Cycles. Journal of Monetary Economics 37, 345–370.