Explaining the Effects of Fiscal Shocks

by

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Dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in the Department of Economics
in the Graduate School of Duke University
2010

Abstract

(Economics)

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Abstract

This dissertation is motivated by the fact that while the literature has had a great deal of success in developing empirical models for monetary policy analysis, the same can not be said for fiscal policy. This work advances our understanding of various issues in identification and modeling of fiscal policy shocks. In particular, the first two chapters work towards building a compelling empirical model for fiscal policy evaluation and the last chapter addresses the importance of fiscal shocks, along with monetary shocks in explaining aggregate macroeconomic fluctuations.

Chapter 1 identifies and explains the effects of a government spending shock. In response to a structural unanticipated government spending shock, output, hours, consumption and wages all rise, whereas investment falls on impact. An estimated dynamic general equilibrium model featuring deep habit formation successfully explains these effects. In particular, deep habits give rise to countercyclical markups and thus act as transmission mechanism for the effects of government spending shocks on private consumption and wages. In addition, I show that deep habits significantly improve the fit of the model compared to a model with habit formation at the level of aggregate goods.

While Chapter 1 considers public spending financed by lump-sum taxes, Chapter 2 further extends the framework to allow for distortionary taxes, and a more careful modeling of the government financing behavior. I use full information Bayesian techniques to estimate this dynamic stochastic equilibrium model, and characterize

the dynamics of the economy in the case of both spending and tax changes. I estimate fiscal multipliers and find the multiplier for government spending to be 1.12, and the maximum impact is when the spending shock hits the economy. In addition, the model predicts a positive but small response of private consumption to increased government spending. The multipliers for labor and capital tax on impact are 0.13 and 0.33, respectively. The effects of tax cuts, on the other hand, take time to build, and exceed the stimulative effects of higher spending at horizons of 12-20 quarters. The expansionary effects of tax cuts are primarily driven by the response of investment. I also carry out several counterfactual exercises to show how alternative financing methods and expected monetary policy have consequences for the size of fiscal multipliers. In addition, I simulate the effects of the American Recovery and Reinvestment Act of 2009 in the context of this empirical model.

The final chapter, which is joint work with Barbara Rossi, analyzes the role of government spending shocks along with monetary policy shocks in explaining macroeconomic fluctuations, in a structural vector autoregression (VAR) where both shocks are identified simultaneously. Our main finding is that government spending shocks are relatively more important in explaining medium cycle fluctuations (defined between 32 and 200 quarters) and monetary shocks play a larger role in explaining business cycle frequencies (between 8 and 32 quarters). We also find that failing to recognize that both monetary and fiscal policy simultaneously affect macroeconomic variables might incorrectly attribute fluctuations to the wrong source.

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1

Explaining the Effects of Government Spending Shocks

1.1 Introduction

Recently in public debates, there is renewed interest in the role fiscal instruments play in stabilizing the economy and about the dynamic effects of discretionary fiscal policy. I am interested in the latter question and the objective of this paper is to identify and explain the effects of government spending shocks in an estimated model.

While many studies have focused on using dynamic stochastic general equilibrium (DSGE) models to analyze consequences of monetary policy and have had great success, I would like to study the effects of fiscal policy in a similar framework. In this paper, I start by showing that since most pre-existing models are not suitable for studying fiscal shocks, understanding the effects of an unexpected increase in government purchases is additionally of particular interest for assessing empirical validity of competing macroeconomic models.

In the case of fiscal policy, identification of shocks is complicated due to the fact that there are usually lags between the announcement of a change in spending or taxes, and the actual implementation once the legislation passes through Congress. Blanchard and Perotti (2002) show that government spending does not react to other contemporaneous macroeconomic variables automatically and so government spending shocks can be identified by a recursive ordering with government spending ordered first in a vector autoregression (VAR).[1] In an alternative approach, Ramey and Shapiro (1998) identified spending shocks by events that signal large military buildups in US history. Ramey (2008) shows that these dates of military buildup Granger-cause the identified structural shocks. Since these events can be thought of as anticipated increases in government defense spending, I have put together both identification schemes to construct structural spending shocks which are independent of any information in the identified military buildup episodes. I find that in response to an unexpected rise in government spending, output, consumption, wages and hours worked, all go up, whereas investment declines on impact.

Baxter and King (1993) show that in a simple real business cycle model with lump-sum taxes, when government spending rises, households face higher taxes and due to the negative wealth effects, they inevitably lower their consumption and increase hours worked. This increase in labor supply also causes real wages to fall. Thus, these models are unable to generate the positive response of consumption and wages to a government spending shock.

Some recent studies have recognized this shortcoming of the existing models and have had varying degree of success in qualitatively matching the response of a few variables of interest. For instance, Linnemann and Schabert (2003) show that in a model with sticky prices, in response to a rise in aggregate demand, firms raise labor demand, which puts upward pressure on wages. However, even in the case where labor demand rises sufficiently to overcome the rise in labor supply, and we

[1] This is the same approach followed by Fatas and Mihov (2001), Gali, Lopez-Salido, and Valles (2007) and Perotti (2007).

see wages going up, it does not necessarily lead to a positive response of consumption. Gali, Lopez-Salido, and Valles (2007) introduce a model that does a fairly good job at matching the qualitative responses of wages and consumption. In addition to sticky prices, they model non-competitive behavior in labor markets and a fraction of the economy consisting of rule of thumb consumers who can not borrow and save, and consume their entire current income each period. If close to half of all consumers in the economy are assumed to be credit constrained, they get a positive response of consumption to a government spending shock. However, the empirical relevance of this explanation has been questioned by Coenen and Straub (2005) who estimate this model with credit constrained consumers for the Euro area. They find the estimated share of rule-of-thumb consumer being relatively low, and unable to generate a positive response of consumption to a government spending shock.[2]

An alternative approach that can successfully predict the positive responses of wages and consumption in response to a government spending shock is introduced in Ravn, Schmitt-Grohe, and Uribe (2006). They develop a model of deep habits in an economy with imperfectly competitive product markets. Deep habits imply that households form habits over narrowly defined categories of consumption goods, such as cars, clothing etc. This feature gives rise to a demand function with a price-elastic component that depends on aggregate consumption demand, and a perfectly price-inelastic component. An increase in aggregate demand in the form of government purchases increases the share of the price-elastic component, and so this rise in price elasticity induces the firms to reduce the markup of price over marginal cost.[3] Thus

[2] Forni, Monteforte, and Sessa (2009) also estimate a DSGE model with rule-of-thumb consumers for Euro data, but model taxes and composition of government spending differently, and get a positive response of consumption. Lopez-Salido and Rabanal (2006) carry out a similar estimation exercise for US data, but they also include non-separable preferences in their framework. They show that allowing for this complementarity between consumption and hours worked leads to a small estimated fraction of rule of thumb consumers, and these two features can work together to give a positive response of consumption.

[3] In an earlier paper, Rotemberg and Woodford (1992) also model countercyclical markups in

labor demand goes up and if the labor demand exceeds labor supply, wages go up in response to a government spending shock. This higher real wage causes individuals to substitute away from leisure towards consumption, resulting in a rise in consumption. I incorporate this mechanism, which has not been explored to a great extent in the context of models explaining the US economy, in my theoretical model.[4]

In contrast to most of the aforementioned studies and others which typically involve only qualitatively matching the impact responses of a few particular variables to a public spending shock, I am undertaking a more complete analysis where firstly instead of calibrating the parameters of the model, I estimate them using evidence from the US data, and secondly I also account for responses of a broader variety of key macroeconomic variables.[5] I am considering a medium scale DSGE model with several nominal and real rigidities that capture the high degree of persistence characterizing macroeconomic time series, developed in Christiano, Eichenbaum, and Evans (2005), which has been shown to fit the data well along different dimensions. The specific departure in this paper is the introduction of deep habits, as a transmission mechanism for government spending shocks.

The model is estimated using a Laplace type estimator suggested by Chernozhukov and Hong (2003), which are defined similarly to Bayesian estimators, but instead of the parametric likelihood function, one can use a general statistical criterion func-

order to generate a rise in real wage along with output in response to demand shocks, with strategic interactions between colluding firms.

[4] Recently, Ravn, Schmitt-Grohe, and Uribe (2007) have used deep habits in an open economy model and shown that it helps to explain the responses of consumption and exchange rate to a domestic public spending shock.

[5] Burnside, Eichenbaum, and Fisher (2004) is similar in spirit as they quantitatively match impulse response functions of several macro variables to a government spending shock. However, the fundamental difference is the identification scheme they use to identify government spending shock which relies on narrative evidence on episodes of military buildup presented in Ramey and Shapiro (1998). They also consider distortionary taxes in their model, whereas in this paper I am only considering lump-sum taxes, however considering distortionary taxation is an extension worth pursuing in future work.

tion. In this paper, I am using the distance between the impulse response function implied by the empirical model and the ones generated by theoretical model. The estimation results suggest that the model does a great job at quantitatively accounting for the estimated responses of the US economy to a public spending shock. In particular, in comparison to a model with superficial habits, the model with deep habits produces impulse responses that are significantly better at matching the magnitude and persistence of the empirical responses for all variables of interest, most notably consumption and real wages.

The rest of the paper is organized as follows: Section 2 describes the empirical evidence regarding the effects of government spending shocks. Section 3 describes the theoretical model with deep habits. In Section 4, I provide the description of the estimation procedure used. Section 5 presents the estimation results and dynamics for both models with superficial and deep habits, Section 6 compares deep habits with other mechanisms for government spending shocks explored in the literature and finally, Section 7 concludes.

1.2 Empirical Evidence

This section describes how the government spending shocks are identified, and shows the responses of the various macroeconomic variables to this shock.

1.2.1 Identification

In this section I analyze the effects of government spending shocks. There are two approaches that have primarily been used in the literature to identify these shocks, and have seemingly different predictions. Ramey and Shapiro (1998) use information from historical accounts and identified the government spending shocks as dates where large increases in defense spending were anticipated. The military date variable, D_t, takes value of 1 in the following quarters: 1950:3, 1965:1 and 1980:1, which correspond with the start of the Korean War, the Vietnam war and the Carter-Reagen buildup respectively. Recently September 11th, 2001 has also been added to the list.

Blanchard and Perotti (2002) identify a government spending shock by using institutional information to show that government spending is predetermined relative to other macroeconomic variables and does not respond contemporaneously to output, consumption etc. in quarterly data. This identification scheme is implemented by ordering government spending first in a VAR and using a Choleski decomposition.

With government spending shocks, implementation lags is a major concern since there may be delay between the announcement and the actual implementation of a government spending change. Ramey (2008) shows that the structurally identified government spending shocks are Granger caused by the lags of the Ramey-Shapiro dummy, as evidence that the structurally identified shocks are in fact not entirely unanticipated.

In this paper, in order to capture unanticipated government spending shocks, I combine the two approaches. For this purpose I use the new narrative evidence presented in Ramey (2008), that is much richer than the Ramey-Shapiro military dates, as it includes additional events when the newspapers started forecasting significant changes in government spending, is no longer a binary dummy variable, and for the dates identified, it equals the present discounted value of the anticipated change in government spending. Since I am interested in unanticipated changes in government spending, I run the following reduced form VAR,

$$Y_t = \alpha_0 + \alpha_1 t + A(L)Y_{t-1} + B(L)\epsilon_t^R + u_t, \tag{1.1}$$

where α_0 is a constant, α_1 is the coefficient of the time trend, Y_t is a vector of the variables of interest, ϵ_t^R is the new Ramey variable and u_t is the reduced form shock. The unanticipated government spending shock is then identified by government spending being ordered first in Y_t and then using Choleski decomposition. Note, that in contrast to the approach of Blanchard and Perotti (2002), due to the addition of the Ramey variables and its lags on the right hand side of the equation, the structurally identified shock in this case is orthogonal to the episodes identified in the narrative approach, and thus captures unanticipated changes in government spending [6]. In this specification $A(L)$ and $B(L)$ are polynomials of degree 4.[7] The data spans 1954:3-2008:4, where the starting date is based on availability of federal funds rate data. Y_t is a vector of the following endogenous variables:

$$Y_t = [g_t \quad y_t \quad h_t \quad c_t \quad i_t \quad w_t \quad \pi_t \quad R_t]'$$

where g_t is logarithm of real per capita government spending, y_t is logarithm of real per capita GDP, h_t is logarithm of per capita hours worked, c_t is logarithm of real per capita consumption expenditure on nondurables and services, i_t is the logarithm of real per capita gross domestic investment and consumption expenditures on durables, w_t is logarithm of real wages in the non-farm business sector, π_t is GDP deflator inflation and R_t is the federal funds rate.[8]

1.2.2 Empirical Findings

The impulse responses of the macro variables in Y_t to the government spending shock are shown in Figure 1.1. The shock is a one standard error shock to government spending, and the impulse responses are shown with 95 % confidence bands constructed by Monte Carlo simulations. The response function are shown for a horizon of 20 quarters.

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[6] This was first suggested to me by Martin Uribe. Since then Jordi Gali has made the same point in his NBER discussion of Ramey (2008).

[7] Akaike and Schwartz criterion support lags lengths of 2 and 1 respectively. The empirical results shown here are robust to these lag lengths.

[8] All the data sources are provided in the Appendix.

Notice that the government spending shock is extremely persistent. Output rises significantly in response to a positive government spending shock. Hours also rise to a significant degree with a slight delay. Investment falls initially and rises after 4 quarters, but the response is insignificant for all horizons following the impact response. The two variables of interest and controversy in the fiscal literature, consumption and wages, both rise in response to this shock. Most of the variables have a hump-shaped response which is extremely persistent and peaks between 10-12 quarters after the shock hits the economy.

The responses shown are broadly consistent with the ones shown in Blanchard and Perotti (2002), Fatas and Mihov (2001) and Gali, Lopez-Salido, and Valles (2007), which employ similar identification schemes, even though the sample size has been updated to include recent data. The impact government spending multiplier for GDP found here is 0.94, which is similar in magnitude to 0.90 found in Blanchard and Perotti (2002), and slightly greater than 1 found by Fatas and Mihov (2001). All these studies also find consumption and wages rising significantly in response to a government spending shock. Mountford and Uhlig (2002) use an agnostic identification procedure based on sign restrictions to identify government spending shocks, and find a weak positive response for consumption, and a weak, mostly insignificant response for real wages.[9] As far as the response of investment is concerned, Blanchard and Perotti (2002) find that investment declines significantly for the first five quarters. Similarly, Fatas and Mihov (2001) also find an initial decline in the response of investment before it starts rising, even though their measure of investment excludes durable consumption. They also show that the main component of investment driving this initial drop is non-residential investment. While Mountford

[9] Studies that employ the narrative approach to identifying government spending shocks, like Ramey and Shapiro (1998) and Edelberg, Eichenbaum, and Fisher (1999), typically find product wages falling significantly and an insignificant response for wages deflated by GDP deflator. While Ramey (2008) finds consumption being crowded out, Edelberg, Eichenbaum, and Fisher (1999) and Burnside, Eichenbaum, and Fisher (2004) find an insignificant response for consumption.

and Uhlig (2002) use a different identification scheme, they also find residential and non-residential investment crowded out by a government spending shock.[10]

Since the findings here are very similar to the ones of Blanchard and Perotti (2002) and Fatas and Mihov (2001), this seems to suggest that the anticipation effects captured by the Ramey variable in the VAR given by equation (3.1) are not very significant.[11]

Inflation and nominal interest rate fall in response to the government spending shock, even though the confidence bands are large and the responses are insignificant at most horizons. At first sight, these responses seem counter-intuitive but have been observed by previous empirical studies as well. Fatas and Mihov (2001) show GDP deflator falling and real T-bill rate rising in response to a government spending shock. Perotti (2002) studies the effects of government spending shocks in OECD countries, and finds that inflation and the 10 year nominal interest rate in the US either have insignificant or negative responses. Mountford and Uhlig (2002) meanwhile employ sign restrictions for identification, and also find both GDP deflator and nominal interest rates falling in response to a government expenditure shock.

1.3 Model

I am considering a model economy that has been studied in Christiano, Eichenbaum, and Evans (2005) and Schmitt-Grohe and Uribe (2005), which is rich in elements that are shown to match the empirical response of the economy to monetary and technology shocks. This model consists of nominal frictions like sticky prices and sticky wages and real rigidities, namely investment adjustment costs, variable capacity utilization and imperfect competition in factor and product markets. In this paper,

[10] Narrative studies usually find gross private investment rising on impact and falling with a delay in response to a spending shock.

[11] The appendix shows the IRFs in both the cases of including and excluding ϵ_t^R, the Ramey variable, in equation(1). It is clear that there are no significant differences between the two IRFs.

since the response of macroeconomic variables to a government spending shock is of particular interest, I introduce deep habits, for which the motivation was given in the introduction.

1.3.1 Households

The economy is populated by a continuum of identical households of measure one indexed by $j \in [0, 1]$. Each household $j \in [0, 1]$ maximizes lifetime utility function,

$$E_0 \sum_{t=0}^{\infty} \beta^t U(x_t^{c,j}, h_t^j), \tag{1.2}$$

The preferences are over consumption and leisure, and take the following form,

$$U(x_t^c, h_t) = \frac{[(x_t^c)^a (1 - h_t)^{1-a}]^{1-\sigma} - 1}{1 - \sigma}$$

where $\sigma \geq 0$ is the coefficient of relative risk aversion, or the inverse of the intertemporal elasticity of substitution. The parameter, σ controls the effect of leisure on the marginal utility of consumption.[12] If $\sigma > 1$, it implies $U_{ch} > 0$, i.e. leisure and consumption are gross substitutes and an increase in hours worked increases marginal utility of consumption. This also means that wages will have a positive effect on consumption growth, so that when real wage rate rises, leisure will decline and consumption will rise. On the other hand, $\sigma < 1$ implies $U_{ch} < 0$, raising hours worked decreases marginal utility of consumption.

The variable x_t^c is a composite of habit adjusted consumption of a continuum of differentiated goods indexed by $i \in [0, 1]$,

$$x_t^{c,j} = \left[\int_0^1 (c_{it}^j - b^c s_{it-1}^C)^{1-\frac{1}{\eta}} di \right]^{1/(1-\frac{1}{\eta})}, \tag{1.3}$$

[12] If $\sigma = 1$, it implies a separable, logarithmic utility function of the form, $a \log x_t^c + (1 - a) \log(1 - h_t)$. Note $U_{ch} = 0$ in this case, and so the marginal utility of consumption is independent of the choice of labor.

where s^C_{it-1} denotes the stock of habit in consuming good i in period t. The parameter $b^c \in [0,1)$ measures the degree of external habit formation, and when b^c is zero, the households do not exhibit deep habit formation. The stock of external habit is assumed to depend on a weighted average of consumption in all past periods. Habits are assumed to evolve over time according to the law of motion,

$$s^C_{it} = \rho^c s^C_{it-1} + (1-\rho^c)c_{it}. \tag{1.4}$$

The parameter $\rho^c \in [0,1)$ measures the speed of adjustment of the stock of external habit to variations in the cross-sectional average level of consumption of variety i. When ρ^c takes the value zero, habit is measured by past consumption. As will become apparent later, this slow decay in habit allows for persistence in the markup movements.

For any given level of consumption of $x^{c,j}_t$, purchases of each individual variety of goods $i \in [0,1]$ in period t must solve the dual problem of minimizing total expenditure, $\int_0^1 P_{it}c_{it}di$, subject to the aggregation constraint (2.3), where P_{it} denotes the nominal price of a good of variety i at time t. The optimal level of c^j_{it} for $i \in [0,1]$ is then given by

$$c^j_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} x^{c,j}_t + b^c s^C_{it-1}, \tag{1.5}$$

where P_t is a nominal price index defined as

$$P_t \equiv \left[\int_0^1 P_{it}^{1-\eta}di\right]^{\frac{1}{1-\eta}}.$$

Note that consumption of each variety is decreasing in its relative price, P_{it}/P_t and increasing in level of habit adjusted consumption $x^{c,j}_t$. Notice that the demand function in equation (2.5) has a price-elastic component that depends on aggregate consumption demand, and the second term is perfectly price-inelastic. An increase in aggregate demand increases the share of the price-elastic component, and thus an increase in the elasticity of demand, inducing a decline in the mark-ups. In addition to this, firms also take into account that today's price decisions will affect future demand, as is apparent due to s_{it-1} term, and so when the present value of future per unit profit are expected to be high, firms have an incentive to invest in the customer base today. Thus, this gives them an additional incentive to appeal to a broader customer base by reducing markups in the current period.

Each household provides a differentiated labor service and faces a demand for labor given by $\left(W_t^j/W_t\right)^{-\tilde{\eta}} h_t^d$. Here W_t^j denotes the nominal wage charged by household j at time t, W_t is an index of nominal wages prevailing in the economy, and h_t^d is a measure of aggregate labor demand by firms. At this given wage, the household j is assumed to supply enough labor, h_t^j, to satisfy demand,

$$h_t^j = \left(\frac{w_t^j}{w_t}\right)^{-\tilde{\eta}} h_t^d, \tag{1.6}$$

where $w_t^j \equiv W_t^j/P_t$ and $w_t \equiv W_t/P_t$.

The household is assumed to own physical capital, k_t, which accumulates according to the following law of motion,

$$k_{t+1}^j = (1-\delta)k_t^j + i_t^j \left[1 - \mathcal{S}\left(\frac{i_t^j}{i_{t-1}^j}\right)\right], \tag{1.7}$$

where i_t^j denotes investment by household j and δ is a parameter denoting the rate of depreciation of physical capital. The function $\mathcal{S}$ introduces investment adjustment costs and has the following functional form, $\mathcal{S}\left(\frac{i_t}{i_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2$, and therefore in the steady state it satisfies $\mathcal{S} = \mathcal{S}' = 0$ and $\mathcal{S}'' > 0$. These assumptions imply the absence of adjustment costs up to first-order in the vicinity of the deterministic steady state.

Owners of physical capital can control the intensity at which this factor is utilized. Formally, let u_t measure capacity utilization in period t. It is assumed that using the stock of capital with intensity u_t entails a cost of $a(u_t)k_t$ units of the composite final good.[13] Households rent the capital stock to firms at the real rental rate r_t^k per unit of capital. Total income stemming from the rental of capital is given by $r_t^k u_t k_t$.

Households are assumed to have access to a complete set of nominal state-contingent assets. Specifically, each period $t \geq 0$, consumers can purchase any desired state-contingent nominal payment A_{t+1}^h in period $t+1$ at the dollar cost $E_t r_{t,t+1} A_{t+1}^h$. The variable $r_{t,t+1}$ denotes a stochastic nominal discount factor between periods t and $t+1$. Households pay real lump-sum taxes in the amount τ_t per period.

The household's period-by-period budget constraint is then given by:

$$E_t r_{t,t+1} a_{t+1}^j + x_t^{c,j} + \omega_t^j + i_t^j + a(u_t^j)k_t^j + \tau_t = \frac{a_t^j}{\pi_t} + r_t^k u_t^j k_t^j + w_t^j \left(\frac{w_t^j}{w_t}\right)^{-\tilde{\eta}} h_t^d + \phi_t, \quad (1.8)$$

where $\omega_t = b^c \int_0^1 P_{it} s_{it-1}^C / P_t di$. The variable a_t^j/π_t denotes the real payoff in period t of nominal state-contingent assets purchased in period $t-1$. The variable ϕ_t denotes dividends received from the ownership of firms and $\pi_t \equiv P_t/P_{t-1}$ denotes the gross rate of consumer-price inflation.

The wage-setting decision of the household is subject to a Calvo-type lottery where a household can not reset optimal wages in a fraction $\tilde{\alpha} \in [0, 1)$ of labor markets. In these markets, the wage rate is indexed to last period's inflation, so $w_t^j = w_{t-1}^j \pi_{t-1}$.

[13] In steady state, u is set to be equal to 1, and so $a(u) = 0$. The parameter of interest, which determines dynamics is $a''(1)/a'(1) = \sigma_a$.

1.3.2 Government

Each period $t \geq 0$, nominal government spending is given by $P_t g_t$. Real government expenditures, denoted by g_t are assumed to be exogenous, stochastic and follow a univariate first-order autoregressive process,[14]

$$\hat{g}_t = \tilde{\rho}_g \hat{g}_{t-1} + \epsilon_t^g, \tag{1.9}$$

where ϵ_t^g is a government spending shock.[15]

Like households, the government is also assumed to form habits over its consumption of individual varieties of goods. This can be thought of as the government favoring transactions with vendors that supplied public goods in the past. Or alternatively, we can think of households deriving utility from public goods that is separable from private consumption and leisure, and they exhibit good-by-good habit formation for public goods also. The government allocates spending over individual varieties of goods, g_{it}, so as to maximize the quantity of composite good produced with the differentiated varieties of goods according to the relation,

$$x_t^g = \left[\int_0^1 (g_{it} - b^g s_{it-1}^G)^{1-1/\eta} di \right]^{1/(1-1/\eta)}.$$

The variable s_{it}^G denotes the government's stock of habit in good i and is assumed to evolve as follows,

$$s_{it}^G = \rho^g s_{it-1}^G + (1 - \rho^g) g_{it}. \tag{1.10}$$

The government's problem consists in choosing g_{it}, $i \in [0, 1]$, so as to maximize x_t^g subject to the budget constraint $\int_0^1 P_{it} g_{it} di \leq P_t g_t$, taking as given the initial condition $g_{it} = g_t$, for $t = -1$ and all i. The resulting demand function for each

[14] In the sensitivity analysis section, a process for government spending with feedback from other variables, as in the VAR, is also considered.

[15] A hatted variable denotes log deviation of a variable from its steady state.

differentiated good $i \in [0, 1]$ by the public sector is,

$$g_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} x_t^g + b^g s_{it-1}^G. \tag{1.11}$$

Government spending expenditures are assumed to be financed by lump-sum taxes. Note that since Ricardian equivalence holds in this model, the path of debt becomes irrelevant.

The monetary authority is assumed to use a Taylor rule of the following form, where there is interest rate smoothing and nominal interest rate responds to deviations of inflation and output from steady state levels.

$$\hat{R}_t = \alpha_R \hat{R}_{t-1} + (1 - \alpha_R)(\alpha_\pi \hat{\pi}_t + \alpha_y \hat{y}_t). \tag{1.12}$$

1.3.3 Firms

Each variety of final goods is produced by a single firm in a monopolistically competitive environment. Each firm $i \in [0, 1]$ produces output using capital services, k_{it}, and labor services, h_{it} as factor inputs . The production technology is given by,

$$F(k_{it}, h_{it}) - \psi,$$

where the function F is assumed to be homogenous of degree one, concave, and strictly increasing in both arguments and has the following functional form,

$$F(k, h) = k^\theta h^{1-\theta}.$$

The parameter $\psi > 0$ introduces fixed costs of operating a firm in each period, and are modeled to ensure a realistic profit-to-output ratio in steady state.

The firm is assumed to satisfy demand at the posted price. Formally,

$$F(k_{it}, h_{it}) - \psi \geq a_{it}, \tag{1.13}$$

where a_{it} is aggregate absorption of good i and includes c_{it}, g_{it} and i_{it}. The objective of the firm is to choose contingent plans for P_{it}, h_{it}, and k_{it} so as to maximize the present discounted value of dividend payments, given by

$$E_t \sum_{s=0}^{\infty} r_{t,t+s} P_{t+s} \phi_{it+s},$$

where,

$$\phi_{it} = \frac{P_{it}}{P_t} a_{it} - r_t^k k_{it} - w_t h_{it} - \frac{\alpha}{2} \left(\frac{P_{it}}{P_{it-1}} - \pi_{t-1} \right)^2,$$

subject to (1.11), (2.5), and the demand function for investment faced by firm i. Note that sluggish price adjustment is introduced following Rotemberg (1982), by assuming that the firms face a quadratic price adjustment cost for the good it produces. This is because the introduction of deep habits makes the pricing problem dynamic and accounting for additional dynamics arising from Calvo-Yun type price stickiness makes aggregation non-trivial.

1.4 Estimation Strategy

In this section, the estimation methodology is discussed. To make comparison with existing studies easier, the strategy followed in this paper is to calibrate most of the parameters to match the estimates in Christiano, Eichenbaum, and Evans (2005).[16] The parameters of interest in the transmission of government spending shocks are the habit formation related parameters, preference parameter and the autoregressive parameter for the government spending process, and these are all estimated.

The group of parameters that are calibrated are shown in Table 1.1. These include the discount factor β, set at $1.03^{-1/4}$, which implies a steady-state annualized real interest rate of 3 percent. The depreciation rate, δ, is set at 0.025, which implies an

[16] An additional concern is the identification of parameters, and the dynamics of the model in response to a government spending shock may fail to contain information about certain parameters.

annual rate of depreciation on capital equal to 10 percent. θ is set at 0.36, which corresponds to a steady state share of capital income roughly equal to 36%. Also, the steady state labor is set at 0.5 that implies a Frisch elasticity of labor supply equal to unity and the share of government spending in aggregate output is taken at 0.20, that matches the average share of government spending in GDP over the sample period considered in this paper.

The labor elasticity of substitution, $\tilde{\eta}$ is set at 21, which implies the markup of wages over marginal rate of substitution between leisure and consumption being 5 percent. The goods elasticity of substitution, η is calibrated to be 5.3 which implies a steady state price markup of 23 percent in the case of superficial habits. However, the steady state value of markup over prices in the case with deep habits is eventually pinned down by the estimated degree of deep habits.

The capacity utilization parameter, σ_a is calibrated to be 0.01, and the investment adjustment cost is set at 2.48. These are values taken from Christiano, Eichenbaum, and Evans (2005). The wage stickiness parameter $\tilde{\alpha}$ is calibrated to be 0.92. Note, that typically utility is defined as a function of a single differentiated type of labor. However, here utility is defined as a function of an aggregate of different types of labor, similar to Schmitt-Grohe and Uribe (2005). As shown in Schmitt-Grohe and Uribe (2006), in this variant of wage stickiness the parameter needs to be higher than the corresponding wage stickiness parameter in the set-up in Christiano, Eichenbaum, and Evans (2005) to obtain the same wage Phillips curve. The parameter value of 0.92 maps into the value estimated in Christiano, Eichenbaum, and Evans (2005) equal to 0.64.

The price stickiness parameter is calibrated to be 17. Recall, that price stickiness is modeled as a quadratic price adjustment cost. The mapping between the Phillips curve implied by a model with a price adjustment cost to the one arising in the Calvo-Yun price stickiness model, suggests that the average duration of price contracts is close to three quarters, as estimated in Christiano, Eichenbaum, and Evans (2005).

Lastly, the parameters in the monetary policy rule are calibrated to be consistent with post-1979 era estimates in Clarida, Gali, and Gertler (2000); the interest rate smoothing parameter is set to be 0.8, and the coefficients on inflation and output are calibrated to be 1.5 and 0.1 respectively.

The set of parameters being estimated are: $\{b^c, \rho^c, b^g, \rho^g, \sigma, \tilde{\rho}_g\}$. I allow for varying degree of deep habit formation in private consumption and public consumption, denoted by b^c and b^g respectively. Similarly, the speed of adjustment of habit formation is different for public and private consumption, given by ρ^c and ρ^g.

To estimate the parameters of interest, I apply the Laplace type estimator (LTE) suggested by Chernozhukov and Hong (2003), which are defined similarly to Bayesian estimators, but use general statistical criterion function instead of the parametric likelihood function. Chernuzhukov and Hong show that these estimators are as efficient as the classical extremum estimators, while being computationally more attractive. The estimates are the mean values of a Markov chain sequence of draws from the quasi-posterior distribution of θ, generated by the tailored Metropolis Hastings algorithm. For the proposal distribution in the algorithm, the initial value of parameters are optimized values generated by running cmaes-dsge.m,[17]and the variance is given by the inverse Hessian matrix computed numerically.

The LTE of the vector θ, minimizes the quasi posterior risk function,

$$\theta = arg \inf_{\xi \in \Theta} [Q_n(\xi)]$$

where the quasi posterior function is defined as,

$$Q_n(\xi) = \int_{\theta \in \Theta} \rho_n(\theta - \xi) p_n(\theta) d\theta$$

[17] This is an optimization routine adapted for use with DSGE models by Martin Andreasen (in Andreasen (2008)), who was kind enough to provide the MATLAB code.

Here $\rho_n(.)$ is the appropriate penalty function associated with an incorrect choice of parameter, and p_n is the quasi-posterior distribution, defined using the Laplace transformation of the distance function L_n and the prior probability of the parameter θ.[18]

$$p_n(\theta) = \frac{e^{L_n(\theta)}\pi(\theta)}{\int e^{L_n(\theta)}\pi(\theta)d\theta}$$

The distance function $L_n(\theta)$ is the weighted sum of squares of the difference between the impulse responses generated by the empirical VAR model, $I\hat{R}F$, and the ones generated by the theoretical model, $IRF(\theta)$.

$$L_n(\theta) = -(IRF(\theta) - I\hat{R}F_n)'V^{-1}(IRF(\theta) - I\hat{R}F_n)$$

Here V is a diagonal weighting matrix with the sample variances of the impulse responses along the diagonal.[19]

The reported estimates are the mean values and standard deviation of the Markov chain sequence of 500,000 draws, which guarantees convergence, with the first 100,000 values burnt out. These draws are generated by the Metropolis Hastings algorithm with an acceptance rate of between 20-30%.

1.5 Estimation Results

In this section, the parameter estimates are presented.

1.5.1 Parameter Estimates and Dynamics in Model with Superficial Habits

Deep habits and superficial habits give rise to the same Euler equation. However, the differences arise in the supply side of the problem. To distinguish between the two, the model was first estimated with superficial habits, so that there is habit formation

[18] I use flat priors, where parameters are restricted to be within the permissible domain, e.g. the deep habit parameters are restricted to be within the unit interval, [0,1).

[19] I am matching impulse responses for 20 periods but a more efficient number of lag length can be determined using the statistical criterion suggested in Hall, Inoue, Nason, and Rossi (2007).

at the level of the aggregate consumption basket instead of on a good-by-good basis. More precisely, the utility function is now,

$$U(c_t - bc_{t-1}, h_t)$$

where b is the superficial habit formation parameter. With superficial habits in place, the model is not very different from the standard medium scale model, considered in Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2007) to cite a few.[20]

The results are shown in Figure 1.2, and the estimates for the model with superficial habits are shown in Table 1.2. The habit formation parameter estimated is much higher than in previous studies and tends to 0.96. The preference parameter, σ is estimated to be 5.9 which implies an intertemporal elasticity of substitution of close to 0.17. The autoregressive parameter, $\tilde{\rho}_g$, in the government spending process is estimated to be 0.96.

Note first that even though the model has nominal rigidities in the form of price and wage stickiness, in addition to variable capacity utilization and investment adjustment cost, the responses are short-lived and not persistent enough to match the empirical evidence. Secondly, the model is able to match the increase in output and fall in investment on impact. However, the response of consumption and wages seem flat, and in the case of consumption, outside the 95% confidence bands. In Figure 1.4, some of the responses in the estimated model are magnified for clarification.

In the model I have abstracted from distortionary taxes and the government only relies on lump-sum taxes. The government spending shock therefore leads to a negative wealth effect since households face higher taxes. This induces them to increase hours worked, so labor supply goes up, and reduce consumption. These are the effects seen in standard RBC models. In the presence of price stickiness,

[20] The complete set of symmetric equilibrium conditions for this case are given in the Appendix.

as shown in Linnemann and Schabert (2003), labor demand goes up in response to a demand shock, and it is possible to see wages rise on impact depending on the monetary policy regime as characterized by the coefficients in the Taylor rule. However, they also show that price stickiness alone does not generate a sufficiently large price markup mechanism to lead consumption to rise.

Since output rises in response to the spending shock, where both capital and labor are inputs in the production function, and investment falls, effective capital, $u_t k_t$ rises in response to the shock. A rise in capacity utilization after the shock hits the economy also shifts the marginal product of labor so that this adds another mechanism for the labor demand to shift sufficiently for us to see a rise in wage in response to the demand shock.

Ultimately, since the preferences are non-separable, and σ is estimated to be greater than 1, the small rise in wages ensures that agents substitute from leisure towards consumption, and at least on impact, this overcomes the negative wealth effect and consumption rises as a result. However, as is clear in Figure 1.4, these effects are all very small in magnitude and do not help to quantitatively or qualitatively match the empirical responses in the long run, and for the case of consumption in particular, the discrepancy between the data and model implied responses is rather severe.

1.5.2 Parameter Estimates and Dynamics in Model with Deep Habits

Next the model is estimated with deep habits and Table 1.2 presents the estimation results.

The deep habit parameters are estimated to be 0.74 and 0.69 for habit formation in private consumption and public consumption respectively. The degree of deep habit formation in household consumption is close to estimates of habits at the level of composite good in the existing literature. The parameters ρ^c and ρ^g measure the speed of adjustment of the stock of external habit to variation in cross-sectional levels of consumption of a given variety. The estimated values of both these parameters is significantly high, indicating that high persistence in markups is needed to match the empirical responses, since wages and consumption do not have a big impact response to the demand shock but peak after 10 or so quarters. The estimated values of deep habit formation parameters imply the steady state value of markup of price over marginal costs being 27%, which is within the range of empirical evidence presented in Rotemberg and Woodford (1999).

The coefficient of relative risk aversion is estimated to be 4.39. This suggests that consumption and leisure are substitutes, and the implied intertemporal elasticity of substitution is 0.22. Even though the empirical evidence is not so clear for this parameter, this estimated value seems to be in line with existing empirical studies.[21]

Figure 1.3 shows the impulse response implied by the model. Note that the estimated model does a reasonably good job at matching the empirical responses. All of the model responses lie within the two-standard deviation confidence intervals of the data. The model is in particular, successful in quantitatively matching the persistent responses of wages and consumption.

In addition to the wealth effects discussed in the previous section, due to deep habits, recall from equation (1.11), the demand faced by firm i from the public sector in period t is of the form,

$$g_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\eta} (g_t - b^g s^G_{t-1}) + b^g s^G_{it-1},$$

and there is a similar demand function for private consumption. The demand function has a price-elastic component that depends on aggregate public consumption

[21] For instance, Barsky, Kimball, Juster, and Shapiro (1997) use microdata to estimate the intertemporal elasticity of substitution of 0.18, and Hall (1988) employs macrodata and concludes that intertemporal elasticity is most likely less than 0.2.

demand, and the second term is perfectly price-inelastic. An increase in aggregate demand increases the share of the price-elastic component, and thus an increase in the elasticity of demand, inducing a decline in the mark-ups. In addition to this, firms also take into account that today's price decisions will affect future demand, and so when the present value of future per unit profit are expected to be high, firms have an incentive to invest in the customer base today. Thus, they induce higher current sales via a decline in the current markup. If producers have market power and are able to set price above the marginal cost, then one of the firm's optimality condition look as follows, $F_2(u_t k_t, h_t^d) = \mu_t w_t$. Here μ_t is the ratio of price to marginal cost, and with imperfect competition, variations in the markup shift the labor demand and therefore, wages increase with output as a result of an increase in demand.[22] This higher real wage cause individuals to substitute away from leisure to consumption, and this substitution effect is large enough to offset the negative wealth effect so that overall consumption rises significantly in response to a government spending shock.

If there is a positive shock to government spending, there are two basic effects: firstly, there is an increase in output supply brought about by the negative wealth effect on labor supply. Secondly, there is an increase in aggregate demand due to a crowding in of consumption. Both these effects raise output, but their relative size determines what happens to prices. There is a drop in inflation in the model since the firms lower markups in response to an increase in aggregate demand. The drop in inflation is inertial due to the slow decay of stock of habit, and eventually reverts back to steady state as aggregate demand comes back to normal. Overall, the monetary variables do not have significant responses to a government spending shock. Given the monetary policy parameters, there is an aggressive anti-inflationary rule

[22] This countercyclicality of the price markup has been empirically documented by Rotemberg and Woodford (1999) and Gali, Gertler, and Lopez-Salido (2007) among others. Monacelli and Perotti (2008), in fact, also show this fall in the markup in response to a government spending shock in a SVAR.

with a significant response to output, which leads to an increase in the real interest rate on impact. Since this rise is not significant, the households do not face large intertemporal substitution effects.

Notice that the empirical results show investment falling on impact and rising to be point-wise positive after 6 quarters. The model with deep habits is able to match the initial drop in investment, but not the subsequent rise, although the theoretical response from the baseline model is within the confidence bands. The rise in labor supply as a result of a spending shock induces a rise in marginal product of capital, and thus as the rental cost of capital goes up, there is a corresponding fall in investment.

1.6 Sensitivity Analysis

1.6.1 Government spending process

In the model, government spending is modeled as an AR(1) process. Next, I consider if the results are robust to the assumption of fiscal policy taking the form of a feedback rule, given by the first equation of the SVAR system given in equation (1.1). This means, the process for government spending is,

$$\hat{g}_t = A^1(L)\hat{Y}_{t-1} + \epsilon_t^g \tag{1.14}$$

where $A^1(L)$ denotes the first row of $A(L)$, and $\hat{Y}_t = [\hat{g}_t \;\; \hat{y}_t \;\; \hat{h}_t \;\; \hat{c}_t \;\; \hat{i}_t \;\; \hat{w}_t \;\; \hat{\pi}_t \;\; \hat{R}_t]'$. The values assigned to $A^1(L)$ are the same as estimated in Section 2, but the behavior of the endogenous variables appearing in the process is dictated by the model's dynamics. This explains any discrepancy between the theoretical and empirical impulse responses of g_t.

Figure 1.6 shows the impulse responses implied by a model with deep habits estimated with this feedback rule for government spending in place. The estimates are given in Table 1.2. The estimated degree of deep habit formation in public and private consumption is slightly higher than the baseline case but the preference parameter is estimated close to 3, which is lower than 4.4, the value in the baseline case. Overall, the impulse response functions once again match the empirical responses, for the most part, just as successfully as the specification with an AR(1) process for government spending.

1.6.2 Role of markup

The key in using deep habits as a transmission mechanism for government spending shocks, is that they induce time-varying countercyclical movements in the markup of prices over marginal costs. However, Monacelli and Perotti (2008) criticize deep habits on the basis of giving rise to private consumption and markup responses that are counterfactually small and large, respectively. This raises questions about the size of markup dynamics in the estimated model with deep habits.

Figure 1.5 shows the response of markup, along with consumption and wages in the estimated model. Monacelli and Perotti (2008) provide empirical evidence on the response of markups in the non-financial corporate business and manufacturing sectors. In response to a 1 percentage point of GDP increase in government spending, they find consumption peaking at 0.5 percentage points of GDP and markup falling by between 0.5 and 1 percent. If the responses in the model are normalized similarly by average share of the variable in GDP, then the model predicts that consumption peaks at a little over 0.3 percentage points of GDP and the markup falls by about 0.5 percent, in response to a 1 percentage point of GDP increase in government spending. The model dynamics are thus in line with their findings.

1.7 Other Transmission Mechanisms for Government Spending Shocks

In standard neoclassical models, as shown in Baxter and King (1993) when government spending rises, households face higher taxes and due to the negative wealth effect, they inevitably lower their consumption and increase hours worked. In these perfectly competitive models, aggregate demand shocks, such as government spending shocks increase employment only by affecting the household's willingness to supply labor and do not affect firm's demand for labor at any given real wage. Thus, these models are unable to generate the positive response of consumption and wages to a government spending shock.

In order to get the positive responses for consumption and wages, the literature has focused on several different strategies. Linnemann (2006) gets a positive response for consumption by considering a utility function that is non-separable in leisure and consumption. When hours worked increased, since leisure and consumption are substitutes, marginal utility of consumption rises. Therefore, there is a comovement between hours worked and consumption, but wages still fall. However, Bilbiie (2006) shows that if one relies on these non-separable preferences, it must be the case that consumption is an inferior good, and that the positive co-movement between consumption and hours is possible only if either consumption or leisure is inferior.

Bouakez and Rebei (2007) consider a simple RBC model where preferences depend on public and private spending, and households are habit forming. If private and government spending are Edgeworth complements, an increases in government spending raises the marginal utility of household consumption, allowing consumption to rise as a result of a spending shock. However, the authors also cite several empirical studies which have estimated the degree of substitutability between private and public spending and generally lead to inconclusive results.

In the two aforementioned studies, the focus has been the response of consumption, and since labor demand is unchanged, real wages fall in the model. Other modifications of the neoclassical model rely on mechanisms for government spending to shift the labor demand curve. If this shift is large enough, it can induce wages to rise, and potentially lead to a subsequent rise in consumption. Rotemberg and

Woodford (1999) model imperfect competition where a small number of firms within an oligopoly collude to keep prices above marginal cost. This collusion is supported by the threat of reverting back to a lower price in the future if a member deviates. When there is an increase in current demand, the gains from undercutting relative to the losses from future punishment are raised. To prevent a breakdown of collusion, the agreement involves smaller markups in this case. Therefore in the face of higher aggregate demand, say due to an increase in government spending, the firms lower markups and increase labor demand, leading to a rise in real wages in the model. They, however do not show the response for consumption.

In Devereux, Head, and Lapham (1996), an increase in government demand raises the equilibrium number of firms that can operate in the intermediate goods sectors, where they model increasing returns to specialization. The resulting shift in labor demand can overcome the increase in labor supply to lead to a higher equilibrium wage. The results, however depend on the magnitude of markup of price over marginal costs which in the model determines the degree of returns to specialization. In order to generate a comovement between hours and wages, and a rise in consumption the required markup is really high, at least 50 percent.

Alternatively, Linnemann and Schabert (2003) show that in a model with sticky prices, in response to a rise in demand due to increased government spending, firms raise labor demand, which puts upward pressure on wages, in the face of the usual negative wealth effects raising labor supply. Thus this is also a way of generating countercyclical markups. If the interest rate rule does not put significant weight on output, it is possible to see real wages increase in equilibrium, but this rise is insufficient to induce consumption to go up.

Along with sticky prices, Gali, Lopez-Salido, and Valles (2007) model non-competitive behavior in labor markets and a fraction of the economy consisting of rule-of-thumb consumers who can not borrow and save, and consume their entire current income each period. In response to a government spending shock, the labor market structure with firms alone determining employment and price rigidities leads to a significant rise in wages. With this increase in wages, the credit constrained consumers raise their consumption. If close to half of all consumers in the economy are assumed to be credit constrained, they get a positive response for aggregate consumption to a government spending shock.

Instead of relying on credit constrained consumers, Monacelli and Perotti (2008) consider a model with sticky prices and households with preferences of the type introduced by Greenwood, Hercowitz, and Huffman (1988). These preferences imply that there is virtually no wealth effect on labor supply, and due to nominal rigidities since the government spending shock results in an increase in labor demand, this boosts wages to a greater extent than with standard preferences. Thus, agents substitute away from leisure to consumption, and it overcomes the negative wealth effect on consumption, and the response of consumption is further strengthened by the degree of complementarity between labor and consumption implied by the preferences. They show the calibrated model-implied impulse responses along with empirical responses for only consumption, wages, markup and investment.[23] Their model can match the initial responses of consumption and wages but has trouble replicating their persistence. In addition, the model has the most difficulty matching the response for investment which is a prolonged negative response, outside the confidence bands after the first 3 quarters, relative to the short-lived response in the data.

Deep habits also relies on generating countercyclical markups, but the fall in markup is sizable relative to markup movements due to price stickiness. Therefore, there is no added assumption of non-optimizing agents or specific form of preferences needed. This paper in addition illustrates that once deep habits are embedded in a

[23] This model in addition to GHH preferences and sticky prices also has habit formation in consumption and investment adjustment costs.

model that has been shown to fit the data along many dimensions, such as responses to technology and monetary shocks, it can also successfully explain the effects of government spending shocks on most macroeconomic variables of interest.[24]

1.8 Conclusion

The objective of this paper is to identify and explain effects of a government spending shock. After accounting for events that signal large changes in military spending, in response to a structural government spending shock, I show that output, consumption, wages all rise in response, whereas investment, inflation and nominal interest rate fall on impact. This paper shows that commonly used DSGE models with superficial habits are unable to match the responses of wages and consumption both qualitatively and quantitatively. Once the model is augmented with deep habits it successfully explains these effects and significantly improves the fit of the model. Deep habit formation in public and private consumption play an important role in matching the significantly positive and persistent responses of consumption and wages to a government spending shock.

The model in this paper has the government relying on lump-sum taxes. One obvious extension is to consider a more realistic fiscal setup with distortionary labor and capital income taxes, where it might also be interesting to explore how in the context of a similar model, the economy responds to discretionary fiscal policy, in the form of not just spending shocks but also tax shocks.

[24] Ravn, Schmitt-Grohe, Uribe, and Uuskla (2009) show that augmenting a model with nominal rigidities with deep habits helps to account both for the price puzzle and for inflation persistence in response to a monetary shock.

1.9 Tables and Figures

Table 1.1: Calibrated parameters

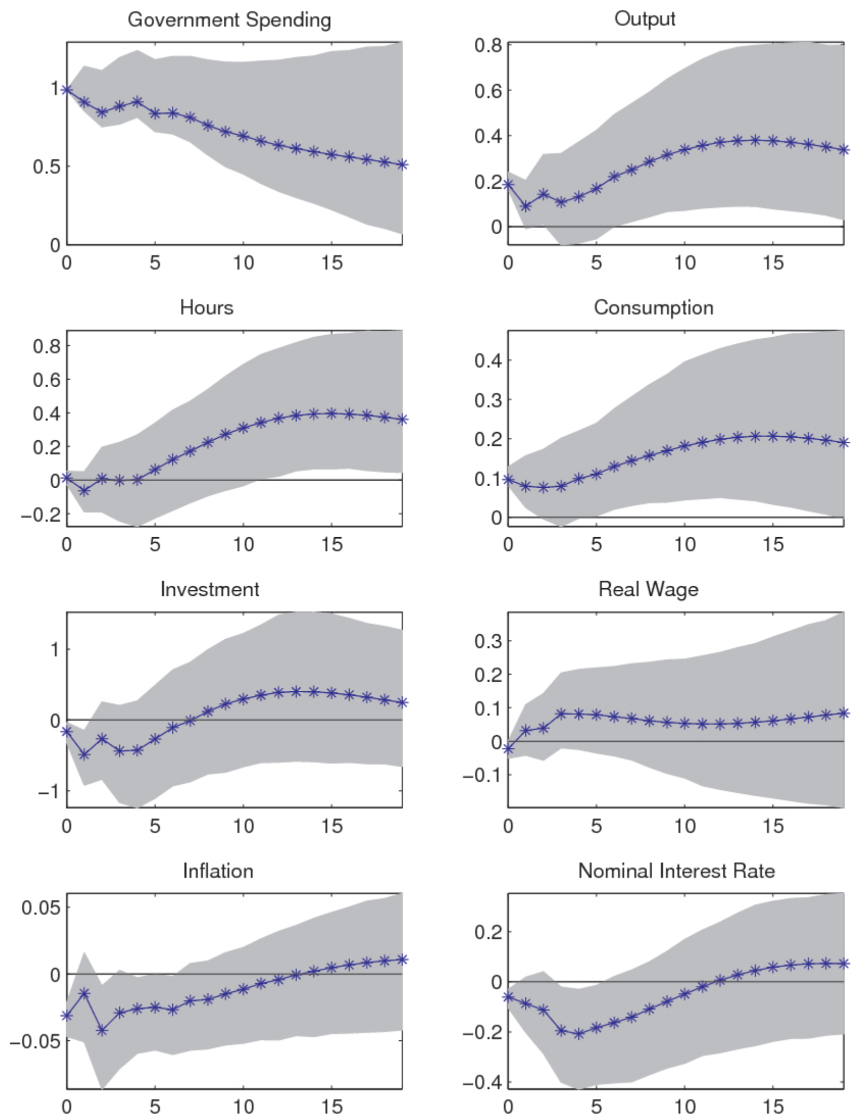
Parameter	Calibrated value
Share of govt. spending in GDP, G/Y	0.20
Depreciation rate, δ	0.025
Discount factor, β	$1.03^{-1/4}$
Wage elasticity of demand for specific labor variety, $\tilde{\eta}$	21
Price elasticity of demand for specific good variety, η	5.3
Capital share, θ	0.36
Capacity utilization parameter, σ_a	0.01
Investment adjustment cost, κ	2.48
Wage stickiness parameter, $\tilde{\alpha}$	0.92
Price stickiness parameter, α	17
Interest rate smoothing parameter, α_R	0.8
Coefficient on inflation, α_π	1.5
Coefficient on output, α_Y	0.1

Table 1.2: Parameter estimates

Parameter	Description	Deep Habits	Superficial Habits	Deep Habits with feedback rule for g_t
b^c	Deep habit in private consumption	0.74 (0.03)	-	0.83 (0.02)
ρ^c	Speed of adj. of private habit stock	0.89 (0.01)	-	0.76 (0.03)
b^g	Deep habit in public consumption	0.69 (0.04)	-	0.72 (0.01)
ρ^g	Speed of adj. of public habit stock	0.98 (0.001)	-	0.98 (0.001)
σ	Coefficient of relative risk aversion	4.39 (0.05)	5.97 (0.15)	3.01 (0.10)
b	Superficial habit persistence parameter	-	0.96 (0.05)	-
$\tilde{\rho}^g$	AR(1) coefficient for g_t	0.97 (0.01)	0.96 (0.09)	-

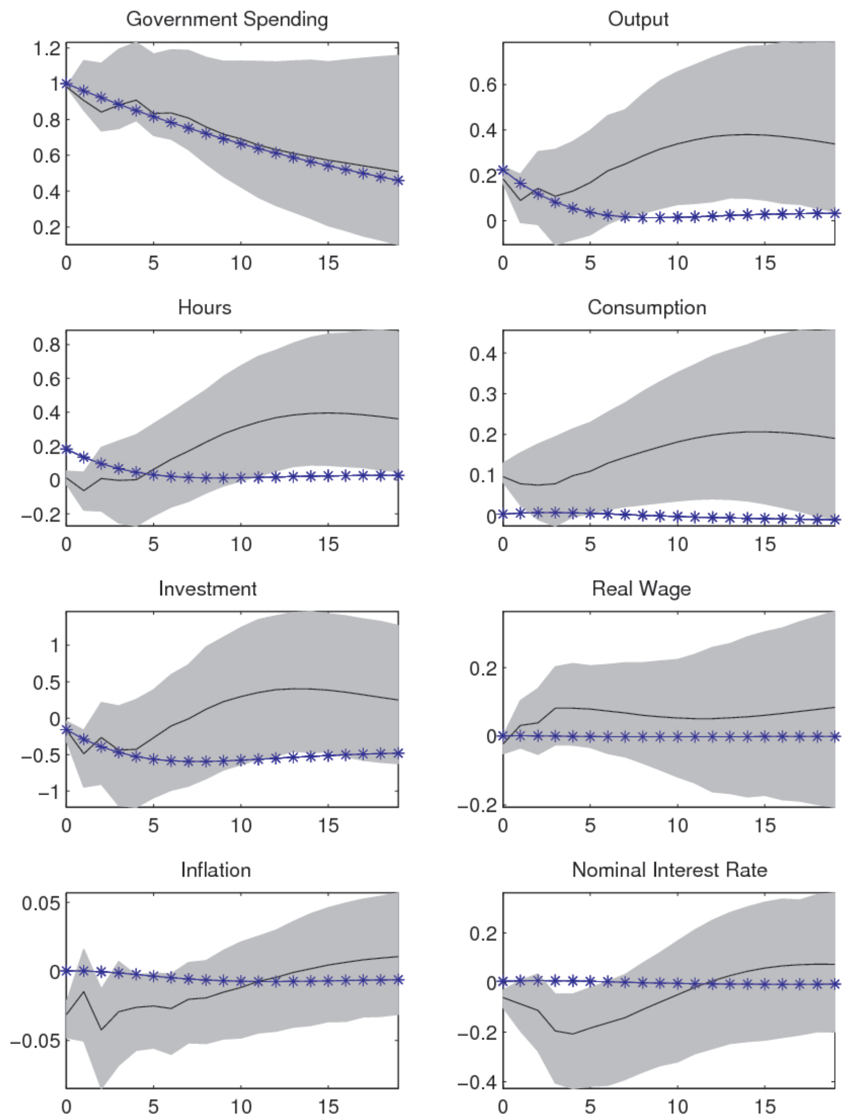
Note: The estimates reported are the mean values of the Markov chains, the values in brackets indicate the standard errors.

FIGURE 1.1: Impulse response function to a one standard deviation government spending shock as identified in the SVAR.



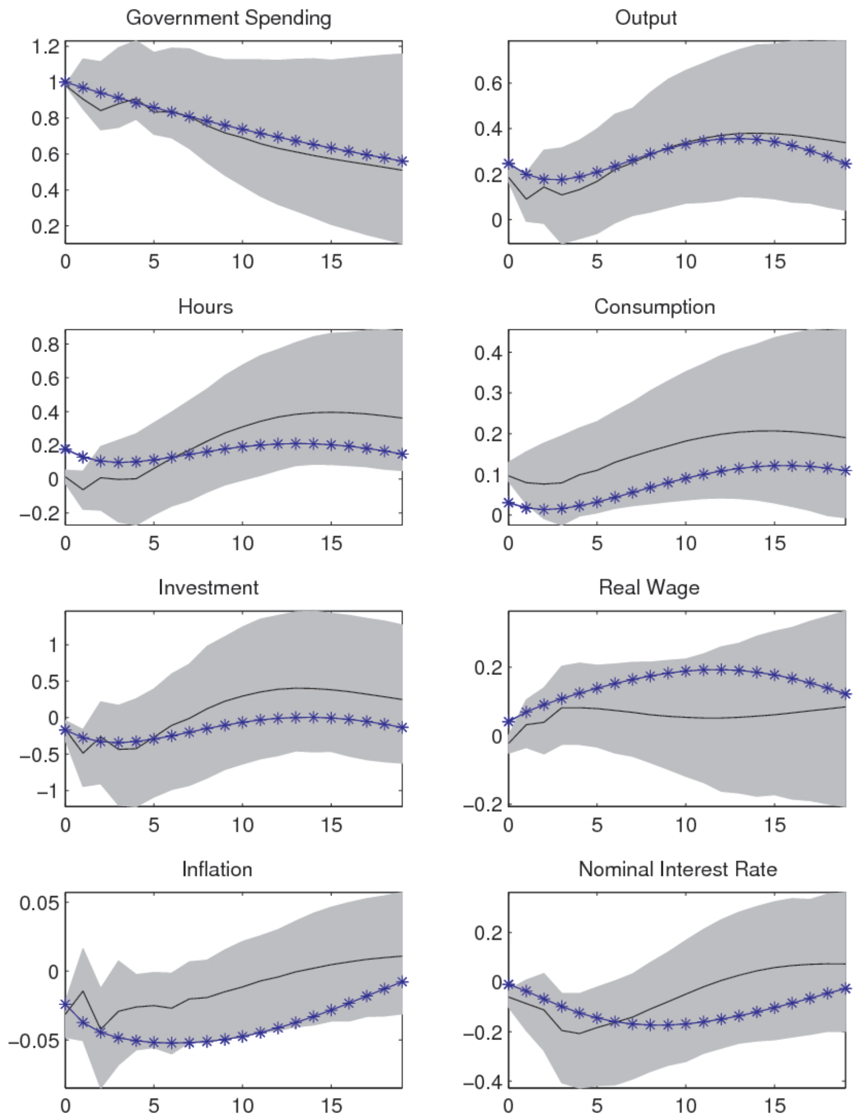
Note: The shaded gray regions are the 95 % confidence bands constructed by Monte Carlo simulations.

FIGURE 1.2: Impulse responses of the model estimated with superficial habits to a government spending shock.



Note: Solid lines are the empirical responses and starred lines are the responses for the estimated model. The vertical axis has percent deviations from steady state and the horizontal axis displays number of quarters after the shock.

FIGURE 1.3: Impulse responses of the model estimated with deep habits to a government spending shock.



Note: Solid lines are the empirical responses and starred lines are the responses for the estimated model. The vertical axis has percent deviations from steady state and the horizontal axis displays number of quarters after the shock.

FIGURE 1.4: Impulse responses of the model estimated with superficial habits for selected variables.

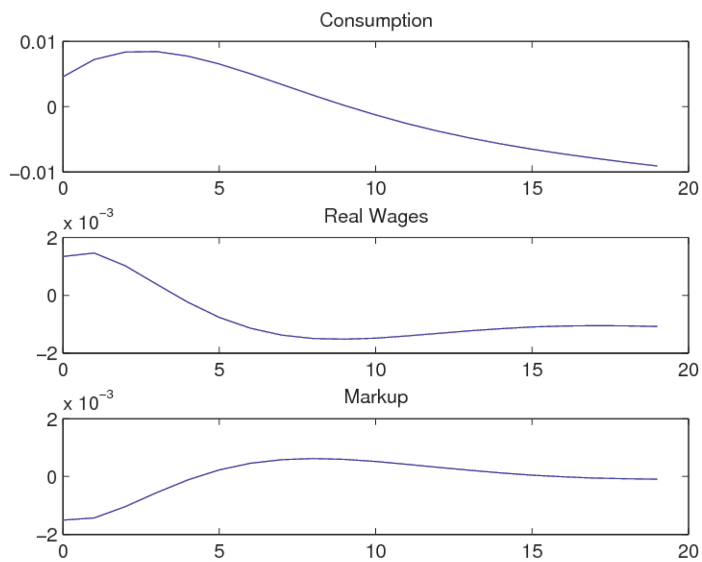


FIGURE 1.5: Impulse responses of the model estimated with deep habits for selected variables.

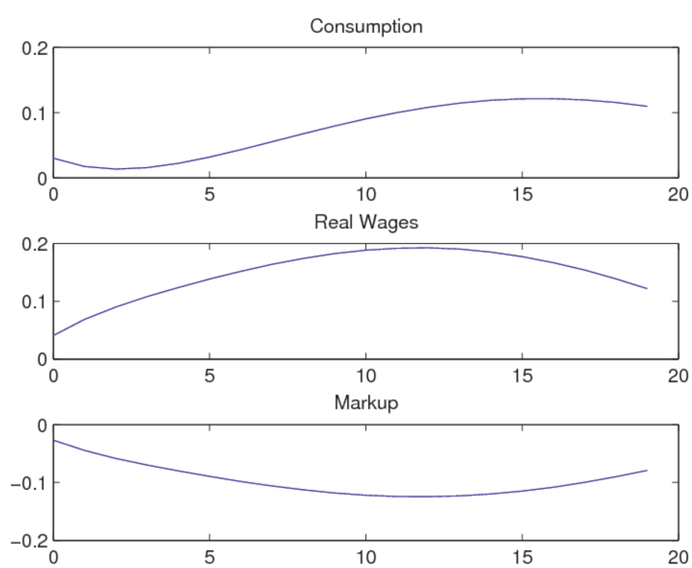
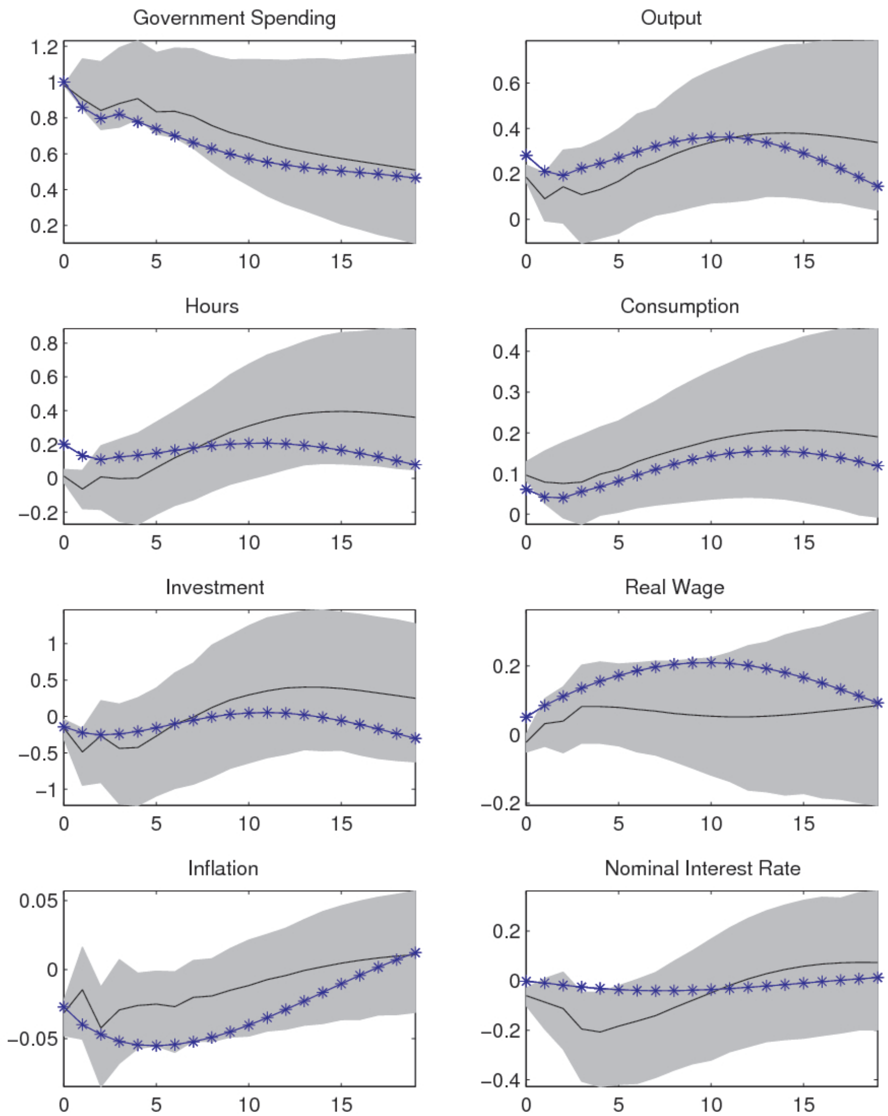


FIGURE 1.6: Impulse responses of the model with deep habits to a government spending shock, when the government spending process in the model is given by the VAR equation.



Note: Solid lines are the empirical responses and starred lines are the responses for the estimated model. The vertical axis has percent deviations from steady state and the horizontal axis displays number of quarters after the shock.

2

On Fiscal Multipliers: Estimates from a Medium Scale DSGE Model

2.1 Introduction

In the current economic crisis, countries around the world have taken extraordinary fiscal measures in order to stimulate their economies with the hope of boosting demand and limiting job losses. For instance, in February 2009, the United States passed a $787 billion American Recovery and Reinvestment Act, which amounts to over 5% of annual GDP. These policy actions, however, have given rise to a heated debate since there is a lack of consensus among economists on the relative stabilizing effects of fiscal policy measures in the form of current tax cuts or increases in spending. The objective of this paper is to shed light on this debate in the context of a micro-founded medium-scale dynamic stochastic general equilibrium (DSGE) model developed and estimated to explain the effects of discretionary fiscal policy.

The model considered in this paper features a rich fiscal block with distortionary labor and capital income taxes and a careful modeling of the government financing behavior. Unlike monetary policy, since there is no widely accepted specification for fiscal policy, this paper considers various fiscal rules, allowing fiscal variables to respond to the state of the economy and the level of government debt. Ultimately, the focus is on how the economy responds to fiscal policy actions in the form of changes in government spending, tax rates and lump-sum transfers.

In addition, the model features a transmission mechanism for government spending shocks, motivated by the fact that most commonly used business cycle models are not appropriate to study the effects of public spending shocks. As shown in the seminal paper by Baxter and King (1993), when government spending financed by lump-sum taxes rises, households face a negative wealth effect and inevitably lower their consumption and increase hours worked. The increase in labor supply also causes real wages to fall. This is, however, contrary to the findings of empirical studies that use structural vector autoregressions (VARs) to identify government spending shocks (e.g. Blanchard and Perotti (2002), Fatas and Mihov (2001)), and find consumption and wages rising in response to increased government consumption.[1] In order to allow for a channel of transmission of government spending shocks, I consider a model which embeds deep habit formation in public and private consumption, as introduced in Ravn, Schmitt-Grohe, and Uribe (2006). Deep habits imply that agents form habits over individual varieties of goods, as opposed to a composite consumption good. This new feature gives rise to counter-cyclical markups, allowing wages to rise in response to a government spending shock. If this increase is large enough, it induces households to substitute away from leisure to consumption, which can potentially overcome the negative wealth effects.[2]

[1] Empirical studies employing different identification schemes, e.g Edelberg, Eichenbaum, and Fisher (1999), Burnside, Eichenbaum, and Fisher (2004) and Mountford and Uhlig (2002) find an insignificant response of consumption and also do not find private consumption crowded out by government consumption. On the other hand, Ramey and Shapiro (1998) and Ramey (2008) argue that anticipated changes in spending driven by military expenditures reduce private consumption.

[2] Chapter 1 shows that a medium scale model with lump-sum taxes, when augmented with deep habits, is able to successfully explain the effects of government spending shocks on most macroeconomic variables. That paper, however, estimates the model using a limited information approach

As recent public debates have revealed, there is no consensus among economists on the size of fiscal multipliers, which summarize the effects of a fiscal policy action on GDP. The need to study fiscal policy and its propagation through the economy in the context of a structural model arises since pre-existing works on fiscal multipliers employ very different identification schemes. This makes it difficult to compare the resulting multiplier estimates. For instance, Blanchard and Perotti (2002) identify government and tax shocks based on the automatic response of fiscal variables to the state of the economy relying on high frequency data at quarterly level and find a spending multiplier for output in the neighborhood of 1 and a tax multiplier of 0.7 on impact.[3] Mountford and Uhlig (2002) use economic theory and econometric techniques to show that the tax multiplier is 0.19 and the spending multiplier is 0.44 on impact but the tax multiplier is significantly larger than the spending multiplier for longer horizons. Romer and Romer (2007), in a narrative study of tax changes find that the exogenous tax changes of 1% of GDP causes a slow on impact but steadily growing contractionary response of GDP and the estimated maximum impact is a fall of 3%.[4] Identification of fiscal shocks is in general complicated due to difficulties in isolating exogenous movements in fiscal variables, that are not simply an automatic response to the economy and also due to lags in implementation. Leeper, Walker, and Yang (2008) point out that small fiscal VARs, employed in empirical identification of fiscal shocks, assign an information set to the econometrician that is strictly smaller than the information set on which agents base their decisions, and so could also lead to biased results for impulse response functions. Also, these VARs generally do not impose the government intertemporal budget constraint or consider fiscal financing

of matching impulse response functions and does not consider distortionary taxes.

[3] Gali, Lopez-Salido, and Valles (2007) also find numbers close to 1 for spending multipliers using a similar identification scheme.

[4] Mertens and Ravn (2008) use the narrative evidence of Romer and Romer (2007) to distinguish between anticipated and unanticipated tax shocks and suggest that output contracts in response to an anticipation of future tax cuts but booms in reaction to implemented tax cuts.

decisions.[5]

In this paper, I undertake a likelihood-based Bayesian estimation of a structural model. This full-information approach fits the model to all the variation in the data, and not just dynamic effects of a policy shock. Along with standard macroeconomic aggregate variables, I also use fiscal variables as observable. These include data on government spending, and time series for labor and capital tax rates, which further allow the model to distinguish between the effects of the two different kinds of tax changes. Using Bayesian techniques I can also find the whole posterior distributions of the fiscal multipliers, which are more informative than just point estimates.

The paper reports the implied multipliers for all the fiscal instruments in the estimated model and shows how the fiscal shocks transmit through the economy. The main results can be summarized as follows: The multiplier for government spending is found to be 1.12. This means that a 1 percent of GDP increase in government spending increases GDP overall by 1.12 percent. The multiplier is larger than 1 since the estimated model predicts a positive response of private consumption to government spending, which is in contrast to models that do not consider a channel of transmission of government spending shocks, but is consistent with other empirical studies. The multipliers for labor and capital tax on impact are much smaller. A cut in tax revenues of 1 percent of GDP, driven by labor and capital taxes cause GDP to increase by 0.13 and 0.33 percent, respectively. However, in contrast to increased spending which has the maximum impact as soon as the shock hits the economy, the effects of tax shocks take time to build. The stimulative effects of tax cuts exceed the effects of higher spending at horizons of 12-20 quarters and are primarily driven by the response of investment. These results also highlight the fact that multipliers vary significantly across the horizon and thus the stimulative effect in the short-run

[5] Chung and Leeper (2007) and Favero and Giavazzi (2007) take debt considerations into a VAR and find that omitting a debt feedback can result in incorrect estimates of the dynamic effects of fiscal shocks.

differs from effects in the longer-run.

This estimated model provides an empirical framework to critically evaluate different fiscal policies. In counterfactual exercises, I examine how alternative financing decisions alter the size of multipliers and the role that automatic stabilizers play in determining the stimulative effect of spending. The results indicate that while the multipliers are mostly unaffected at shorter horizons of up to a year, the method of financing, either by increased deficits or raising taxes more aggressively is important for longer-run consequences.

I also provide evidence on how expected monetary policy have consequences for the stimulative effects of fiscal measures. The interaction between monetary and fiscal policy has recently gained significant attention, particularly in understanding the consequences of fiscal policy action under current circumstances when nominal interest rates are near zero. See for example Christiano, Eichenbaum, and Rebelo (2009), Cogan, Cwik, Taylor, and Wieland (2009), Davig and Leeper (2009) and Eggertsson (2009). The results in this paper are complementary. I find that the response of the monetary authority to deviations of output from steady state has significant effects on the size of fiscal multipliers. In fact, if the monetary authority is relatively accommodative, then increased spending has a significantly higher stimulative effect.

Lastly, I simulate the impact of the American Recovery and Reinvestment Act of 2009 in the estimated model, as a combination of increased government spending and a cut in labor taxes. This fiscal stimulus plan results in a considerable expansion in GDP, with the largest effects predicted in early 2010. These effects on output, however are accompanied by a significant rise in government debt, and since the households are forward-looking and anticipate higher taxes in the future to finance this plan, the stimulative effects on GDP decline rapidly over the course of next few years.

This paper is related to earlier work by Coenen and Straub (2005), Lopez-Salido and Rabanal (2006) and Forni, Monteforte, and Sessa (2009). These papers estimate a model of fiscal policy that extends the work of Gali, Lopez-Salido, and Valles (2007), and feature a fraction of the population being liquidity constrained in order to match the empirical evidence on the effects of government spending shocks.[6] However, in contrast to this paper, the focus in the aforementioned papers has primarily been to see if the estimated model can reconcile the positive response of aggregate consumption to government spending. They do not explore detailed fiscal rules or consider the consequences of alternative financing methods and expected monetary policy on fiscal multipliers.

The rest of the paper is organized as follows: Section 2 describes the theoretical model. In Section 3, I provide the description of the estimation procedure used. Section 4 presents the estimation results and model dynamics and Section 5 highlights the fiscal multipliers implied by the estimates. Section 6 shows some counterfactual exercises to consider alternative financing decisions. In Section 7, I explore the interaction between monetary and fiscal policy. Section 8 shows the simulation of the American Recovery and Reinvestment Act of 2009 and finally, Section 9 concludes.

2.2 Model

This is a medium scale DSGE model based on the work of Christiano, Eichenbaum, and Evans (2005). Most features are standard to the literature, such as nominal rigidities in the form of price and wage stickiness, and real rigidities in the form of variable capacity utilization and investment adjustment cost. This framework serves

[6] Along with sticky prices, Gali, Lopez-Salido, and Valles (2007) model non-competitive behavior in labor markets and a fraction of the economy consisting of rule-of-thumb consumers who can not borrow and save, and consume their entire current income each period. In response to a government spending shock, price rigidities leads to a rise in wages which causes credit constrained consumers to raise their consumption. If a large fraction of all consumers in the economy are assumed to be credit constrained, they get a positive response for aggregate consumption to a government spending shock.

as a starting point since it has been shown to fit the data well, for example by Del-Negro, Schorfheide, Smets, and Wouters (2005) and Smets and Wouters (2007). The specific departures include deep habits in public and private consumption, as first introduced in Ravn, Schmitt-Grohe, and Uribe (2006), as a transmission mechanism for government spending shocks and a detailed fiscal block.

2.2.1 Households

The economy is populated by a continuum of identical households of measure one indexed by $j \in [0,1]$. Each household $j \in [0,1]$ maximizes lifetime utility function, which depends on consumption, x_t^c, hours worked, h_t and government provided goods, x_t^g, given by

$$E_0 \sum_{t=0}^{\infty} \beta^t d_t \left\{ U(x_t^{c,j}, h_t^j) + V(x_t^g) \right\}. \tag{2.1}$$

In this formulation, d_t is an intertemporal preference shock, or a shock to consumer's impatience level and affects both the marginal utility of consumption and marginal disutility of labor. It follows an autoregressive process,[7]

$$\hat{d}_t = \rho_d \hat{d}_{t-1} + \epsilon_t^d, \tag{2.2}$$

where $\rho^d \in [0,1]$ is the autoregressive coefficient, and ϵ_t^d is i.i.d $N(0, \sigma_d^2)$. Households derive utility from consumption of government provided goods, given by x_t^g here, which is separable from private consumption and leisure. This means that public spending does not affect the marginal utility of private consumption or leisure.[8]

The variable x_t^c is a composite of habit adjusted consumption of a continuum of

[7] Throughout the paper, a hatted variable represents log deviations from its steady state.

[8] This is a common assumption in the literature, and studies such as Aschauer (1985), Ni (1995) and McGrattan (1994) who examine whether in fact private and public consumption are substitutes or complements find mixed and inconclusive results.

differentiated goods indexed by $i \in [0, 1]$,

$$x_t^{c,j} = \left[\int_0^1 (c_{it}^j - b^c s_{it-1}^C)^{1-\frac{1}{\eta}} di \right]^{1/(1-\frac{1}{\eta})}, \tag{2.3}$$

where s_{it-1}^C denotes the stock of habit in consuming good i in period t, the parameter η is the elasticity of substitution between intermediate goods. The parameter $b^c \in [0, 1)$ measures the degree of external habit formation, and when b^c is zero, the households do not exhibit deep habit formation. The stock of external habit is assumed to depend on a weighted average of consumption in all past periods. Habits are assumed to evolve over time according to the law of motion,

$$s_{it}^C = \theta^c s_{it-1}^C + (1 - \theta^c) c_{it}. \tag{2.4}$$

The parameter $\theta^c \in [0, 1)$ measures the speed of adjustment of the stock of external habit to variations in the cross-sectional average level of consumption of variety i. When θ^c takes the value zero, habit is measured by past consumption. This slow decay in habit allows for persistence in markup movements.

For any given level of consumption $x_t^{c,j}$, purchases of each individual variety of good $i \in [0, 1]$ in period t solves the dual problem of minimizing total expenditure, $\int_0^1 P_{it} c_{it} di$, subject to the aggregation constraint (2.3), where P_{it} denotes the nominal price of a good of variety i at time t. The optimal level of c_{it}^j for $i \in [0, 1]$ is then given by

$$c_{it}^j = \left(\frac{P_{it}}{P_t} \right)^{-\eta} x_t^{c,j} + b^c s_{it-1}^C, \tag{2.5}$$

where P_t is a nominal price index defined as

$$P_t \equiv \left[\int_0^1 P_{it}^{1-\eta} di \right]^{\frac{1}{1-\eta}}.$$

Note that consumption of each variety is decreasing in its relative price, P_{it}/P_t and increasing in level of habit adjusted consumption $x_t^{c,j}$. The demand function in equation (2.5) has a price-elastic component that depends on aggregate consumption demand, and the second term is perfectly price-inelastic. An increase in aggregate demand increases the share of the price-elastic component, and thus increases the elasticity of demand, inducing a decline in the mark-up. In addition to this, firms also take into account that today's price decisions will affect future demand, as is apparent due to s_{it-1} term, and so when the present value of future per unit profit are expected to be high, firms have an incentive to invest in the customer base today. Thus, this gives them an additional incentive to appeal to a broader customer base by reducing markups in the current period. This countercyclicality of the price markup has been empirically documented by Bils (1987), Rotemberg and Woodford (1999) and Gali, Gertler, and Lopez-Salido (2007) among others.[9]

Each household j is a monopolistic provider of a differentiated labor service, and is assumed to supply enough labor, h_t^j, to satisfy demand,

$$h_t^j = \left(\frac{w_t^j}{w_t}\right)^{-\tilde{\eta}} h_t, \tag{2.6}$$

where $w_t^j \equiv W_t^j/P_t$ and $w_t \equiv W_t/P_t$. W_t^j denotes the nominal wage charged by household j at time t, W_t is an index of nominal wages prevailing in the economy, and h_t is a measure of aggregate labor demand by firms. The parameter $\tilde{\eta}$ is the elasticity of substitution between differentiated labor types. In addition, wage rigidities are modeled as a convex cost of adjusting nominal wages which is zero at steady state. The real total adjustment cost for household j is given by, $\frac{\tilde{\alpha}}{2}\left(\frac{P_t w_t^j}{P_{t-1} w_{t-1}^j} - \bar{\pi}\right)^2$, where $\tilde{\alpha}$ denotes the wage adjustment cost parameter.

The household is assumed to own physical capital, k_t, which accumulates accord-

[9] Monacelli and Perotti (2008), in fact, also show this fall in the markup in response to a demand shock in the form of increased government spending, in a structural VAR.

ing to the following law of motion,

$$k_{t+1}^{j} = (1-\delta)k_t^j + i_t^j \left[1 - \mathcal{S}\left(\mu_t \frac{i_t^j}{i_{t-1}^j} \right) \right], \tag{2.7}$$

where i_t^j denotes investment by household j and δ is a parameter denoting the rate of depreciation of physical capital. The function $\mathcal{S}$ introduces investment adjustment costs and has the following functional form, $\mathcal{S}\left(\mu_t \frac{i_t}{i_{t-1}}\right) = \frac{\kappa}{2}\left(\mu_t \frac{i_t}{i_{t-1}} - 1\right)^2$, and therefore in the steady state it satisfies $\mathcal{S} = \mathcal{S}' = 0$ and $\mathcal{S}'' > 0$. These assumptions imply the absence of adjustment costs up to first-order in the vicinity of the deterministic steady state. Here, μ_t denotes an efficiency shock to the investment adjustment cost. It also follows an autoregressive process given by

$$\hat{\mu}_t = \rho_\mu \hat{\mu}_{t-1} + \epsilon_t^\mu, \tag{2.8}$$

where $\rho^\mu \in [0,1]$ is the autoregressive coefficient, and ϵ_t^μ is i.i.d $N(0, \sigma_\mu^2)$.

Owners of physical capital can control the intensity at which this factor is utilized. Formally, let u_t measure capacity utilization in period t. It is assumed that using the stock of capital with intensity u_t entails a cost of $a(u_t)k_t$ units of the composite final good.[10] Households rent the capital stock to firms at the real rental rate r_t^k per unit of capital. Total income stemming from the rental of capital is given by $r_t^k u_t k_t$.

The household's period-by-period budget constraint is given by

$$\begin{aligned} E_t r_{t,t+1} a_{t+1}^j \quad + \quad & x_t^{c,j} + \omega_t^j + i_t^j + a(u_t^j)k_t^j + w_t \frac{\tilde{\alpha}}{2}\left(\frac{w_t^j}{w_{t-1}^j}\pi_t - \bar{\pi} \right)^2 \\ = & \frac{a_t^j}{\pi_t} + (1-\tau_t^k) r_t^k u_t^j k_t^j + (1-\tau_t^w) w_t^j h_t^j + \delta q_t \tau_t^k u_t^j k_t^j + tr_t^j + \phi_t^j, \end{aligned} \tag{2.9}$$

where $\omega_t = b^c \int_0^1 P_{it} s_{it-1}^C / P_t di$. The variable $a_t/\pi_t \equiv A_t/P_t$ denotes the real payoff in period t of nominal state-contingent assets purchased in period $t-1$. The variable ϕ_t

[10] In steady state, u is set to be equal to 1, and so $a(u) = 0$. During the estimation, $a''(1)/a'(1) = \sigma_u$ is estimated, which determines dynamics.

denotes dividends received from the ownership of firms and $\pi_t \equiv P_t/P_{t-1}$ denotes the gross rate of consumer-price inflation. The households face labor and capital income tax rates, given by τ_t^w and τ_t^k respectively, and get a lump-sum transfer from the government, given by tr_t. The term $\delta q_t \tau_t^k u_t k_t$ represents a depreciation allowance for tax purposes.[11]

Each household chooses processes for $x_t^{c,j}$, h_t^j, a_{t+1}^j, w_t^j, k_{t+1}^j, i_t^j, and u_t^j in order to maximize the utility function subject to (2.6), (2.7), (2.9) and the standard no-Ponzi-game constraint, taking as given the processes for ω_t, w_t, r_t^k, $r_{t,t+1}$, π_t, ϕ_t, τ_t^k, τ_t^w and tr_t and the initial conditions a_0^h and k_0.

2.2.2 Fiscal and Monetary Policy

Similar to households, the government is also assumed to form habits on consumption of individual varieties of goods. Recalling the expression in (2.1), households also derive utility from public goods. Utility over public consumption is assumed to be separable from private consumption and leisure, and the households also form external habits over these public goods. As motivated in Ravn, Schmitt-Grohe, and Uribe (2007), the provision of public services in one community, such as street lighting or garbage collection, creates other communities to also want access to those public services. Otherwise, this can also be thought of as the government favoring transactions with procurement contractors from whom they have purchased public goods in the past.

The government allocates spending over individual varieties of goods, g_{it}, so as to maximize the quantity of a composite good, x_t^g, produced with a differentiated

[11] This is because part of the payment that capital owners receive from renting out their capital stock merely reflects compensation for the stocks depreciation. Therefore, this component of revenue is not income, and so should not be subject to taxation. In practice, depreciation expenses are tax deductible.

varieties of goods according to the following relation,

$$x_t^g = \left[\int_0^1 (g_{it} - b^g s_{it-1}^G)^{1-1/\eta} \right]^{1/(1-1/\eta)}.$$

The parameter b^g measures the degree of habit formation of government consumption and the variable s_{it}^G denotes the government's stock of habit in good i and is assumed to evolve as follows,

$$s_{it}^G = \theta^g s_{it-1}^G + (1 - \theta^g) g_{it}, \tag{2.10}$$

where θ^g is the rate of depreciation of the stock of habits. The government's problem consists of choosing g_{it}, $i \in [0,1]$, so as to maximize x_t^g subject to the budget constraint $\int_0^1 P_{it} g_{it} \leq P_t g_t$, taking as given the initial condition $g_{it} = g_t$, where g_t denotes real government expenditures. The resulting demand function for each differentiated good $i \in [0,1]$ by the public sector is

$$g_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} x_t^g + b^g s_{it-1}^G,$$

which is analogous to the demand function for household consumption. Therefore, introducing deep habits in public consumption, along with private consumption, is needed to generate countercyclical markups in response to both an increase in private and public consumption demand.

The fiscal authority issues bonds, b_t and raises tax revenues, τ_t and the expenditures include government purchases, g_t and lump-sum transfers to households, tr_t. The government budget constraint looks as follows,

$$b_t = R_{t-1} \frac{b_{t-1}}{\pi_t} + g_t + tr_t - \tau_t, \tag{2.11}$$

where tax revenues, τ_t are given by,

$$\tau_t = \tau_t^w w_t h_t + \tau_t^k (r_t^k u_t k_t - \delta q_t u_t k_t). \tag{2.12}$$

Unlike monetary policy, there is no widely accepted specification for fiscal policy. For instance, in earlier work, McGrattan (1994) introduces reduced form fiscal rules with a VAR representation of exogenous state variables, namely technology shocks, government spending and tax rates. Braun (1994) also runs a VAR for government spending and tax rates, and after dropping insignificant coefficients settles on AR(1) processes for both spending and taxes. Leeper (1991) has a fiscal rule with taxes responding to the level of real outstanding government debt, and Schmitt-Grohe and Uribe (2007) show that such rules can approximate optimal policy rules. Jones (2002) has a reduced form representation where tax and spending rates are functions of their own lags, current and lagged output and current and lagged hours, to reflect the notion that policymakers care about output and employment. He also distinguishes between the effects of exogenous fiscal shocks and effects of feedback rules. Mertens and Ravn (2008) assume stochastic AR(2) processes for tax rates, and allow no feedback from the economy. However, they distinguish between anticipated and unanticipated tax shocks.

In recent work, Romer and Romer (2007) use narrative evidence to identify the size and reasons behind all major postwar tax policy actions. They find tax policy actions as either being motivated by counter-cyclical actions or changes in spending, which they call endogenous policy changes, or tax changes in order to deal with an inherited budget deficit or raise long-run growth, classified as exogenous changes in their analysis. They estimate the effects of exogenous tax movements on output and point out that failing to account for influences of economic activity on tax policy leads to biased effects of macroeconomic effects of tax changes.[12] In order to address such concerns, in this paper, taxes are modeled to allow for automatic stabilizers by responding to the state of the economy and feedback reaction to debt in order to

[12] Leeper, Walker, and Yang (2009) also emphasize endogeneity of tax policy.

prevent large debt to GDP ratios, and the processes for tax rates look as follows,[13]

$$\hat{\tau}_t^k = \rho_k \hat{\tau}_{t-1}^k + \rho_{k,b} \hat{b}_{t-1} + \rho_{k,y} \hat{y}_{t-1} + \epsilon_t^k \tag{2.13}$$

and

$$\hat{\tau}_t^w = \rho_w \hat{\tau}_{t-1}^w + \rho_{w,b} \hat{b}_{t-1} + \rho_{w,y} \hat{y}_{t-1} + \epsilon_t^w. \tag{2.14}$$

Here ϵ_t^k and ϵ_t^w denote innovations in the two tax rates and are i.i.d $N(0, \sigma_k^2)$ and $N(0, \sigma_w^2)$, respectively. The response of the tax rates to the level of debt ensure fiscal solvency. For instance, in the case of increased government expenditures, taxes will respond to the increasing deficit so that the intertemporal government budget constraint is satisfied. Note that the tax rates are assumed to respond to lagged values of the debt and output deviations from the steady state. This helps to isolate the effects of fiscal shocks on the economy at least on impact, and is a reasonable assumption as the model is used to match quarterly data.

Real government expenditures, g_t, have a process with an autoregressive term and a response to lagged output to capture automatic stabilizers,

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \rho_{g,y} \hat{y}_{t-1} + \epsilon_t^g, \tag{2.15}$$

where ϵ_t^g is a government spending shock, assumed to be i.i.d $N(0, \sigma_g^2)$.[14] Lump-sum transfers, tr_t, have the following process which also features a response to the state of the economy. This captures the fact that during recessions, transfers automatically go up, for instance in the form of unemployment and welfare benefits,

$$\hat{tr}_t = \rho_{tr} \hat{tr}_{t-1} + \rho_{tr,y} \hat{y}_{t-1} + \epsilon_t^{tr}, \tag{2.16}$$

[13] The fiscal rules are specified in terms of taxes and expenditures. However, these fiscal rules together with the government's budget constraint imply an evolution process of debt or deficit, which at times seems the main policy instrument in public debates.

[14] In a recent paper, Corsetti, Meier, and Muller (2009) model government spending to respond to the level of debt as well, and show that this causes an eventual reversal of spending and can explain consumption rising in response to a government spending shock. Leeper, Plante, and Traum (2009) also allow government spending to respond to the level of debt, in a real model studying fiscal financing.

where ϵ_t^{tr} represents a shock to transfers, and is i.i.d $N(0, \sigma_t r^2)$. Transfers are modeled as neutral payments in the model, and primarily play the role of a residual in the government budget constraint. So a transfer shock can be thought of as a shock to the budget constraint, not captured by spending or tax shocks.[15]

The monetary authority follows a Taylor type rule,

$$\hat{R}_t = \alpha_R \hat{R}_{t-1} + (1 - \alpha_R)(\alpha_\pi \hat{\pi}_t + \alpha_Y \hat{y}_t) + \epsilon_t^m, \quad (2.17)$$

with interest rate smoothing, governed by the parameter α_R and a response to deviation of inflation and output from their respective steady states, denoted by $\hat{\pi}$ and $\hat{y}_t$ respectively. ϵ_t^m is a monetary shock and is i.i.d $N(0, \sigma_m^2)$.

2.2.3 Firms

Each variety of final goods is produced by a single firm in a monopolistically competitive environment. Each firm $i \in [0, 1]$ produces output using as factor inputs capital services, k_{it} and labor services, h_{it}. The production technology is given by,

$$z_t F(k_{it}, h_{it}) - \psi, \quad (2.18)$$

where F is a homogenous of degree one, concave function strictly increasing in both its arguments and ψ introduces fixed costs of operating a firm in each period, and are modeled to ensure a realistic profit-to-output ratio in steady state. The variable z_t denotes an exogenous technology shock, following an AR(1) process,

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \epsilon_t^z, \quad (2.19)$$

where $\rho^z \in [0, 1]$, and ϵ_t^z is i.i.d $N(0, \sigma_z^2)$.

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[15] The Appendix reports how alternative modeling assumptions for government spending and transfers compare to this specification, in terms of marginal likelihood. These specifications include exogenous process for transfers and spending, and also allowing transfers to respond to the level of debt.

The objective of the firm is to choose contingent plans for P_{it}, h_{it}, and k_{it} so as to maximize the present discounted value of dividend payments, given by

$$E_t \sum_{s=0}^{\infty} r_{t,t+s} P_{t+s} \phi_{it+s}$$

where

$$\phi_{it} = \frac{P_{it}}{P_t} a_{it} - r_t^k k_{it} - w_t h_{it} - \frac{\alpha}{2} \left(\frac{P_{it}}{P_{it-1}} - \bar{\pi} \right)^2,$$

subject to demand functions for public, private and investment goods faced by firm i. Here a_{it} denotes aggregate absorption of good i, which includes c_{it}, i_{it} and g_{it}. Note that price rigidities are introduced following Rotemberg (1982), by assuming that the firms face a quadratic price adjustment cost for the good it produces. I choose this specification of price rigidities because the introduction of deep habits makes the pricing problem dynamic and accounting for additional dynamics arising from Calvo-Yun type price stickiness makes aggregation non-trivial.[16]

2.2.4 Market Clearing

Integrating over all firms and taking into account that the capital-labor ratio is common across firms, the aggregate demand for the composite labor input, h_t, satisfies $h_t = \int_0^1 h_{it} di$, and that the aggregate effective level of capital, $u_t k_t$ satisfies $u_t k_t = \int_0^1 k_{it} di$, this implies a resource constraint that looks as follows,

$$z_t F(u_t k_t, h_t) - \psi = c_t + g_t + i_t + a(u_t) k_t + \frac{\alpha}{2} (\pi_t - \bar{\pi})^2 + \frac{\tilde{\alpha}}{2} \left(\pi_t^w - \bar{\pi} \right)^2 w_t. \quad (2.20)$$

Equilibrium marginal costs and capital-labor ratios are identical across firms. Therefore, one can aggregate the firm's optimality conditions with respect to labor and capital. The complete set of symmetric equilibrium conditions are given in the Appendix.

[16] Modeling price stickiness via a quadratic cost leads to the same Phillips curve and dynamics up to first order as Calvo-Yun price stickiness.

2.3 Estimation

The competitive equilibrium conditions of the model are log-linearized around a non-stochastic steady state.[17] The system of equations can then be written as follows,

$$x_t = F(\Theta)x_{t-1} + Q(\Theta)\epsilon_t, \tag{2.21}$$

where x_t are the model variables, the matrices F and Q are functions of Θ, the structural parameters of the model and ϵ_t are the structural shocks in the model.

2.3.1 Data and Estimation Strategy

Since the focus of this paper is fiscal policy in the context of a DSGE model, in departure from most pre-existing Bayesian estimation papers, in addition to aggregate macroeconomic variables, I include fiscal variables as observable. The following quarterly data series, spanning 1958:1-2008:4, are used in the estimation, $[c_t\ i_t\ \pi_t\ R_t\ g_t\ b_t\ \tau_t^k\ \tau_t^w]$, where c_t is real per capita consumption, i_t is real per capita investment, π_t is price inflation, R_t is the federal funds rate, g_t is real per capita total government purchases, b_t is real federal debt held by public, τ_t^k is the capital tax rate and τ_t^w is the labor tax rate.[18] Details on the construction of each time series are provided in the Appendix.

The measurement equation connects the observables, obs_t to the model variables,

$$obs_t = H(\Theta)x_t + \upsilon_t. \tag{2.22}$$

The matrix H is a function of the structural parameters of the model and υ_t denotes measurement errors. The dynamic system characterized by the state equation, (2.21) and this measurement equation is estimated using Bayesian techniques, where the

[17] The complete set of equilibrium conditions along with the steady state are given in the Appendix. The model is log-linearized and solved using the method of Schmitt-Grohe and Uribe (2004).

[18] The data used in the estimation starts in 1958:1, due to unavailability of property tax data prior to that date, which is used in the construction of capital tax data.

object of interest is the joint posterior distribution of the parameters, which combines the prior distribution and the likelihood function. The priors for the parameters being estimated are given in the next subsection, and the likelihood is computed using the Kalman filter, under the assumption of all the structural shocks being normally distributed. The Metropolis-Hastings algorithm is used to sample from the posterior proposal distribution, which is a multivariate normal, $N(0, c\Sigma)$. The algorithm is initialized using the maximized posterior mode from the optimization routine csminwel.m, by Chris Sims, and Σ is the inverse of the numerical Hessian evaluated at this posterior mode. The scaling factor c is chosen to ensure an acceptance rate of close to 30 %. 1.5 million draws are generated, where the first 500,000 are used as burn-in period, to lose any dependence on initial values. Ultimately, several convergence diagnostics are used to ensure the convergence of these Monte Carlo chains.[19]

2.3.2 Calibration and Priors

Some of the parameters which are hard to identify or pin down in steady state are calibrated. These include the discount factor β, set at $1.03^{-1/4}$, which implies a steady-state annualized real interest rate of 3 percent. The depreciation rate, δ, is set at 0.025, which implies an annual rate of depreciation on capital equal to 10 percent. θ is set at 0.30, which corresponds to a steady state share of capital income roughly equal to 30%. The labor elasticity of substitution, $\tilde{\eta}$ is set at 21, and goods elasticity of substitution, η is set at 5.3, since with the introduction of deep habits the price markup movements are jointly determined by deep habit parameters and η is generally not well identified.

Some of the steady state variables are also calibrated based on averages over the sample period considered in the paper. The share of government spending in aggregate output is set at 0.18, and the annual average of the ratio of debt to GDP

[19] The diagnostics include trace plots, examining the autocorrelation functions and CUSUM plots.

pins down the steady state value to be 0.33. Similarly, the steady state values of the capital and labor tax rates are based on mean of the constructed series of average tax rates over the sample size, and are 0.41 and 0.23 respectively. Also, the steady state labor is set at 0.5, which corresponds to a Frisch elasticity of labor supply of unity.

Table 2 shows the prior distribution for the parameters being estimated. These are consistent with the literature and the means of the distribution were set based on estimates from pre-existing studies. The autoregressive coefficients in the shock processes have a beta distribution with a mean of 0.7 and standard deviation of 0.2. The only exception is the government spending process which is known to be highly persistent. The priors on standard deviations of the shocks have an inverse gamma distribution and are quite disperse. The deep habit parameters are assumed to have a beta distribution and the mean is in line with estimates from Chapter 1, where deep habits are explored as a transmission mechanism for government spending shocks with a limited information approach. The capacity utilization and investment adjustment cost parameters have normal distributions with means of 2.5 and 2 respectively, in line with estimates from Smets and Wouters (2007) and Altig, Christiano, Eichenbaum, and Linde (2005). The coefficient of relative risk aversion σ is assumed to have a normal distribution with a mean of 2, which is higher than the logarithmic case. The nominal rigidity parameters have a normal distributions where the means correspond approximately with an adjustment frequency of close to four quarters, in the mapping between the Phillips curve coefficient implied by convex adjustment costs specification and the one with Calvo-Yun type rigidities. The standard deviation of these prior distributions are large to accommodate uncertainty in these parameters.

Monetary policy rule parameters have prior distributions similar to the ones adopted in Smets and Wouters (2007) and the mean values are also consistent with estimates from Clarida, Gali, and Gertler (2000). On the other hand for fiscal policy rule parameters, the literature is less informative and so the priors are diffuse and span a larger parameter space. As mentioned above, the tax rate processes are assumed to be persistent. The tax rate elasticities to debt are assumed to have a gamma distribution with a mean of 0.5 and a standard deviation of 0.2, which is similar to Forni, Monteforte, and Sessa (2009). Blanchard and Perotti (2002) provide evidence regarding output elasticities of tax revenues, an average value of 2.08. This would mean that with 1% increase in output, tax revenues rise by close to 2%, which would roughly mean a 1% rise in tax rates. The tax rate elasticities for both tax rates are thus assumed to have a gamma distribution with mean 1 and standard deviation of 0.5. Blanchard and Perotti (2002) find no strong evidence of automatic stabilizers for government spending. Thus the government spending elasticity to output is assumed to have a normal distribution with mean -0.05 and the transfers elasticity to output is assumed to have a mean of -0.1. In order to further clarify the economic content of the priors, the Appendix shows the fiscal multipliers implied by the priors, in Table B.1.

2.4 Estimation results

2.4.1 Parameter estimates

The mean and 5 and 95 percentiles of the posterior distribution for the parameters estimated are given in Table 2. All the shocks are significantly persistent. The preference parameter, investment adjustment cost and capacity utilization parameters are estimated to be consistent with estimates in the literature.[20] The degree of deep habit in private consumption is quite high, and the estimates for θ^g and θ^c suggest that the stock of habits for both public and private consumption depreciates slowly.

[20] The parameter estimates for the preference and capacity utilization parameters are similar to the prior, but robustness of these results were verified by estimating the model with different priors, but the posterior converges to very similar values.

The monetary policy parameters are estimated to indicate high degree of interest rate smoothing and a significant response to inflation, satisfying the Taylor principle. Since monetary policy is active for the sample considered here, fiscal rule parameters are such that government debt is fully backed by future taxes in order for the equilibrium to be determinate, and so that the intertemporal government budget constraint is satisfied. The tax rates are persistent, and have a significant response to both the level of debt and output. Capital tax rates are found to be more responsive to the state of the economy than labor tax rates. While there is evidence for automatic stabilizers for transfers, government spending is does not have a particularly large countercyclical component.

A discussion on the overall goodness of fit of the estimated model can be found in the Appendix. Figure B.1 displays the actual observable series used in the estimation along with the posterior mean of their smooth version according to the estimated model. The fit for almost all variables is close to perfect. Figure B.2 and Table B.2 compare a set of statistics implied by the model to those measured in the data, and show that overall, the model seems to provide a good fit to the data.

2.4.2 Transmission of fiscal shocks

Figures 2.1- 2.4 show the impulse response functions as a result of shocks to the fiscal variables. The x-axis shows quarters after the shock hits the economy and the y-axis shows percentage deviations from the steady state. The impulse response functions are computed for randomly chosen 1000 parameter draws from the Monte Carlo chains. The solid lines denote the median response and the dashed lines correspond to the 5th and 95h percentiles.

Figure 2.1 shows that in response to a 1 percent increase in government spending, output, consumption, hours and wages rise, whereas investment falls with a delay. There are standard negative wealth effects that leads households to increase labor supply which leads to a rise in output. There is a negative wealth effect on consumption as well, but since the model embeds deep habits in public and private consumption, an increase in government spending demand induces a decline in the mark-ups. These variations in the markup shift the labor demand and therefore, wages increase with output as a result of an increase in demand. This higher real wage cause individuals to substitute away from leisure to consumption, and this substitution effect is large enough to offset the negative wealth effect so that overall consumption rises in response to a government spending shock. However, these effects are short-lived since the government spending is financed by a rise in distortionary taxes, which affects the marginal return on labor and capital. Investment does not move much on impact and slowly falls in response to a shock, primarily due to the rise in capital taxes.

The estimation is carried out using a full-information approach and fit the model to all the variation in the data, not just the dynamic effects of a spending shock. Even then, the responses of the variables are well in line with the literature on structurally identified VARs that study the effects of government spending shocks (see for example Blanchard and Perotti (2002) and Fatas and Mihov (2001)). In particular, the model is in agreement with this literature in predicting positive responses of consumption and wages to a spending shock. The positive response of consumption, however, is small in magnitude and as mentioned earlier, relatively short-lived in the model. As far as investment is concerned, Blanchard and Perotti (2002) also find an insignificant response on impact and a significantly negative response with a delay. The model predictions on investment are although different from Fatas and Mihov (2001), who show that investment falls on impact and then slowly rises to become positive. Unlike the observable used in the estimation in this paper, their measure of investment does not account for durable consumption. But they also show separately that durable consumption rises in response to a spending shock.

Figure 2.2 shows that in response to a 1 percent decrease in the labor tax rate, output, hours, consumption and investment all rise. Wages fall on impact and then slowly rise above steady state. There is a wealth effect that results in consumption rising and labor falling, along with an intratemporal substitution effect leading to consumption rising further and labor rising due to a higher return on labor. This rise in labor supply results in wages rising in equilibrium. The cut in labor tax rate also causes the return on capital to go up due to its effects on labor supply, leading to a rise in investment. Investment has a hump-shaped response due to investment adjustment costs. Also, note that since the degree of deep habit formation in private consumption is estimated to be high, it suggests households have a strong desire to smooth consumption, which also translates in a shift of demand from consumption to investment goods.

Figure 2.3 shows that a 1 percent fall in the capital tax rate results in hours, investment and wages rising. Hours rise after a slight delay and consumption has a small negative response. With a fall in capital tax rate, the after-tax return on capital goes up, resulting in a rise in investment. Here the response of investment is once again hump-shaped, and peaking at close to 5 quarters after the shock hits the economy, because of investment adjustment cost. Intertemporal substitution effects lead agents to delay consumption and raise labor supply. However, wealth effects work in the opposite direction. In addition, capacity utilization goes up as there is reallocation from labor to capital. These effects are generally similar to ones seen in standard neoclassical models (for example Braun (1994)). Looking at the equilibrium effects on consumption and labor, one has to take into account that soon after a fall in the capital tax rate, the labor tax rate rises to finance the deficit, and thus the consumption response is muted.

In both cases of a fall in labor and capital taxes, the model predicts a significant rise in investment. While the literature does not tend to distinguish between capital and labor taxes, Blanchard and Perotti (2002), who identify a shock to total tax revenues in a SVAR, and Romer and Romer (2007) who identify tax shocks using a narrative approach, both also find significant crowding out of investment in response to a positive tax shock. Mertens and Ravn (2008) use the narrative approach of Romer and Romer (2007) to distinguish between anticipated and unanticipated tax shocks. The responses in the model are consistent with their findings regarding responses to unanticipated tax shocks. The only exception is the response of consumption to a capital tax shock, but unlike the case shown in this paper, Mertens and Ravn (2008) consider the effects of capital tax shocks while restricting the reaction of labor taxes.

Lastly, Figure 2.4 shows that the responses to a 1 percent rise in lump-sum transfers are all insignificant on impact. Transfers have a positive wealth effect, but as is clear from the figure, there is a negligible effect on impact and the medium to longer run responses are driven by the rise in capital and labor taxes used to finance this increase in transfers. Therefore, there is not a significant positive stimulative effect on output.

2.5 The Estimated Size of Fiscal Multipliers

The stimulative effects of a fiscal action are generally framed in terms of multipliers. Most of the pre-existing evidence on multipliers comes from the empirical literature, which has explored different identification schemes for fiscal shocks. This paper, however, is novel in its approach of estimating both government spending and tax multipliers in the context of a structural general equilibrium model, using a full information econometric methodology.

The effects of fiscal policy are typically summarized by the impact multiplier, which is the increase in the level of output k periods ahead in response to a change in the fiscal variable of interest given by ΔF_t at time t.[21]

$$\text{Impact multiplier } k \text{ periods ahead} = \frac{\Delta Y_{t+k}}{\Delta F_t}.$$

So the spending impact multiplier is given by, $\frac{\Delta Y_{t+k}}{\Delta G_t}$, and for the tax rates the impact multiplier is given in terms of the change in total tax revenues, so its $\frac{\Delta Y_{t+k}}{\Delta T_t}$, where T_t denotes tax revenues. The two tax shocks are normalized so that they result in a 1 percent decrease in total tax revenues.

The impact multipliers for the estimated model are reported in Table 3, along with 95 percentile confidence bands for horizons of 1, 4, 12 and 20 quarters after the shock hits the economy. The government spending multiplier for output is 1.12 on impact and slowly decreases to be negative in the long-run. This means that on impact, a 1 percent of GDP increase in government spending results in a larger than 1 percent overall increase in GDP.

The tax multipliers in the first quarter are small. A 1 percent of GDP fall in total tax revenues driven by labor tax cuts and capital tax cuts result in a 0.13 percent and 0.33 percent rise in GDP, respectively. But the effects of taxes take time to build, and both the capital and labor tax multipliers are maximized between 4 and 12 quarters. However, magnitude-wise taxes consistently have a smaller multiplier than spending for shorter horizons, and exceed the spending multiplier for horizons of 12 and 20 quarters.

The impact multipliers, however, do not take into account that a shock at time t to tax rates or government spending results in a particular future path for the fiscal instruments given by the processes defined in the modeling section. In order to capture the cumulative effects of the fiscal shock along the entire path up to a given period, I follow Mountford and Uhlig (2002), and report the present value multiplier,

[21] For instance the government spending multiplier is computed as follows, $\frac{\Delta Y_{t+k}}{\Delta G_t} = \frac{\%\Delta Y_{t+k}}{\%\Delta G_t}\frac{Y}{G}$, where Y and G are the steady state values of output and government spending respectively.

which also discounts future effects.

$$\text{Present value multiplier } k \text{ periods ahead } = \frac{E_t \sum_{j=0}^{k} (1+R)^{-j} \Delta Y_{t+j}}{E_t \sum_{j=0}^{k} (1+R)^{-j} \Delta F_{t+j}},$$

gives the increase in present value of output over the next k periods, as a result of a shock at time t to the fiscal variable of interest, F.

The present value multipliers are given in Table 4. The impact and present value multipliers take the same value in quarter 1, by definition. The present value tax multipliers build over time, whereas the spending multiplier decreases across the horizon. At longer horizons, tax and spending multipliers for output have the same magnitude. In fact, after close to 5 years, a cumulative one dollar decrease in tax revenues driven by labor tax cuts results in a one dollar increase in GDP, and exceeds the stimulative effects of increased spending. Notice also, that in terms of multipliers, labor tax cuts while not as effective as capital tax cuts in the short-run, boost output to a larger degree in the long-run.

Table 5 shows the present value spending and tax multipliers for components of GDP, consumption and investment. The spending multiplier for consumption is found to be positive, however rather small in the short-run, and in the long-run is negative. This positive multiplier for consumption is in line with structural VAR studies, while in contrast to standard models that do not explicitly introduce a mechanism for public spending shock to transmit through the economy. The spending multiplier for investment is not significant in the first few quarters but becomes negative in the long-run. The positive multiplier for consumption and the insignificant response of investment on impact also explain the size of the spending multiplier for output, being larger than one. If for instance, consumption and investment are both crowded out in response to a spending shock, and have negative multipliers, then the resulting multiplier for output would be less than one.[22]

Consumption has a small and positive multiplier in response to a labor tax shock on impact which becomes larger at longer horizons. Conversely, the consumption multiplier is small and negative in response to a capital tax shock. Also, notice that the multiplier for investment in response to both tax shocks is sizable. This suggests that the expansionary effects of both labor and capital tax cuts on output are primarily driven by the stimulative effects on investment.

Table 5 also shows the multipliers for hours worked in the model, since the main motivation behind a fiscal stimulus plan is typically to boost demand and to raise employment.[23] Employment has a significantly positive spending multiplier, which is largest on impact, and slowly decaying over the horizon. This increase in hours worked, as a result of increased public spending, is due to both a rise in labor supply and demand. Labor supply shifts mainly because of households anticipating an increase in taxes, and price rigidities and countercyclical markups lead to a rise in labor demand of the firms with the shift in aggregate demand. The employment multiplier is also positive for labor tax cuts, and while on impact the effects are small, they build significantly over time. These effects are primarily driven by the increase in labor supply due to the resulting higher return on labor. Unlike increased spending and labor tax cuts, capital tax cuts do not stimulate hours worked on impact. The multiplier for hours worked is positive for a range of 5-18 quarters after the shock hits the economy, but even then the magnitude is much smaller than the effects of alternative fiscal instruments. This suggests that increased government spending and lowering labor taxes are effective at stimulating hours worked.

[22] This is true in the estimated DSGE model of Smets and Wouters (2007), which is not developed to study fiscal policy, as they do not consider a transmission mechanism for government spending shocks and assume spending financed by lump-sum taxes.

[23] It might be worthwhile, however, to consider a model with search frictions in the labor market, to fully explain the effects of fiscal shocks on labor, both at the extensive (employment) and intensive (hours per worker) margins.

There are some recent DSGE models where the effects of a spending shocks are estimated and spending multipliers can be inferred. (See for example Coenen and Straub (2005), Lopez-Salido and Rabanal (2006) and Forni, Monteforte, and Sessa (2009).) These papers consider mechanisms to replicate the positive response of consumption to a spending shock, as suggested by VAR evidence, and find the spending multiplier in the range of 0.7 and 2. On the other hand, there has been no significant prior work done on estimating tax multipliers in a structural model.[24]

There is, however, a great deal of evidence in the VAR literature measuring the stimulative effects of spending increases and tax cuts. Studies employing structural VARs, such as Fatas and Mihov (2001), Blanchard and Perotti (2002) and Gali, Lopez-Salido, and Valles (2007), also find output multipliers for spending close to 1.[25] As mentioned earlier, these papers also find positive consumption multipliers. Blanchard and Perotti (2002) also emphasize the negative effect on investment of an increase in government purchases, which is seen in the model at longer horizons of 12 and 20 quarters.

The slow rise in the stimulative effects of tax cuts are also documented in this literature, for example by Blanchard and Perotti (2002), Romer and Romer (2007) and Mountford and Uhlig (2002). The effects of tax shocks found here, however, are smaller than the ones documented in these studies. One of the reasons is that they consider a shock to total tax revenues and do not distinguish between labor and capital taxes. Mountford and Uhlig (2002) also document large effects of tax cuts because they consider deficit financed tax shocks, whereas in the model, once labor taxes are lowered in order to stimulate the economy, there is an eventual increase

[24] An exception is Forni, Monteforte, and Sessa (2009) who estimate both tax and spending multipliers for the Euro area.

[25] Ramey (2008) employs a narrative approach, based on identifying episodes of large military buildups, and finds the maximum spending multiplier to be 1.1. Mountford and Uhlig (2002) use a sign restrictions approach to identify fiscal shocks, and find the spending multiplier to be 0.65. These variations in the multipliers can be attributed to differences in identification schemes.

in capital taxes in response to the resulting deficit. The significant response of investment to the tax shocks is also found in this literature. Both Romer and Romer (2007) and Blanchard and Perotti (2002), though employing different identification schemes, find that tax raises are highly contractionary primarily due to the effects on investment.

2.6 Counterfactual Fiscal Policy Experiments

2.6.1 Deficits versus Tax Financing

In the baseline model, government spending is financed by an increase in taxes and government debt. In this section, I evaluate the scenario where the government, relative to the historically estimated rules, is more or less aggressively committed to retiring the debt. This is done in a similar manner to the exercise shown in Uhlig (2009), where the rate at which taxes respond to the level of debt is varied. More precisely, the processes for labor and capital tax rates are given as follows,

$$\hat{\tau}_t^k = \rho_k \hat{\tau}_{t-1}^k + \gamma \rho_{k,b} \hat{b}_{t-1} + \rho_{k,y} \hat{y}_{t-1} + \epsilon_t^k, \tag{2.23}$$

$$\hat{\tau}_t^w = \rho_w \hat{\tau}_{t-1}^w + \gamma \rho_{w,b} \hat{b}_{t-1} + \rho_{w,y} \hat{y}_{t-1} + \epsilon_t^w, \tag{2.24}$$

where $\gamma = 1$ corresponds to the baseline estimated rule. When γ is less than 1, then taxes are less responsive to debt and government spending is primarily financed by issuing debt. The values of $\gamma > 1$ correspond with taxes rising more aggressively in response to a deficit, and so government spending is financed by higher taxes than the baseline case.

Figure 2.5 shows the present value spending multiplier for output at various horizons, as γ is varied between 0.5 and 10, where 0.5 is the smallest value for which the equilibrium is determinate. In the short-run both the spending and output multipliers are generally unaffected as taxes are overall slow to adjust to the rising level of debt. However, at longer horizons the multipliers become significantly smaller when taxes respond more aggressively to the level of debt, in response to spending and tax shocks. In the case of tax shocks, because agents in the economy internalize that a tax cut today will be financed by aggressive tax increases in the future, the present value multipliers for longer horizons in fact become negative.

Figure 2.6 shows the evolution of debt over a horizon of 20 quarters for varying degrees of γ, in response to a government spending shock. Typically, debt takes as long as 50-100 years to come back to steady state. The slow evolution of debt has been documented by others, such as Chung and Leeper (2007). After fiscal disturbances hit the economy, when γ is as high as 5 or 10, then debt returns to steady state in 5-15 years. In conclusion, while the multipliers are mostly unaffected at shorter horizons of up to a year, the method of financing, either by increased deficits or raising taxes, is important for longer-run consequences.

2.6.2 Lump-sum versus Distortionary Taxation

A common assumption in the literature is exogenous fiscal policy with deficits financed by lump-sum taxes, which implies Ricardian equivalence holds and the timing of the taxes does not affect the equilibrium. However, as pointed out in Baxter and King (1993), in a neoclassical model there are significant differences between government spending financed by changes in tax rates or changes in lump-sum transfers. The changes in lump-sum transfer payments are equivalent to debt financing when sequences for tax rates are fixed. In fact, in their calibrated model, there is a negative effect on output of an increase in government purchases when it is financed entirely by distortionary taxes. This is because of strong substitution effects on labor supply of tax rates.

In this section, the spending multiplier in the case of the estimated endogenous rules for tax rates are compared with the scenario when instead of the distortionary taxes responding, the spending is financed by lump-sum taxes. This is done by shutting down the response of the distortionary taxes, by setting $\hat{\tau}_t^w = \hat{\tau}_t^k = 0$. In order to model the increase in lump-sum taxes instead, in Equation (2.16), I consider an additional term, where lump-sum transfers respond to the level of debt. This means that after an increase in government spending, while tax rates do not respond, lump-sum transfers adjust to ensure fiscal solvency and the return of the level of debt to steady state.[26]

Figure 2.7 shows that the present value spending multiplier for output is consistently lower in the case of spending financed by distortionary taxes. Note, however, that the method of financing government spending, at least in the short run does not have very significant effects. This is because, in the baseline model with distortionary taxes, the tax rates do not respond on impact and otherwise evolve slowly. Looking at the longer horizon, in the case of spending financed by lump-sum taxes, the multiplier is near one even close to 20 quarters, whereas in the estimated model with endogenous tax rates, the multiplier significantly decreases over time. This points towards careful consideration of conclusions about effects of fiscal policy in simpler models where government purchases are assumed to be financed entirely by lump-sum taxes which is equivalent to deficit financing.

2.6.3 Automatic Stabilizers

In this section, the role of automatic stabilizers is explored on the present value spending multiplier for output. These capture changes in government revenues and expenditures due to the changes in the state of the economy and do not require any discretionary action on the part of the government while playing the role of stabilizing fluctuations in the economy. This is done by varying the value of μ in the

[26] This is done by setting the coefficient of transfer to lagged debt, $\rho_{tr,b} = -0.1$, where this values ensures determinacy of equilibrium or the intertemporal government budget constraint being satisfied.

following processes,

$$\hat{\tau}_t^k = \rho_k \hat{\tau}_{t-1}^k + \rho_{k,b}\hat{b}_{t-1} + \mu\rho_{k,y}\hat{y}_{t-1} + \epsilon_t^k, \tag{2.25}$$

$$\hat{\tau}_t^w = \rho_w \hat{\tau}_{t-1}^w + \rho_{w,b}\hat{b}_{t-1} + \mu\rho_{w,y}\hat{y}_{t-1} + \epsilon_t^w, \tag{2.26}$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + \mu\rho_{g,y}\hat{y}_{t-1} + \epsilon_t^g, \tag{2.27}$$

$$\hat{tr}_t = \rho_{tr}\hat{tr}_{t-1} + \mu\rho_{tr,y}\hat{y}_{t-1} + \epsilon_t^{tr}. \tag{2.28}$$

Figure 2.8 reports the present value spending multiplier at different horizons for different values of μ. The automatic stabilizers take the estimated values when μ=1. In the case of a government spending shock hitting the economy, it raises output, which results in a rise in capital and labor tax rates, and a decrease in transfers due to their countercyclical nature.

Now, when these stabilizers are larger, in order to dampen short-run fluctuations in the economy, the effects of an increase in government spending are reduced at all horizons, since the economy is stabilized by further increases in taxes and decreases in transfers. However, even though this is a short-run mechanism for mitigating the impact on demand, the effects in the long-run are further exacerbated, as seen in the diverging present value multipliers at horizons close to 20 quarters.

2.7 Sensitivity of Fiscal Multipliers to Monetary Policy

In this section, I consider how the stance of the monetary policy affects the size of fiscal multipliers. The role of monetary authority is important in determining the movements of the real interest rate, which through intertemporal effects plays a role in how macroeconomic variables react to fiscal shocks.

I start by exploring how the coefficients in the monetary policy rule affect the impact multiplier of output in response to the government spending, capital and labor tax shocks, shown in Figure 2.9. In the top panel, the nominal interest rate smoothing parameter, α_R, is varied between 0.01 and 0.99, keeping the other parameters constant. The spending and capital tax multipliers for output rise with a higher value of α_R, whereas the labor tax multiplier falls for higher values of the parameter. This is because in the case of spending and capital tax cuts, a higher value of α_R means the monetary authority increases the real interest rate less rapidly, thus increasing the expansionary effects of these fiscal actions. In response to a labor tax cut, the model predicts a fall in inflation. Therefore higher values of α_R imply that the desire to smooth interest rate strengthens in opposition to the downward pressure on interest rate due to effects of inflation.

The middle panel of Figure 2.9 shows that as the coefficient on inflation in the monetary policy rule, α_π is perturbed, it does not significantly alter the impact multipliers in the case of increased government spending or reduced taxes overall. This is because inflation has a limited response to the fiscal shocks. However, notice also that as α_π increases, the largest effect is on the impact labor tax multiplier, which decreases. This is because a labor tax cut causes households to increase labor supply due to a higher return on labor. This causes a fall in wages and lower marginal costs results in a fall in inflation. Therefore a larger response to inflation results in a smaller rise in real interest rate, though these effects are small in magnitude.

The last panel, shows that as the coefficient on output, α_Y, is varied between 0 and 0.5, the impact multipliers are significantly affected, particularly in the case of the government spending multiplier for output. As α_Y rises, the impact multiplier for output uniformly falls in the case of all fiscal shocks. If the nominal interest rate are highly responsive to the deviations of output from the steady state, then in the case of both spending and tax shocks, the nominal interest rate will rise sharply, causing the real interest rate to go up. This leads to a fall in aggregate demand and results in a smaller output multiplier.[27]

[27] These effects of the size of the coefficient on deviations of output in the monetary policy rule,

The role of monetary policy is explored further by considering two extreme cases, one where the monetary authority is very aggressive in stabilizing both inflation and output (α_π=2 and α_Y=0.5), and the second where the monetary policy does not react significantly to variations in the state of the economy (α_π=1.1 and α_Y=0).[28] Figure 2.10 shows the present value fiscal multipliers for output, consumption and investment under these two rules and the estimated monetary policy rule. The x-axis shows the horizon in quarters.

The first row in Figure 2.10 shows the present value government spending multiplier. The multipliers for all components of demand are found to be larger than the baseline case under the accommodative monetary policy, and smaller in the case of the aggressive monetary rule. In the estimated model, because markups are countercyclical, a government spending shock leads to an initial small decline in inflation, and inflation eventually rises once aggregate demand comes back to normal. The nominal interest rate responds significantly to both inflation and the rise in output, and overall this results in a rise in the real interest rate. In the case of aggressive monetary policy, the real interest rate rises more than the baseline scenario which is primarily due to the strong response to deviations in output from the steady state. This leads to a fall in both consumption and investment demand in response to a government spending shock, and the output multiplier is less than one, even on impact. The case of monetary policy with a limited response to inflation and output results in the real interest rate falling in response to a government spending shock, which creates an incentive for agents to consume and invest more, thus raising the government spending multiplier. This suggests that if the monetary authority reacts strongly to the state of the economy, then it limits the stimulative effects of increased

α_Y, on aggregate demand in response to a government spending shock, are also pointed out in Linnemann and Schabert (2003).

[28] Note that $\alpha_\pi = 1.1$ is the smallest reaction consistent with a determinate equilibrium in the estimated model.

government spending. Alternatively, in the presence of a relatively accommodative monetary policy, government spending has a higher stimulative effect on aggregate demand.[29]

The same effects are at play in response to a capital tax cut, as shown in the second row of Figure 2.10, so that an accommodative monetary policy results in a higher overall stimulative effects on output, consumption and investment.

However, less responsive monetary policy does not imply a larger stimulative effect in the case of all fiscal measures. The last row of Figure 2.10 shows the labor tax multiplier in the case of the estimated monetary policy rule, along with the two alternate rules. The labor tax multipliers for output, consumption and investment are lower in the case of both new rules, relative to the estimated monetary policy rule. When α_{π}=1.1 and α_{Y}=0 , since inflation falls in response to the cut in labor taxes, a smaller response to inflation results in a larger rise in real interest rate than the baseline estimated model, causing components of demand to fall. This leads to a smaller multiplier effect of labor tax cuts when the monetary policy is not reacting strongly to both inflation and output. In the case of α_{π}=2 and α_{Y}=0.5, the rise is real interest rate is limited due to the large response to inflation, but because of the aggressive response to deviations of output from steady state, overall real interest rate rises much more than the baseline case. This once again results in a smaller multiplier in response to a labor tax cut.

In this section, I have shown that the stance of monetary policy has important implications for the size of fiscal multipliers. An accommodative monetary policy that has a limited response to inflation and output deviations, results in higher overall

[29] Davig and Leeper (2009) also document similar interactions between monetary policy and the size of fiscal stimulus due to increased spending, where monetary policy determines the size of the implied intertemporal substitution effects arising in response to a spending shock, and thus the ultimate response of components of aggregate demand. Their focus however is regime switching in both monetary and fiscal policy, and they characterize fiscal multipliers also in the regime where monetary policy is passive and fiscal policy is active.

stimulative effects of increased spending and capital tax cuts. This is however, not the case for all fiscal measures, as shown in the case of labor tax cuts. In this paper, I consider the case of active monetary policy, since fiscal policy is estimated to be passive. Recent work by Cogan, Cwik, Taylor, and Wieland (2009), Christiano, Eichenbaum, and Rebelo (2009) and Eggertsson (2009) provide supporting evidence, to show that when the monetary policy is completely unresponsive or the nominal interest is at the zero bound, the monetary-fiscal interactions have significant effects on the size of fiscal multipliers.

2.8 Simulating the American Recovery and Reinvestment Act of 2009

In early 2009, the US Congress passed a \$ 787 billion package in order to stimulate the economy. The stimulus package comprises of both increased government spending and tax cuts. In this section, the effects of the package on the economy are analyzed by simulating the implied changes in government spending and taxes in the estimated model.

In order to analyze the impact of increased spending contained in the stimulus package, note that two thirds of the bills goes towards public investment and government purchases, and aid to state governments. These government purchases, are mostly one time only expenditures and phased to take place over the course of several years. The transfers to state and local governments are to be used both for purchases of goods and services, and towards avoiding raising taxes. Romer and Bernstein (2009) assume that 60% of these transfers are used towards spending. Cogan, Cwik, Taylor, and Wieland (2009) use this assumption and report the path of government purchases as a share of GDP due to the stimulus package, over the course of the next few years. Roughly a third of the package goes towards tax cuts. The largest component, close to \$ 116 billion, is in the form of payroll tax credits.[30]

[30] The rest are tax cuts for individuals in the form of expanded child credits, college credit, home

In the model, these payroll tax credits can be thought of as a cut in the labor income tax rate.[31]

In order to simulate the American Recovery and Reinvestment Act of 2009 in the model, the path of government purchases from this stimulus package, as specified by Cogan, Cwik, Taylor, and Wieland (2009), is introduced as a sequence of anticipated shocks into the economy. This means that in 2009:I, agents in the economy observe the entire path of expected government spending as shown in Figure 1, Panel A. In addition, the tax cut is introduced as a 1% cut in labor income taxes in 2009:I, as shown in Figure 1, Panel B. Next the responses to both these shocks are computed in the model and are shown in Figure 2. The model predicts that the effects on GDP of the stimulus package would be most significantly felt during early 2010. There is a small increase in output initially as the households anticipate larger spending in the following years and while the tax cuts are initialized in 2009, their effects take time to build and the largest impact on GDP is a few quarters after the initial shock. Also notice that by late 2012, output multiplier is negative, even though government spending is still above steady state in order to stimulate the economy. This is because the agents are forward-looking and internalize that the large increase in spending is going to be financed by higher taxes. In fact, in response to the government spending stimulus alone, the consumption multiplier is negative starting mid 2010, because of households anticipating expenditures financed by higher taxes. It is also clear that this fiscal expansion comes with a large increase in the level of debt, which remains above steady state for many years.

buyer's credit etc. A small fraction are tax cuts for companies, for example to use current losses to offset profits made in the previous five years and extended tax credits for renewable energy production.

[31] Since, these payroll tax credits are close to 2 percent of the total tax revenues, and Blanchard and Perotti (2002) estimate the output elasticity of total tax revenues to be 2.08, this can be thought of as a 1% decrease in the tax rate. Uhlig (2009) also simulate this tax change as a 1 % reduction in the labor tax rate.

While the government purchases path is taken from Cogan, Cwik, Taylor, and Wieland (2009), the impact on GDP of the fiscal stimulus package are found to be larger than the ones reported in their paper. Focusing only on the effects of government spending, Cogan, Cwik, Taylor, and Wieland (2009) find the effects on GDP maximized in 2010, and that is an increase in GDP of close to 0.5 % (as shown in Figure 2 of their paper). However, the estimated model predicts GDP rising by as much as 0.78% due to increased spending alone, in late 2010. These differences arise because Cogan, Cwik, Taylor, and Wieland (2009) compute the impact on GDP based on spending multipliers from the estimated DSGE model of Smets and Wouters (2007), which are smaller than the ones estimated in this paper. Unlike the model of fiscal policy in this paper, in Smets and Wouters (2007), spending is financed by lump-sum taxes and the primary effects of increased government spending are negative wealth effects experienced by the households, resulting in a significant crowding out of both private consumption and investment. They do not consider a transmission mechanism for government spending and thus produce an empirically counterfactual large negative response of consumption to a positive spending shock.

One caveat to note in this analysis is that this has not taken into account that the role of monetary policy under current circumstances is limited as the Fed has recently been holding the nominal interest rate near zero.

In addition, since the model has a feedback from output to government spending, some of the changes in spending might be attributed to automatic stabilizers and would not be a shock. It is important to notice though that the countercyclical component of government spending is estimated to be rather small. To verify whether automatic stabilizers are significant in this case, I simulate government spending for 2009:1, using data on GDP and spending in 2008, and do not find evidence of larger deviations of government spending from steady state relative to 2008. This suggests that the extraordinary increase in government spending introduced in the stimulus package is in fact discretionary fiscal policy.

2.9 Conclusion

This paper provides evidence on the effects of fiscal policy actions in the context of a model featuring distortionary tax rates and rich fiscal rules, estimated using detailed fiscal data on tax rates, spending and debt.

I find that government spending has a large stimulative effect on impact, which decreases significantly at longer horizons. Tax cuts, on the other hand are always less stimulative in the short-run but their effects build over time. In particular, the impact multiplier for government spending is 1.12 and the estimated model predicts a positive response of private consumption to government spending, which is in contrast to models that do not consider a channel of transmission of government spending shocks, but is consistent with empirical studies. The multipliers for labor and capital tax on impact are 0.13 and 0.33 respectively, which exceed the stimulative effects of increased spending at horizons of 12-20 quarters. These effects of tax shocks are primarily driven by the response of investment.

In addition, counterfactual exercises reveal that the speed at which government debt is retired following a fiscal shock has consequences for the stimulative effect of the fiscal policy action, and these are most important at longer-run horizons. Also, although governments might rely on discretionary fiscal policy to stimulate the economy in the short-run, there are long lasting dynamics and the short-run effects can sharply differ from long-run effects of a fiscal policy action.

While assessing the role of monetary policy, I find that the response of the monetary authority to deviations of output from the steady state is significantly important in determining the movements of the real interest rate. This in turn, through intertemporal effects, has consequences for the size of fiscal multipliers. In fact, if the monetary authority reacts strongly to the state of the economy, then it limits the stimulative effects of increased government spending. Conversely, an accommodative monetary results in a higher fiscal multipliers for increased spending. However, less responsive monetary policy does not imply a larger stimulative effect in the case of all fiscal measures, as shown in the case of labor tax cuts.

2.10 Tables and Figures

Table 2.1: Calibrated Parameters

Parameter	Description	Calibrated value
δ	Depreciation rate	0.025
β	Discount factor	0.9926
$\tilde{\eta}$	Wage elasticity of demand	21
η	Price elasticity of demand	5.3
θ	Capital share	0.30
π	Steady state inflation	$1.042^{1/4}$
u	Steady state capacity utilization	1
h	Steady state labor	0.5
g/y	Share of govt. spending in GDP	0.18
b/y	Ratio of debt to GDP (annual)	0.33
τ^k	Steady state capital tax rate	0.41
τ^w	Steady state labor tax rate	0.23

Table 2.2: Prior and Posterior Distribution of Estimated Parameters.

Parameter	Description	Prior			Posterior	
		Dist.	Mean	Std. Dev.	Mean	[5,95]
ρ_k	Autocorr. of τ_t^k	B	0.7	0.2	0.89	[0.88, 0.90]
ρ_w	Autocorr. of τ_t^w	B	0.7	0.2	0.91	[0.90, 0.92]
ρ_g	Autocorr. of g_t	B	0.8	0.2	0.92	[0.89, 0.93]
ρ_d	Autocorr. of d_t	B	0.7	0.2	0.68	[0.67, 0.70]
ρ_{tr}	Autocorr. of tr_t	B	0.7	0.2	0.75	[0.73, 0.77]
ρ_z	Autocorr. of z_t	B	0.7	0.2	0.82	[0.80, 0.83]
ρ_μ	Autocorr. of μ_t	B	0.7	0.2	0.70	[0.67, 0.73]
σ_k	Std. Dev. of ϵ_t^k	IG	0.5	1	0.012	[0.010, 0.013]
σ_w	Std. Dev. of ϵ_t^w	IG	0.5	1	0.009	[0.008, 0.010]
σ_g	Std. Dev. of ϵ_t^g	IG	0.5	1	0.015	[0.014, 0.017]
σ_d	Std. Dev. of ϵ_t^d	IG	0.5	1	0.156	[0.137, 0.177]
σ_{tr}	Std. Dev. of ϵ_t^{tr}	IG	0.5	1	0.054	[0.038, 0.090]
σ_z	Std. Dev. of ϵ_t^z	IG	0.5	1	0.024	[0.021, 0.026]
σ_m	Std. Dev. of ϵ_t^m	IG	0.5	1	0.018	[0.016, 0.020]
σ_μ	Std. Dev. of ϵ_t^m	IG	0.5	1	0.077	[0.072, 0.083]
b^c	Deep habit in c_t	B	0.7	0.1	0.96	[0.95, 0.97]
θ^c	Adj. of habit stock of c_t	B	0.8	0.1	0.58	[0.55, 0.60]
b^g	Deep habit in g_t	B	0.7	0.1	0.74	[0.73, 0.76]
θ^g	Adj. of habit stock of g_t	B	0.8	0.1	0.96	[0.95, 0.97]
α	Price adj. cost	N	17	5	44.07	[40.5, 47.7]
$\tilde{\alpha}$	Wage adj. cost	N	100	30	95.40	[92.4, 97.7]
σ	Preference parameter	N	2	1	2.12	[2.01, 2.33]
σ_u	Capacity util. parameter	N	2.5	0.5	2.57	[2.45, 2.68]
κ	Investment adj. cost	N	2	0.5	3.04	[2.98, 3.07]
α_R	Int. rate smoothing	B	0.8	0.2	0.52	[0.51, 0.54]
α_π	Response of R_t to π_t	N	1.6	0.2	1.55	[1.53, 1.56]
α_Y	Response of R_t to y_t	N	0.1	0.05	0.051	[0.045, 0.057]
$\rho_{k,b}$	Response of τ_t^k to b_{t-1}	G	0.5	0.25	0.015	[0.009, 0.021]
$\rho_{w,b}$	Response of τ_t^w to b_{t-1}	G	0.5	0.25	0.016	[0.010, 0.024]
$\rho_{k,y}$	Response of τ_t^k to y_{t-1}	G	1	0.5	0.131	[0.119, 0.140]
$\rho_{w,y}$	Response of τ_t^w to y_{t-1}	G	1	0.5	0.114	[0.101, 0.124]
$\rho_{g,y}$	Response of g_t to y_{t-1}	N	-0.05	0.05	-0.0032	[-0.012, -0.000]
$\rho_{tr,y}$	Response of tr_t to y_{t-1}	N	-0.1	0.05	-0.122	[-0.141, -0.104]

Note: B denotes Beta, G denotes Gamma, IG denotes Inverse Gamma and N denotes Normal.

Table 2.3: Impact Multipliers

Government Spending Multiplier				
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{\Delta Y_{t+k}}{\Delta G_t}$	1.12	0.85	0.16	-0.14
	[1.10, 1.13]	[0.79, 0.90]	[0.06, 0.26]	[-0.21, -0.07]

Labor Tax Multiplier				
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{\Delta Y_{t+k}}{\Delta T_t^w}$	0.13	0.34	0.34	0.17
	[0.11,0.15]	[0.32, 0.41]	[0.28 , 0.40]	[0.11, 0.22]

Capital Tax Multiplier				
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{\Delta Y_{t+k}}{\Delta T_t^k}$	0.33	0.36	0.19	0.04
	[0.32, 0.34]	[0.34, 0.39]	[0.16, 0.22]	[0.01, 0.07]

Note: These measure the increase in the level of output k quarters ahead in response to a change in the fiscal variable of interest at time t. The reported numbers are the median multipliers and the 95 percentiles are given below in brackets.

Table 2.4: Present Value Multipliers

	Government Spending Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta Y_{t+k}}{PV\Delta G_{t+k}}$	1.12	1.13	0.97	0.77
	[1.10, 1.13]	[1.11, 1.14]	[0.95, 0.99]	[0.72, 0.81]
	Labor Tax Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta Y_{t+k}}{PV\Delta T^w_{t+k}}$	0.13	0.31	0.70	0.99
	[0.11,0.15]	[0.27, 0.35]	[0.59, 0.82]	[0.79, 1.23]
	Capital Tax Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta Y_{t+k}}{PV\Delta T^k_{t+k}}$	0.33	0.44	0.64	0.76
	[0.32, 0.34]	[0.42, 0.46]	[0.58, 0.71]	[0.64, 0.90]

Note: These measure the present discounted value of the cumulative change in output over the present value cumulative change in the fiscal variable of interest, over the k quarters. The reported numbers are the median multipliers and the 95 percentiles are given below in brackets.

Table 2.5: Present Value Multipliers for Consumption, Investment and Hours

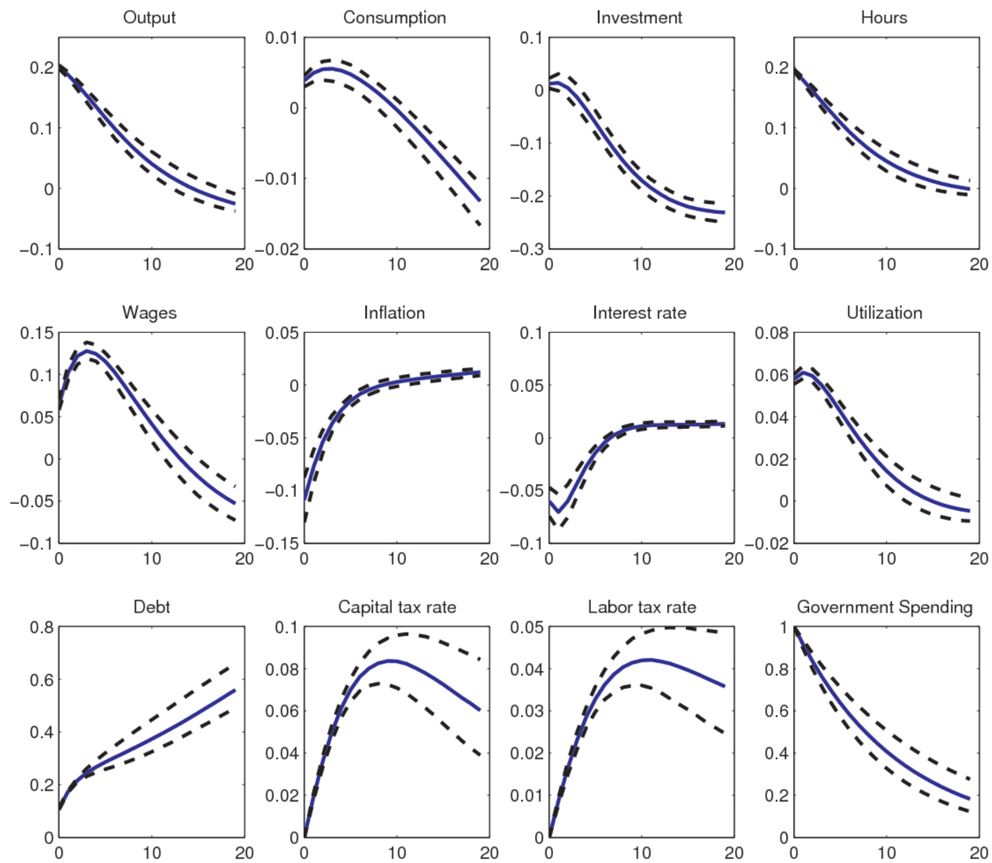
	Government Spending Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta C_{t+k}}{PV\Delta G_{t+k}}$	0.013	0.019	0.018	-0.004
	[0.010, 0.015]	[0.014, 0.022]	[0.009, 0.022]	[-0.021, 0.005]
$\frac{PV\Delta I_{t+k}}{PV\Delta G_{t+k}}$	0.017	0.013	-0.113	-0.268
	[0.006, 0.028]	[-0.009, 0.036]	[-0.164, -0.070]	[-0.356, -0.193]
$\frac{PV\Delta H_{t+k}}{PV\Delta G_{t+k}}$	0.670	0.661	0.582	0.507
	[0.663, 0.677]	[0.658, 0.667]	[0.567, 0.593]	[0.479, 0.525]

	Labor Tax Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta C_{t+k}}{PV\Delta T^w_{t+k}}$	0.015	0.034	0.105	0.205
	[0.013, 0.019]	[0.028, 0.042]	[0.085, 0.129]	[0.158, 0.263]
$\frac{PV\Delta I_{t+k}}{PV\Delta T^w_{t+k}}$	0.105	0.255	0.569	0.778
	[0.095, 0.118]	[0.230, 0.281]	[0.497, 0.656]	[0.641, 0.950]
$\frac{PV\Delta H_{t+k}}{PV\Delta T^w_{t+k}}$	0.081	0.187	0.371	0.450
	[0.074, 0.09]	[0.171, 0.209]	[0.324, 0.434]	[0.369, 0.560]

	Capital Tax Multiplier			
	Quarter 1	Quarter 4	Quarter 12	Quarter 20
$\frac{PV\Delta C_{t+k}}{PV\Delta T^k_{t+k}}$	-0.006	-0.009	-0.018	-0.031
	[-0.008, -0.005]	[-0.010, -0.007]	[-0.024, -0.011]	[-0.047, -0.014]
$\frac{PV\Delta I_{t+k}}{PV\Delta T^k_{t+k}}$	0.072	0.163	0.326	0.419
	[0.066, 0.079]	[0.147, 0.182]	[0.282, 0.380]	[0.336, 0.514]
$\frac{PV\Delta H_{t+k}}{PV\Delta T^k_{t+k}}$	-0.053	-0.006	0.032	-0.005
	[-0.049, -0.057]	[-0.014, 0.002]	[0.017, 0.047]	[-0.037, 0.024]

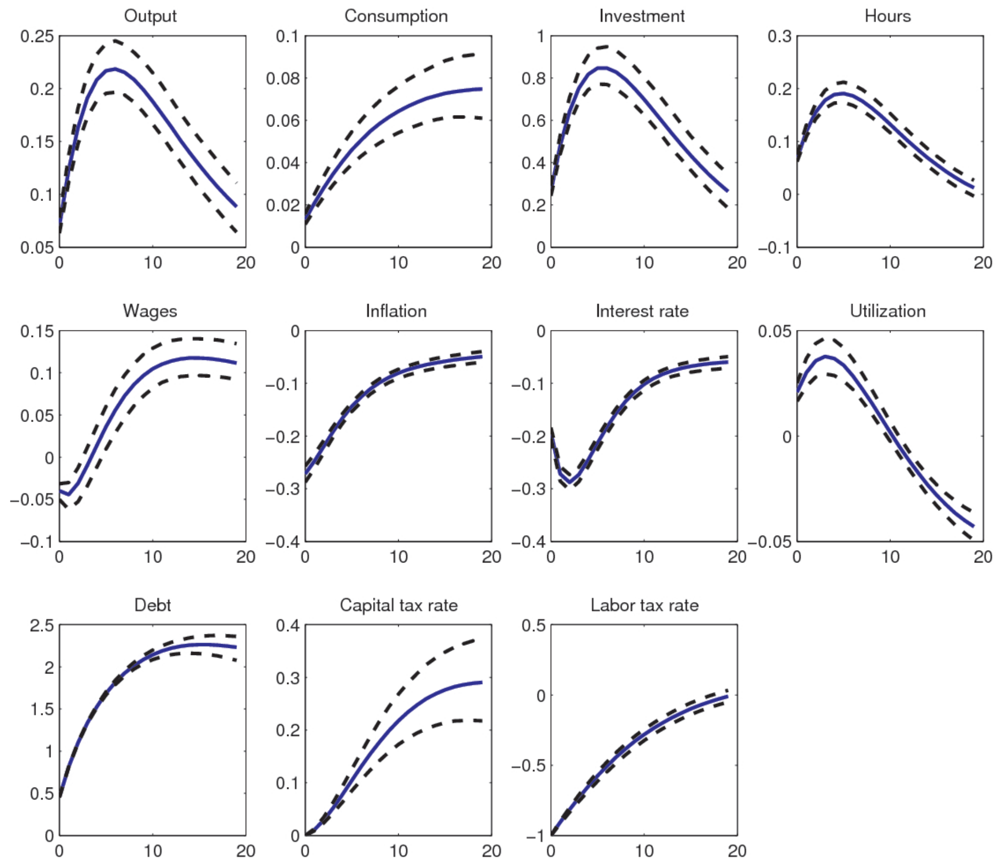
Note: The reported numbers are the median multipliers and the 95 percentiles are given below in brackets.

FIGURE 2.1: Impulse response functions to a one percent increase in government spending.



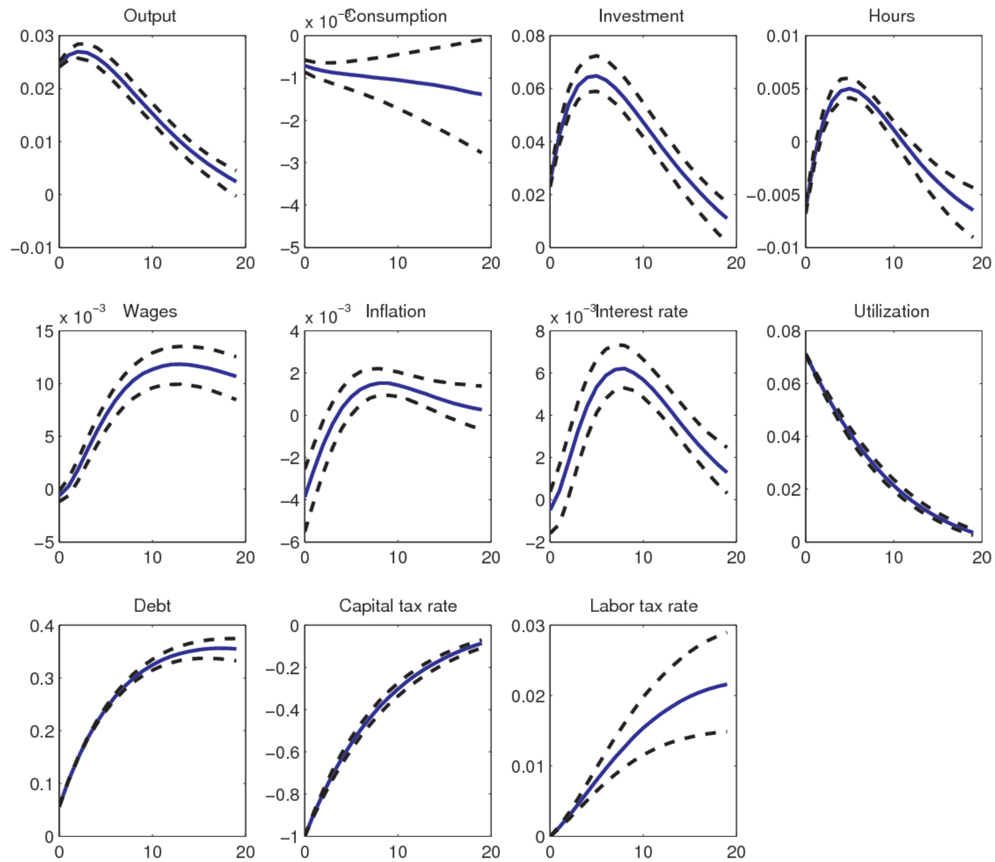
Note: The dashed lines are the 95 % confidence bands. The y-axis gives the percentage deviation from steady state and the x-axis gives the time horizon in quarters. The responses of inflation and nominal interest rate to the shock are annualized.

FIGURE 2.2: Impulse response functions to a one percent decrease in the labor tax rate.



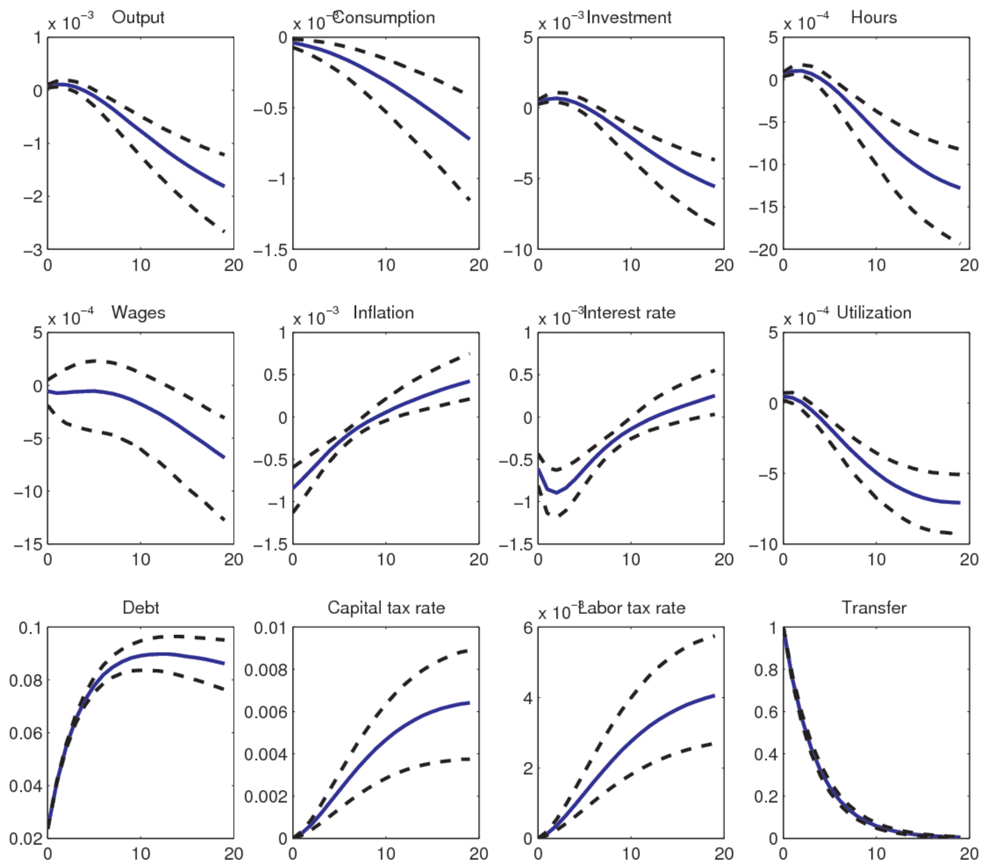
Note: The dashed lines are the 95 % confidence bands. The y-axis gives the percentage deviation from steady state and the x-axis gives the time horizon in quarters. The responses of inflation and nominal interest rate to the shock are annualized.

FIGURE 2.3: Impulse response functions to a one percent decrease in the capital tax rate.



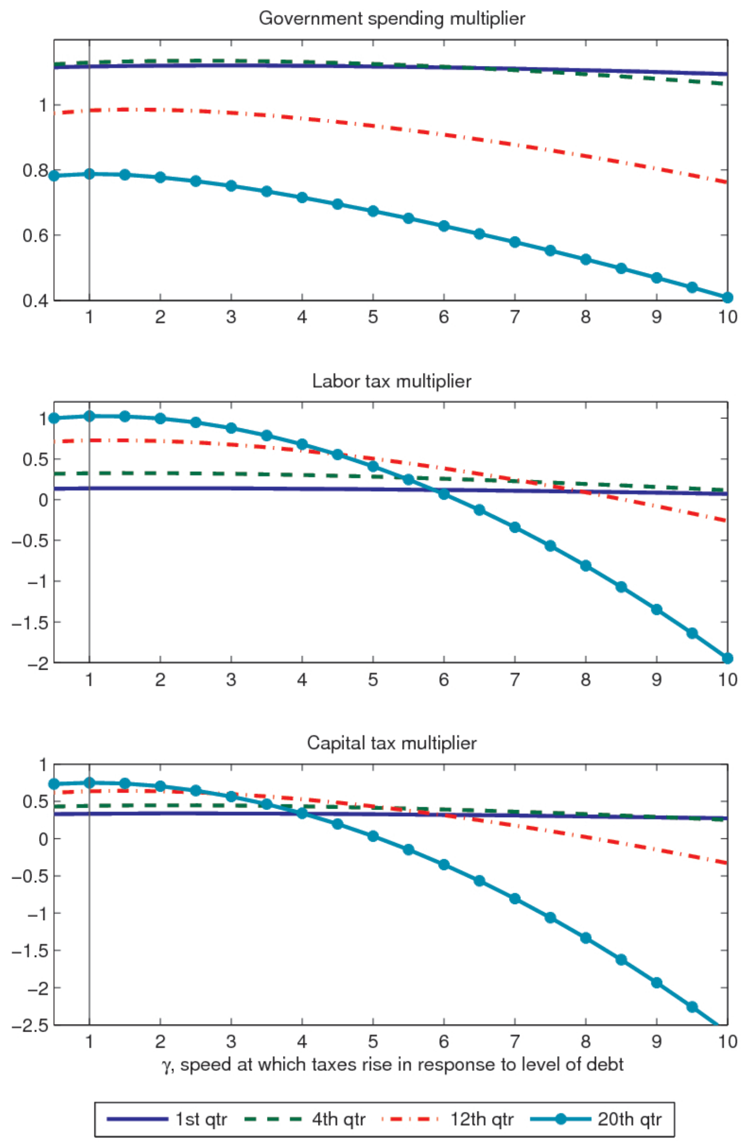
Note: The dashed lines are the 95 % confidence bands. The y-axis gives the percentage deviation from steady state and the x-axis gives the time horizon in quarters. The responses of inflation and nominal interest rate to the shock are annualized.

Figure 2.4: Impulse response functions to a one percent increase in transfers.



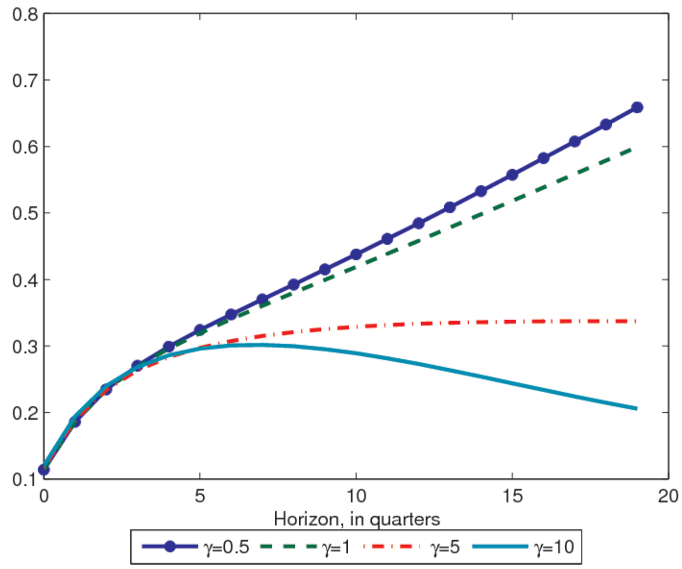
Note: The dashed lines are the 95 % confidence bands. The y-axis gives the percentage deviation from steady state and the x-axis gives the time horizon in quarters. The responses of inflation and nominal interest rate to the shock are annualized.

Figure 2.5: Counterfactual experiment: Deficit versus tax financing



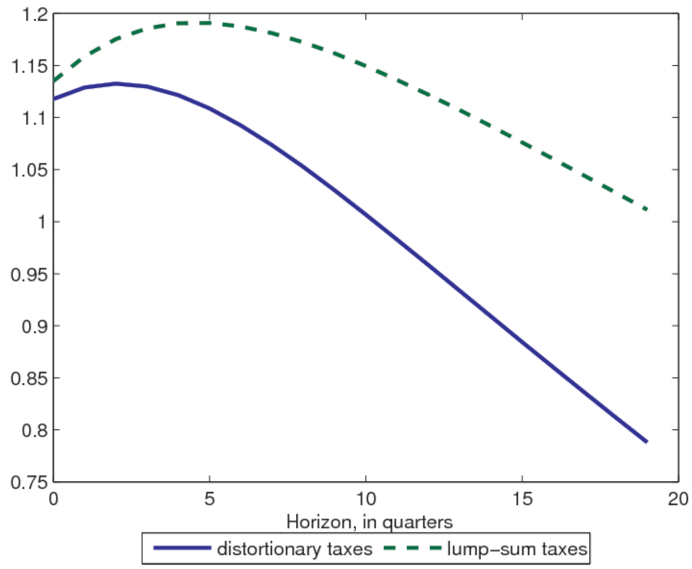
Note: The x-axis is the value of γ, the speed at which taxes respond to debt in the counterfactual exercise. $\gamma = 1$ corresponds to the baseline estimated model.

FIGURE 2.6: Response of debt to a government spending shock for varying values of γ



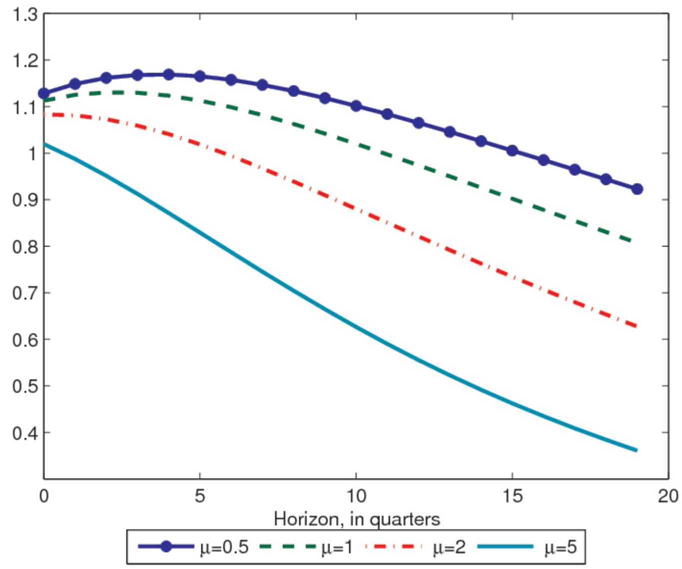
Note: γ is the speed at which taxes respond to debt in the counterfactual exercise. $\gamma = 1$ corresponds to the baseline estimated model. The x-axis gives the time horizon in quarters.

Figure 2.7: Counterfactual experiment: Lump-sum versus distortionary taxation



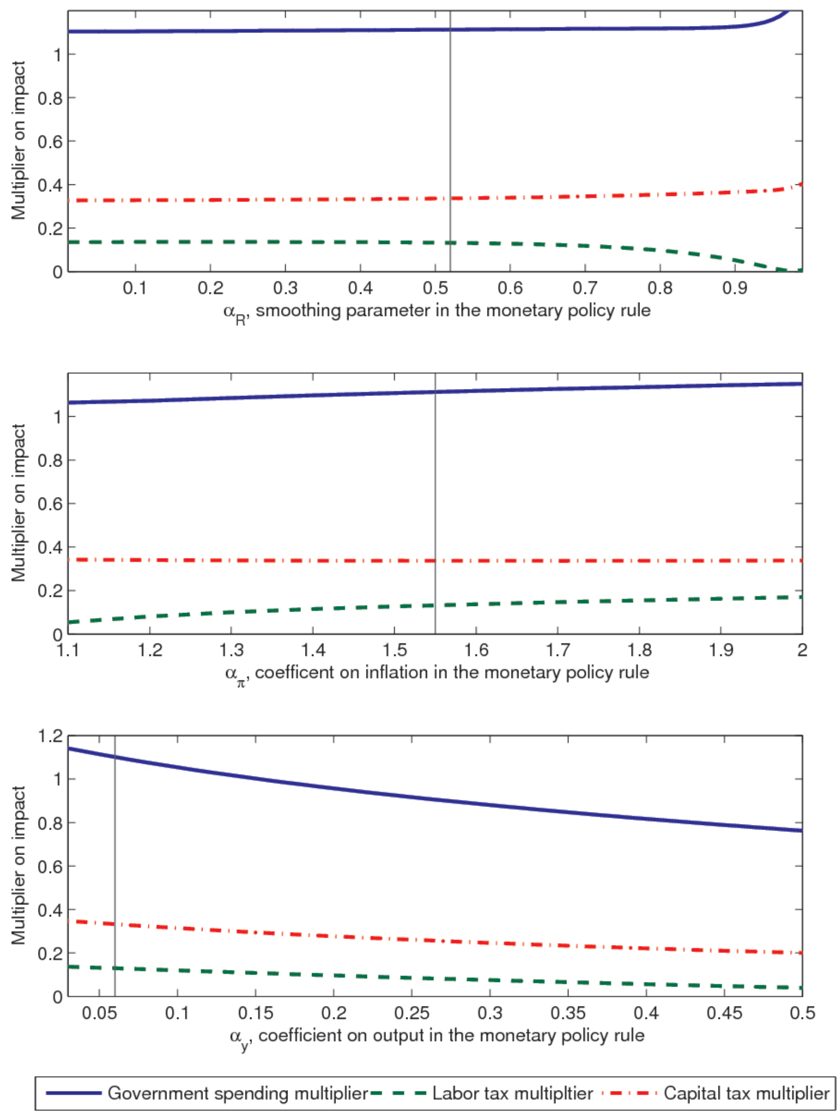
Note: The present value spending multiplier for output is computed under the estimated model with the endogenous estimated rule for tax rates and in the case when tax rates do not respond and spending is financed by lump-sum taxes instead. The x-axis gives the time horizon in quarters.

FIGURE 2.8: Present value government spending multiplier for output for varying values of μ



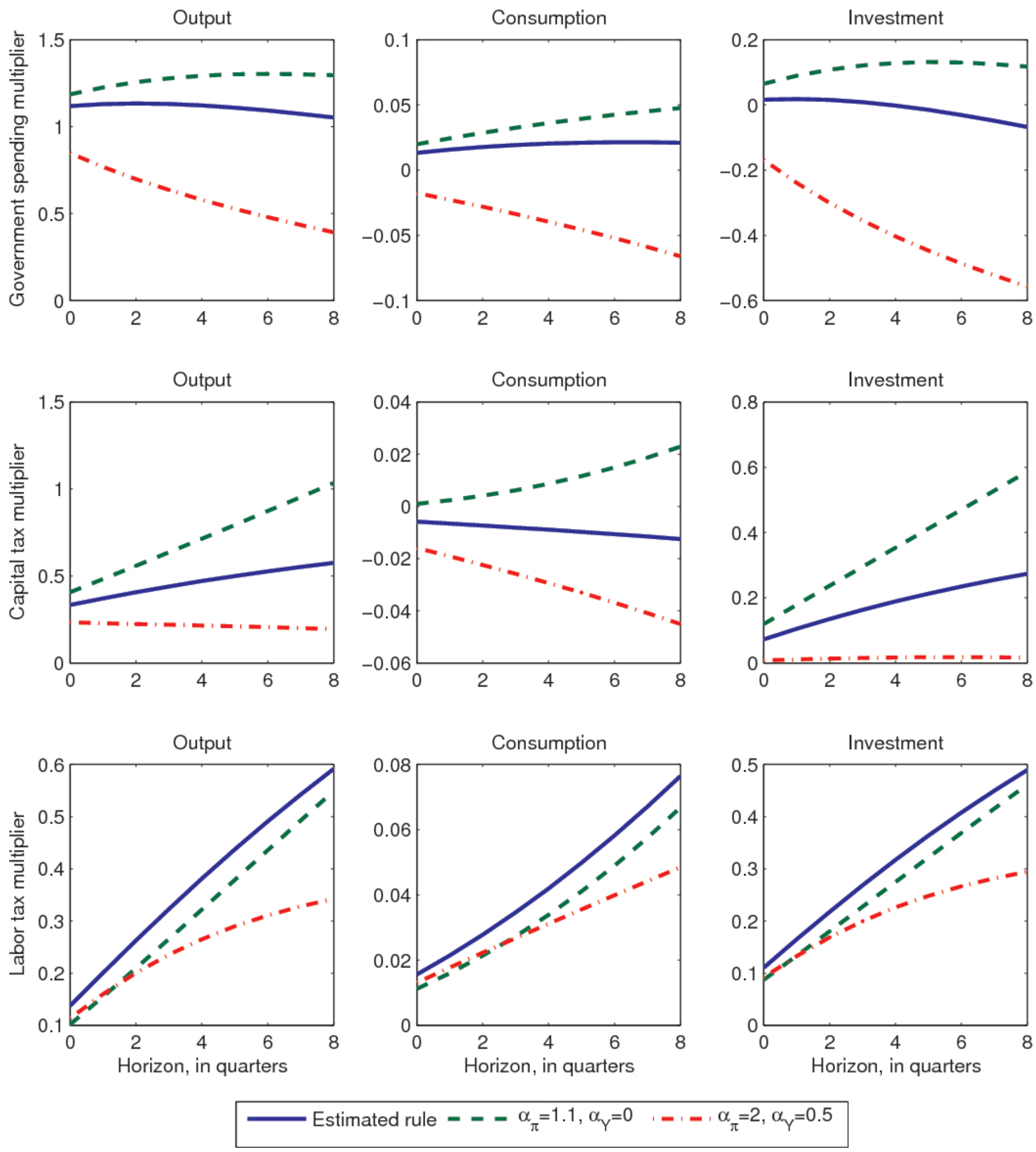
Note: μ is the speed at which automatic stabilization takes place in the counterfactual exercise. $\mu = 1$ corresponds to the baseline estimated model. The x-axis gives the time horizon in quarters.

FIGURE 2.9: Sensitivity of fiscal multipliers to monetary rule parameters



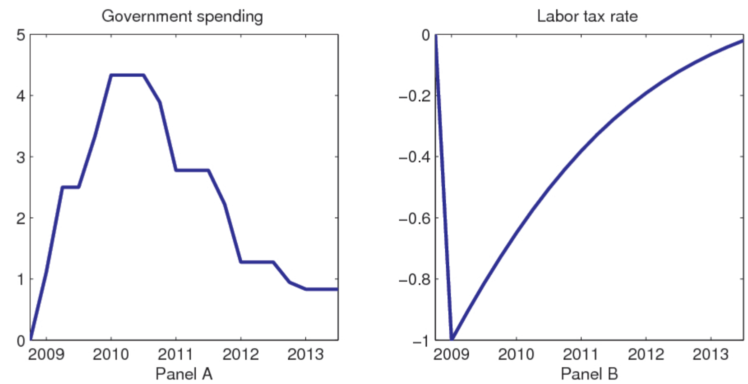
Note: The top panel shows the government spending, labor and capital tax multipliers on impact for output, for varying degree of α_R, the smoothing parameter, the middle panel shows multipliers for varying degree ofα_π, the coefficient on inflation and the bottom panel shows the multipliers when α_Y , the coefficient on output, is varied in the Taylor type monetary policy rule. The vertical lines correspond to the estimated values of the parameters.

Figure 2.10: Fiscal multipliers for various monetary policy rules.



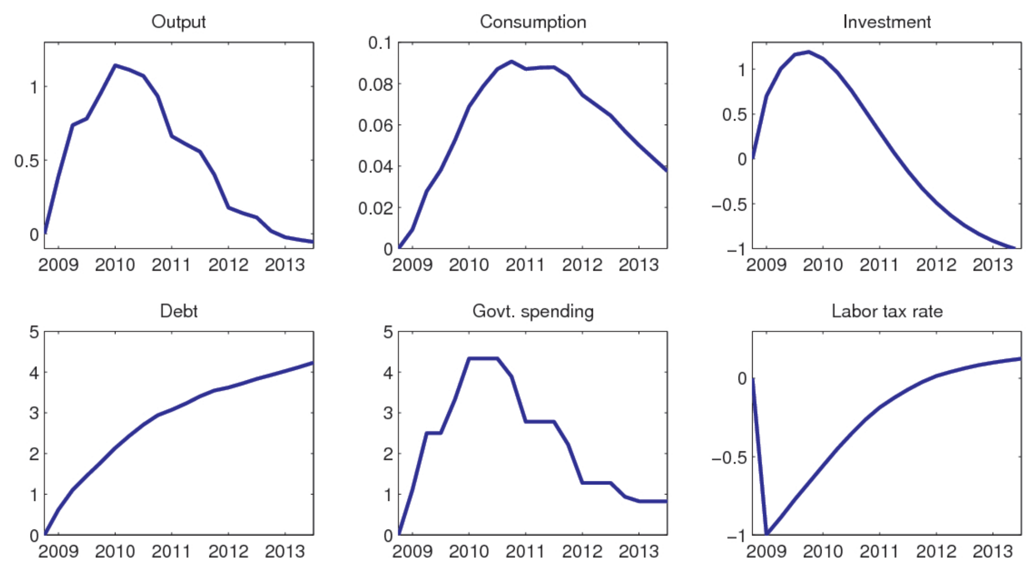
Note: The first row shows the present value spending multiplier for output, consumption and investment at various horizons. The second row shows the present value capital tax multipliers, and the last row shows the present value labor tax multipliers. The x-axis gives the time horizon in quarters. The solid line is the baseline estimated model, the dashed line is the passive monetary policy rule ($\alpha_\pi = 1.1$ and $\alpha_Y = 0$) and the dash dotted line is the aggressive monetary policy rule ($\alpha_\pi = 2$ and $\alpha_Y = 0.5$) .

Figure 2.11: Simulating the American Recovery and Reinvestment Act of 2009



Note: Panel A shows the implied government spending path and Panel B shows the labor tax cut implied by the stimulus package. The y-axis gives percentage deviations from steady state.

Figure 2.12: Impact of the American Recovery and Reinvestment Act of 2009



Note: Impact of combined fiscal actions, increased spending and cut in labor taxes, implied by the ARRA 2009. The y-axis gives percentage deviations from steady state.

3

What Is the Importance of Monetary and Fiscal Shocks in Explaining US Macroeconomic Fluctuations?

3.1 Introduction

The main contribution of this paper is to jointly analyze the importance of fiscal and monetary policy shocks in explaining US macroeconomic fluctuations. The existing empirical literature lacks such an analysis, as it separately considers either monetary policy or fiscal policy; the two are never examined together. For example, **?**) and Romer and Romer (1989) focus only on monetary policy shocks, whereas Blanchard and Perotti (2002), Perotti (2007), Ramey and Shapiro (1998), Ramey (2008) and Gali, Lopez-Salido, and Valles (2007) only focus on government spending shocks.[1] Since both monetary and fiscal policy simultaneously affect fluctuations in macroeconomic time series data, it is important to qualitatively analyze their roles and to quantitatively evaluate their importance in explaining these fluctuations.

[1] Some papers like Fatas and Mihov (2001) and Perotti (2002) study the effects of government spending shocks and include T-bill rates in their VARs, but do not consider joint effects of fiscal and monetary shocks.

This paper has two main findings, both in the form of new stylized facts. The first stylized fact we uncover is that fiscal and monetary policy shocks have different effects on macroeconomic fluctuations, depending on their frequencies. In particular, we show that fiscal policy shocks are most important for explaining medium cycle fluctuations in output, consumption and hours, whereas monetary policy shocks are most important for explaining business cycle fluctuations in those three variables. Figure 3.1 clearly shows this point. The figure plots de-trended output (solid line) along with the fluctuations of output "attributed to monetary policy shocks" (dotted line) and those "attributed to fiscal shocks" (dashed line).[2] The figure suggests that the output fluctuations attributed to fiscal shocks are a medium-run phenomenon, whereas those attributed to monetary policy shocks are a short-run phenomenon. We then proceed to carefully support our results by using both spectral variance decompositions as well as forecast error variance decompositions. The limited role of public spending shocks in driving business cycle fluctuations in output has been recognized earlier in the literature on estimating medium-scale DSGE models. However, by focusing only on business cycle frequencies, this literature has missed the empirically important effects of fiscal shocks at medium cycles, which we uncover in this paper.

The second stylized fact we establish is that failing to consider fiscal and monetary variables simultaneously in empirical analyses leads researchers to incorrectly attribute economic fluctuations to the wrong source. For instance, an important drawback of existing analyses that focus only on monetary policy shocks is that they ignore the importance of fiscal shocks altogether. In particular, we show that the large fluctuations experienced in Gross Domestic Product (GDP) at the beginning of the 1990s were due to fiscal shocks related to the Gulf War episode rather than to monetary policy. Similarly, omitting monetary policy variables in the VAR may

[2] The latter are obtained via "counterfactual" experiments. See Section 3 for more details.

lead to incorrectly attributing fluctuations in 1973 and 1980 to fiscal shocks rather than to their true cause, the monetary policy shocks.

Finally, our empirical results provide an additional stylized fact in the current debate on the identification of government spending shocks. In a series of papers, Perotti (2007), and Ramey (2008) disagree on the effects of government spending shocks on certain macroeconomic variables (see also Blanchard and Perotti (2002)). We show that the government spending shocks identified in the two papers have significantly different effects on output at different frequencies: the government spending shock identified by Perotti (2007) mainly affects medium frequency components of macroeconomic variables, whereas the Ramey (2008) shock equally affects all frequencies. We also show that some of the differences between the two approaches are attenuated by including a measure of monetary policy in the analysis.

The present paper is structured as follows. The next section provides a description of the data. Section 3 evaluates the importance of fiscal and monetary policy shocks via counterfactual analyses. Section 4 shows more detailed empirical results based on spectral and forecast error variance decompositions. Section 5 shows how the inclusion of fiscal policy affects our understanding of US monetary policy in the last two decades and, vice versa, how the inclusion of monetary variables affect the interpretation of fiscal policy shocks. Section 6 discusses the implications of our findings for the Perotti (2007) and Ramey (2008) debate, and Section 7 reports robustness analyses. Section 8 concludes.

3.2 Data Description

This paper analyzes the effects of monetary and fiscal policy shocks in a Vector Autoregressive (VAR) framework. Our basic VAR is the following:

$$Z_t = K + \Gamma t + A(L) Z_{t-1} + B(L) \varepsilon_t^R + u_t \tag{3.1}$$

where $t = 1, ..., T$, $Z_t = (G_t, X_t', r_t)'$, G_t is government spending, r_t is the federal funds rate, and X_t is a vector of macroeconomic variables including GDP (Y_t), hours worked in the non-farm business sector (h_t), non-durables and services consumption (c_t), gross private investment and durable consumption (i_t), real wage in the non-farm business sector (w_t), and GDP deflator inflation (π_t). All variables except the interest rate are in logs, and the real values are deflated by using the GDP deflator. The VAR includes a constant (K), a time trend (Γt),[3] as well as a "narrative" measure of the government spending shocks discussed in Ramey (2008). The inclusion of the latter helps us avoid Ramey's criticism regarding government spending shocks identified by VAR procedures.[4] Data are quarterly, from 1954:IV to 2006:IV. $A(L)$ and $B(L)$ are set to be lag polynomials of degree 4 to be consistent with the existing literature on monetary and fiscal policy shocks. We identify the fiscal and monetary policy shocks by using a Cholesky decomposition where government spending is ordered first and the federal funds rate last. That is, the structural shocks, ε_t, are obtained as: $u_t = A_0 \varepsilon_t$, where A_0 is lower triangular. The government spending and monetary policy shocks are, respectively, the first and the last elements of the vector ε_t.[5]

[3] We specify a VAR with variables in levels and a deterministic time trend in order to be consistent with the existing empirical works on fiscal shocks. The shocks identified with our procedure are close to i.i.d. shocks in terms of persistence and other characteristics. The robustness section discusses alternative de-trending procedures.

[4] Ramey (2008) shows that the government spending shocks identified by a narrative procedure using dummy variables associated with the episodes of military build-up in Ramey and Shapiro (1998) Granger-cause government spending shocks identified in a structural VAR with government spending ordered first. By including the dummy variables in our VAR, our results are robust to this criticism. Section 7 discusses empirical results based on other VAR specifications.

[5] The BIC criterion selects one lag for the VAR, and all the main qualitative results presented in this paper continue to hold with this choice of lag length. For completeness, figures in the Appendix report the impulse responses to both government spending and monetary policy shocks identified in equation (3.1). The main results in the paper are robust to changing the order of the variables in X_t.

3.3 The Importance of Fiscal and Monetary Policy Shocks: a Counterfactual Analysis

This section evaluates the relative importance of fiscal and monetary policy shocks in explaining US macroeconomic fluctuations by using historical counterfactual analyses. We will first focus on GDP and ask the question: how much of the volatility in US GDP is explained by each of the two shocks? Then, we will verify the robustness of our results for other variables.

To answer this question, we first estimate the VAR described by equation (3.1) and then, conditional on the VAR parameter estimates, we perform a counterfactual analysis where we assume that the economy is driven only by each individual shock, one-at-a-time. To be precise, partition ε_t according to equation (3.1) as: $\varepsilon_t = (\varepsilon_{g,t}, \varepsilon'_{X,t}, \varepsilon_{r,t})'$. By setting $\left\{\varepsilon'_{X,t}\right\}_{t=1}^{T} = 0$, $\{\varepsilon_{r,t}\}_{t=1}^{T} = 0$ in the estimated VAR, we obtain the path of GDP that would have been observed if only government shocks were present, which we refer to as the "counterfactual with $\varepsilon_{g,t}$" (labeled $Y_{g,t}$). On the other hand, by setting $\left\{\varepsilon'_{X,t}\right\}_{t=1}^{T} = 0$, $\{\varepsilon_{g,t}\}_{t=1}^{T} = 0$, we obtain the path of GDP that would have been observed if only monetary policy shocks were present, which we refer to as the "counterfactual with $\varepsilon_{r,t}$" (labeled $Y_{r,t}$).

Figure 3.1 shows the results. A few striking empirical stylized facts are clearly visible in the figure. First, monetary policy shocks seem to contribute mostly to short-run fluctuations in GDP, whereas government spending shocks seem to contribute mostly to medium-run fluctuations. Second, government spending shocks seem to generate more persistent GDP fluctuations than monetary policy shocks.

This empirical evidence suggests that monetary policy shocks might most likely be important for explaining business cycle fluctuations in GDP, whereas fiscal shocks might most likely explain medium term fluctuations in GDP. To further investigate this issue, we extract the business and medium cycle components of GDP by using the bandpass filter (Baxter and King (1993)). We follow Stock and Watson (1999) and identify output at business cycle frequencies to be fluctuations between 6 and 32 quarters, labeled Y_t^{BC}. We follow Comin and Gertler (2006) to identify medium cycle fluctuations, which are fluctuations at frequencies between 32 and 200 quarters, labeled Y_t^{MC}.[6]

The right panels in Figure 3.2 show GDP's business cycle fluctuations (top panel) and medium-cycle fluctuations (bottom panel). The left side panels in the same figure, on the other hand, show the counterfactual with fiscal policy shocks (top panel) and monetary policy shocks (bottom panel). It is visually clear that output fluctuations at business cycle frequencies are strongly correlated with the historical counterfactual due to monetary policy shocks, $Y_{r,t}$, and, at the same time, the output fluctuations at medium cycle frequencies are instead strongly correlated with the historical counterfactual due to the fiscal shock, $Y_{g,t}$.

This suggest our first main empirical stylized fact:

Stylized fact #1: Fiscal shocks are mainly responsible for medium cycle fluctuations in output, whereas monetary policy shocks are mainly responsible for its business cycle fluctuations.

This is a novel empirical fact, with noteworthy implications for policy analysis. In fact, for example, our finding implies that monetary policy is more effective at stabilizing output fluctuations at business cycle frequencies while fiscal policy is more effective at stabilizing output in the medium/long run. Interestingly, the recent literature on estimating macroeconomic models has analyzed the importance of fiscal shocks in medium-scale DSGE models and has found that the contribution of fiscal

[6] Comin and Gertler (2006) refer to frequencies between 2-200 quarters as the medium cycle, and frequencies between 32-200 quarters as the medium cycle component. In this paper, however, we refer to the frequencies between 32-200 quarters as the medium cycle, so that business and medium cycle frequencies do not overlap.

shocks for explaining output fluctuations is negligible.[7] Our analysis corroborates these findings. However, by focusing on business cycle frequencies, this literature has missed the empirically important effects of fiscal shocks at medium cycles, which instead our analysis uncovers.

The same pattern also arises for other important macroeconomic variables, such as consumption and hours worked. As shown in Figures 3.3 and 3.4, the medium cycle components of these variables clearly track the fluctuations in those series due to the government spending shock, whereas their business cycle components track the fluctuations explained by the monetary policy shock. This suggests that our findings are quite general, and not exclusively valid for output. In the case of investment, we find that monetary policy shocks are still very important for explaining business cycle fluctuations, but the link between medium cycle fluctuations and fiscal shocks seems more tenuous. This might be related to the fact that investment fluctuations are much more volatile than fluctuations in the other macroeconomic variables.

To quantitatively assess the strength of the correlation between the business/medium cycle components of GDP and the GDP counterfactuals due to fiscal and monetary shocks, Figure 3.6 shows cross correlations at various leads and lags. In the left panel, the solid line depicts the correlation between the counterfactual due to fiscal shocks and the business cycle component of output at various leads and lags, $corr\left(Y_{g,t}, Y_{t+j}^{BC}\right)$. The dotted line in the same panel depicts the correlation between the counterfactual due to monetary policy shocks and the business cycle component of output, $corr\left(Y_{r,t}, Y_{t+j}^{BC}\right)$. The figure shows that monetary policy shocks are much more important in explaining business cycle fluctuations.

In the right panel of Figure 3.6, the solid line reports the correlation between

[7] For instance, Smets and Wouters (2007) find that for horizons close to 4 quarters, the forecast-error variance of output due to government spending shock is less than 10 %. Justiniano, Primiceri, and Tambalotti (2009) carry out a spectral decomposition and find that government spending shocks explain only 2 % of fluctuations in output at business cycle frequencies.

the counterfactual due to fiscal shocks and the business cycle component of output at various leads and lags, $corr\left(Y_{g,t}, Y_{t+j}^{BC}\right)$. The dotted line reports the correlation between the counterfactual due to fiscal shocks and the medium cycle component of output, $corr\left(Y_{g,t}, Y_{t+j}^{MC}\right)$. According to the figure, indeed the correlation between the counterfactual due to fiscal shocks and the medium cycle component is substantially larger than that with the business cycle component, and the highest correlation is contemporaneous.

To conclude, the counterfactual analyses in this section suggest that the business cycle fluctuations in three macroeconomic variables (output, consumption and hours) are driven mostly by monetary policy shocks, whereas the medium cycle fluctuations are mainly driven by fiscal shocks. The next section will provide additional empirical evidence to directly assess whether this is the case.

3.4 Spectral and Forecast Error Variance Decompositions

In order to further substantiate our claim that fiscal shocks are mainly responsible for medium cycle fluctuations, this section directly quantifies the effects of these shocks by using spectral variance decompositions as well as forecast error variance decompositions. As we will show, both decompositions strongly support our first stylized fact.

First, let us consider spectral variance decompositions. Table 3.1 shows the contribution of both fiscal shocks (upper panel) and monetary policy shocks (bottom panel) at the frequencies that are typically associated with business and medium cycles. The upper panel shows that fiscal shocks are much more important at medium cycles than business cycles for output, consumption, and hours. The lower panel shows instead that, for the same variables, monetary policy shocks are more relevant at business cycle frequencies.[8] By comparing both panels in the table, it is clear that

[8] Altig, Christiano, Eichenbaum, and Linde (2005) also carry out a structural VAR exercise, and

fiscal shocks are more relevant than monetary policy shocks at medium cycles, and that monetary policy shocks are more relevant than fiscal shocks at business cycle frequencies. The results clearly support our first empirical stylized fact. Note that the contribution at medium frequency components of government spending shocks are significantly different than those at business cycle frequencies for GDP, hours as well as consumption.

Figure 3.7 shows that our results hold regardless of the definition of frequencies associated with business and medium cycles. In Figure 3.7, the solid line depicts to the percentage of variance in GDP explained by a government spending shock at various frequencies, and the dashed line depicts the percentage contribution of the monetary policy shock. The contribution of the government spending shock at any given frequency is constructed as a ratio of the following two components: at the numerator, the spectral density of GDP assuming that only the government spending shock affects GDP; at the denominator, the spectral density when all shocks are allowed to affect GDP. Similarly for monetary policy. The figure shows the contributions for both business and medium cycle frequencies, between $\frac{2\pi}{200}$ and $\frac{2\pi}{6}$, that is 6-200 quarters.[9] Notably, our empirical results in Table 3.1 could be strengthened by assuming a slightly different definition of medium cycle. In fact, note that at medium cycle frequencies the variance of the spectrum due to each of the two shocks intersect. This happens around a frequency equal to 0.10, corresponding to 63 quarters. If we

find the contribution of monetary shocks in explaining output at business cycle frequencies is around 16%, which is close to our estimate.

[9] More in detail, the contribution of each shock at any given frequency is calculated as follows. First, calculate the spectral density of the linearly detrended Z_t based on the structural shocks that are not anticipated by Ramey (2008) events, $S_Z\left(e^{-i\omega}\right) = H\left(e^{-i\omega}\right)A_0A_0'H\left(e^{-i\omega}\right)$, where $H\left(L\right) \equiv \left[I - A\left(L\right)L\right]^{-1}$. The spectral density of Z_t assuming only the j^{th} shock hits the economy is given by $S_Z^j(e^{-i\omega}) = H\left(e^{-i\omega}\right)A_0D_jA_0'H\left(e^{-i\omega}\right)$, where D_j is a matrix of zeros except for a unity in the j^{th} diagonal element. Let $S_{Z_k}^j(e^{-i\omega})$ denote the spectral variance for the k-th variable in Z_t. The fraction of variance in the $k-th$ variable in Z_t due to shock j at frequency ω is given by: $S_{Z_k}^j(e^{-i\omega})/S_{Z_k}(e^{-i\omega})$, which we report multiplied by 100. Government spending shocks correspond to $j = 1$, and monetary policy shocks correspond to $j = 8$.

redefine the business cycle to be between 8 and 63 quarters, and the medium cycle to be between 63 and 200 quarters, our results would be even stronger, as there is a monotonic increase in the spectrum of GDP due to fiscal shocks at low frequencies.

Next, we turn to forecast error variance decompositions. These provide additional empirical evidence on the contribution of each shocks in explaining the fluctuations in each of the macroeconomic variables. Table 3.2 shows that the percentage variance of macroeconomic fluctuations due to fiscal shocks is higher at longer horizons; in particular, for GDP the percentage variance due to fiscal shocks is largest at 34 quarters. On the other hand, the percentage variance due to monetary policy shocks is higher at shorter horizons; for example, in the case of GDP, the percentage variance due to monetary policy shocks is largest at 12 quarters.[10] The table also reports asterisks to highlight when the FEVDs at short and long horizons are different, and shows that the differences are significant for a variety of series. Therefore, forecast error variance decompositions also strongly support our first stylized fact.

3.5 Interaction between Fiscal and Monetary Policy Shocks

Since existing studies focus only on monetary policy shocks and completely ignore the importance of fiscal shocks, or vice versa, this section demonstrates that failing to consider fiscal and monetary variables simultaneously in empirical analyses leads researchers to incorrectly attribute economic fluctuations to the wrong source.

3.5.1 How does the inclusion of fiscal policy affect our understanding of US monetary policy?

In principle, including fiscal shocks may have consequences for the identification of monetary policy shocks. The goal of this section is to evaluate whether this is the case in practice by studying whether adding fiscal policy in the structural VAR leads

[10] Our finding regarding monetary policy shocks are qualitatively similar to the forecast error variance decomposition results in Christiano, Eichenbaum, and Evans (2005).

us to re-assess the importance of monetary policy shocks in specific episodes.

Our benchmark is a VAR without government spending, that is:

$$W_t = \widetilde{K} + \widetilde{\Gamma} t + \widetilde{A}(L) W_{t-1} + \widetilde{u}_t \tag{3.2}$$

where $W_t = (X_t', r_t)'$ are the endogenous variables, and the monetary policy shock is identified via a Cholesky decomposition where the interest rate is ordered last. We will denote the monetary policy shock estimated in the benchmark VAR by $\widetilde{\varepsilon}_{r,t}$.[11] Similarly, we will estimate the monetary policy shock in the basic VAR in equation (3.1) and denote it by $\widehat{\varepsilon}_{r,t}$.

Figure 3.8 plots the difference between the monetary policy shocks estimated in VARs with and without the government spending, $\widehat{\varepsilon}_{r,t} - \widetilde{\varepsilon}_{r,t}$. The figure shows that the inclusion of fiscal policy significantly changes the interpretation of certain episodes. The most striking example is the Gulf War episode, dated 1990:3. By omitting fiscal shocks in the VAR, one would attribute the large fluctuations in GDP at that time to monetary policy shocks, whereas GDP fluctuations around that time were mainly driven by the fiscal event.

It is also interesting to analyze whether the inclusion of fiscal policy substantially changes traditional forecast error variance decompositions (FEVD) and impulse responses for monetary policy shocks. Figure 3.9 plots the percentage change in the FEVD of GDP due to monetary policy shocks resulting from the inclusion of fiscal policy relative to a baseline scenario with no fiscal variables.[12] Negative values indicate that including fiscal policy variables in the VAR decreases the percentage of the forecast error variance of GDP that monetary policy shocks explain at the selected horizons. Due to our finding that fiscal policy explains mostly medium cycle

[11] Note that $\widetilde{\varepsilon}_{r,t}$ is the last element in the identified $\widetilde{\varepsilon}_t$ vector, where $\widetilde{u}_t = \widetilde{A}_0 \widetilde{\varepsilon}_t$, and $\widetilde{A}_0$ is lower triangular.

[12] Technically, this is $(FEVD^m_{baseline} - FEVD^m_{nog})/(FEVD^m_{nog})$, where $FEVD^m_{baseline}$ is the FEVD of GDP due to monetary policy shock in the baseline VAR, and $FEVD^m_{nog}$ is the FEVD of GDP due to monetary policy shock in a VAR with no fiscal variable.

fluctuations, we focus on 40 quarters ahead FEVD. Such FEVD are estimated recursively over centered rolling windows in order to capture important events such as the Gulf War episode. The choice of the window size reflects a trade-off between consistent estimation and the ability to capture time variation. Our choice of a window size of 100 quarters ensures sufficiently precise estimation while still leaving enough observations to recover the evolution of the relative FEVD over time. Figure 3.9 shows that the relative contribution of monetary policy shocks in explaining output fluctuations substantially decreases when we include fiscal policy in the VAR. This happens in particular in two episodes: around the Gulf War episode (1990) and in the late seventies, thus showing that not all the output fluctuations that the literature attributes to monetary policy in the seventies are directly related to monetary policy actions.

Impulse response analysis confirms these conclusions. Figure 3.10 analyzes how the impulse response function of GDP to a monetary policy shock is affected by the inclusion of fiscal variable in the VAR. The figure plots the impulse response function of GDP to a monetary shock in a VAR with and without government spending. We find that the presence of government spending in the VAR affects the responses to a monetary shock differently in different periods. We selected two representative subsamples, before and after 1980:4. Figure 3.10 shows that excluding fiscal variables in the VAR results in incorrectly attributing some of the fiscal shocks' effects on GDP to monetary shocks at medium to longer horizons.

3.5.2 How does the inclusion of monetary policy affect our understanding of US fiscal policy?

Unlike in the case of monetary policy, where changes are implemented rather promptly, for fiscal policy the legislative process can take some time. During the delay in the announcement and the implementation of new fiscal policy measures, the agents in the economy may acquire information on these measures and react accordingly. Therefore, by excluding the monetary policy variable (the federal funds rate, in our case), we might be ignoring the information that lagged values of the interest rate carry about changes in current government spending, which eventually affects our measure of the government spending shock.[13]

To assess whether the exclusion of monetary policy significantly changes our understanding of the fiscal policy transmission mechanism, we run a VAR without the federal funds rate, that is:

$$\Xi_t = \overline{K} + \overline{\Gamma} t + \overline{A}\,(L)\,\Xi_{t-1} + \overline{B}\,(L)\,\epsilon_t^R + \overline{u}_t \tag{3.3}$$

where $\Xi_t = (g_t, X_t')'$ are the endogenous variables, and the government spending shock is identified via a Cholesky decomposition where government spending is ordered first. We will denote the government spending shock estimated in the benchmark VAR described in equation (3) by $\overline{\varepsilon}_{g,t}$.[14] VAR specifications omitting the monetary policy variable such as equation (3.3) are reported by Blanchard and Perotti (2002) and Ramey (2008). Similarly, we will estimate the government spending shock in the basic VAR in equation (3.1) and denote it by $\widehat{\varepsilon}_{g,t}$.

Figure 3.11 plots the difference between the government spending shocks estimated in VARs with and without the federal funds rate, $\widehat{\varepsilon}_{g,t} - \overline{\varepsilon}_{g,t}$. The figure shows that the inclusion of the proxy for monetary policy affects the interpretation of fiscal shocks for some specific dates that Romer and Romer (2004) associate with a monetary policy shock. For instance, the big spike that we observe in Figure 3.10 around 1973:4 corresponds to the large monetary policy shocks identified by Romer and Romer (2004) in Table 3.2 around September-October 1979. Similarly, the large

[13] Yang (2007), in the same spirit, shows that by including lagged interest rates and prices in the VAR, the responses to a tax shock are altered, thus suggesting that these variables contain information about macroeconomic variables related to current tax changes.

[14] Note that $\overline{\varepsilon}_{g,t}$ is the first element in the identified $\overline{\varepsilon}_t$ vector, where $\overline{u}_t = \overline{A}_0 \overline{\varepsilon}_t$, and $\overline{A}_0$ is lower triangular.

difference between the two shocks around 1980:2, corresponds to the monetary shock identified by Romer and Romer (2004) in February-May 1980. This demonstrates that if one does not include a measure of monetary policy in the analysis, one would attribute the fluctuations in GDP in 1973:4 and 1980:2 to fiscal shocks, whereas in reality GDP fluctuations were mainly driven by monetary policy shocks at that time.

Figure 3.12 plots the percentage change in the FEVD of GDP due to fiscal policy shocks resulting from the inclusion of monetary policy relative to a baseline scenario with no monetary variables. Due to our finding that monetary policy mainly explains short run fluctuations in output, we focus on 4 quarters ahead FEVD. Figure 3.11 demonstrates that the relative contribution of fiscal policy shocks in explaining output fluctuations substantially decreases when we exclude monetary policy in the VAR, especially during the late seventies and early eighties, during the same time periods in which Romer and Romer (2004) identify unusual monetary policy shocks. Therefore, the interaction of monetary and fiscal policy variables is crucial for understanding the relative importance of fiscal shocks in explaining output fluctuations in the short run.

Figure 3.13 analyzes how the response of GDP to a government spending shock is affected by the inclusion of monetary policy variables in the VAR. The figure shows that excluding monetary variables in the VAR results in incorrectly failing to attribute important medium to long-run effects of fiscal policy on output and attribute larger effects of fiscal shocks on GDP at short horizons, especially before 1980:4.

Overall, the results in this section suggest our second stylized empirical fact:

Stylized fact #2: Failing to recognize that both monetary policy and fiscal policy simultaneously affect macroeconomic variables might incorrectly attribute macroeconomic fluctuations to the wrong source.

3.6 Comparing Two Leading Methodologies for Identifying Fiscal Shocks

In the current literature there are two main alternative schemes used to identify government spending shocks.[15] This section compares these competing approaches, and shows that the shocks identified by the two procedures have very different implications at business and medium cycles.

Let us start by briefly describing the two approaches. In the first approach, the government spending shock is identified by the assumption that government spending does not react contemporaneously to other macroeconomic variables – see Blanchard and Perotti (2002), Fatas and Mihov (2001) and Perotti (2007), among others. Following this approach, typically the government spending shock, denoted here by $\varepsilon_{Perotti,t}$, is estimated via a Cholesky decomposition in the following VAR:

$$Z_t = K_1 + \Gamma_1 t + A_1 (L) Z_{t-1} + u_{1,t} \tag{3.4}$$

where $Z_t = (G_t, X_t', r_t)'$ and government spending is ordered first. Notice that the VAR no longer includes the "narrative" measure of the government spending shocks discussed in Ramey (2008), ε_t^R. In what follows, we will refer to $\varepsilon_{Perotti,t}$ as "Perotti's government spending shock".[16]

In the second approach, episodes of military build-ups in US history are identified as spending shocks via a narrative approach – see Ramey and Shapiro (1998), Burnside, Eichenbaum, and Fisher (2004) and Ramey (2008), among others. We focus on the database provided by Ramey (2008), which is much richer than the Ramey and Shapiro (1998) military dates for two reasons. First, the database includes additional dates associated with the unfolding of events that induced newspapers to start forecasting significant changes in government spending, thereby including many more

[15] There is yet another alternative approach in identifying fiscal shocks using sign restrictions that is not considered here. See Mountford and Uhlig (2002).

[16] Note that $\varepsilon_{Perotti,t}$ is the first element in the identified $\varepsilon_{1,t}$ vector, where $u_{1,t} = A_{1,0}\varepsilon_{1,t}$, and $A_{1,0}$ is lower triangular.

episodes than those in Ramey and Shapiro (1998). A second advantage of Ramey's database is that it provides a quantitative measure of the extent of the expected military buildups, estimated by the present discounted value of the change in the anticipated government spending. This measure thus includes both episodes of increases and decreases in government spending. Following this approach, the time series of government spending shocks, labeled $\varepsilon_{Ramey,t}$, is estimated in the following VAR:

$$Z_t = K_2 + \Gamma_2 t + A_2 (L) Z_{t-1} + u_{2,t} \tag{3.5}$$

where $Z_t = \left(\varepsilon_t^R, X_t', r_t\right)'$. The government spending shock in this case is identified via a Cholesky decomposition where the "narrative" measure of the government spending shocks discussed in Ramey (2008), ε_t^R, is ordered first. In what follows, we will refer to $\varepsilon_{Ramey,t}$ as "Ramey's government spending shock".[17]

Figure 3.14 analyzes the contribution of both government spending shocks, $\varepsilon_{Perotti,t}$ and $\varepsilon_{Ramey,t}$, at different frequencies. The figure shows the fraction of the variance of GDP due to each shock at different frequencies. The dashed line is the contribution of the government spending shock and the solid line is the contribution of the monetary policy shock. The upper panel shows results for Perotti's government spending shock, whereas the lower panel focuses on Ramey's government spending shock. It is pretty clear that Perotti's government spending shock is mainly associated with medium cycles, whereas Ramey's government spending shock affects both business and medium cycle frequencies equally. This is an additional difference regarding the effects of fiscal shocks identified via recursive ordering versus narrative approaches that is worth pointing out.

Table 3.3 provides further empirical evidence by reporting the contribution of the two fiscal policy shocks in explaining the fluctuations in each of the macroeconomic

[17] Note that $\varepsilon_{Ramey,t}$ is the first element in the identified $\varepsilon_{2,t}$ vector, where $u_{2,t} = A_{2,0}\varepsilon_{2,t}$, and $A_{2,0}$ is lower triangular.

variables at various horizons via forecast error variance decompositions. The table shows that the percentage variance of fluctuations in GDP, hours and consumption due to Perotti's government spending shock is bigger than that of Ramey's government spending shock in general, but especially so at long horizons. In particular, the contribution to the forecast error variance of the shock identified via Perotti (2007) approach to both GDP and consumption is about 30% at medium to long horizons (20 to 40 quarters) whereas that of the shock identified via Ramey (2008) approach is never more than 3% at those horizons. Unreported results show that the contribution of the Ramey's government spending shock in explaining the volatility of most macroeconomic variables equally affects all horizons (reaching a maximum around 17 quarters for output), whereas the contribution of Perotti's government spending shock increases with the forecast horizon (reaching a maximum around 30 quarters for output). The empirical evidence for real wages is more mixed, although it remains true that the importance of Perotti's government spending shock is much larger than that of Ramey's government spending shock at longer horizons.

Furthermore, Blanchard and Perotti (2002), Perotti (2007), and Ramey (2008) disagree on the effects of government spending shocks on other macroeconomic variables. At the core of the disagreement are the two different identification procedures that we are comparing in this section. For example, the shocks identified with the two methodologies have different effects on consumption. In particular, in Perotti's identification, a positive government spending shock *increases* consumption, whereas in Ramey's identification the same shock *decreases* consumption.[18] The real wage is another variable that in certain specifications has different responses under the two methodologies: Perotti (2007) shows that real wages increase in response to a fiscal shock identified via a recursive VAR procedure, whereas Ramey (2008) shows

[18] Some other papers employing the narrative approach find this response to be insignificant – cfr. Burnside, Eichenbaum, and Fisher (2004) and Edelberg, Eichenbaum, and Fisher (1999).

that real wages decrease in response to her narrative shock. Interestingly, we also find that adding a measure of monetary policy in the VAR helps alleviate the differences in the impulse responses to consumption identified by the two approaches. Figures C.3- C.6 in the Appendix show this point. In particular, Figures C.3 and C.4, respectively, show impulse responses to a government spending shock identified by Perotti's and Ramey's approaches in a VAR that includes the federal funds rate as a measure of monetary policy. Figures 19 and 20 show instead the same impulse responses in a VAR that does not include monetary variables, thereby excluding the federal funds rate. The latter VAR specification is that considered in the original papers by Perotti (2007) and Ramey (2008). By comparing the impulse responses of consumption identified by Ramey's narrative approach in Figures 18 and 20, we note that the responses change considerably. The response is always negative in the VAR that does not include monetary variables, and significantly different from zero in the first few quarters, similarly to the empirical evidence reported in Ramey (2008). However, including monetary variables substantially changes the shape: the response becomes negative on impact and positive afterwards, and the response is almost never significant.[19] A similar result holds for the response of real wages: including monetary variables shifts the response to Ramey (2008) government spending shock upwards, so that the response becomes positive and more similar to that of Perotti (2007).

3.7 Robustness Analysis

This section investigates whether our main findings regarding the differences in the relative importance of government spending and monetary policy shocks at various frequencies are robust to sub-sample analysis, the inclusion of taxes, different mone-

[19] Most of the difference in the shape of the responses is accounted by the inclusion/exclusion of the federal funds rate, and including/excluding inflation does not change the qualitative results.

tary policy identification schemes, and changes in trend due to the great productivity slowdown.

3.7.1 Sub-sample analysis

First, we assess whether our results are robust over time. We divide the data into sub-samples identified consistently with the Great Moderation (Stock and Watson (2003)). We impose a structural break in 1984:1, the estimated date of the break in the volatility of US GDP growth documented by McConnell and Perez-Quiros (2000). The results from the spectral decomposition of GDP for the two sub-samples is given in Table 3.4. Due to the smaller sample size of the two sub-samples, we select the VAR lag length to be one, as suggested by the BIC criterion.

In the first sub-sample, the relative importance of government spending shocks at medium cycle frequencies is very high relative to business cycle frequencies, and the difference is much smaller for the second sub-sample. Overall, however, government spending shocks play a larger role at medium cycles *relative to* monetary policy shocks. In particular, government spending shocks explain a larger percentage of the variance of GDP at medium cycle relative to business cycle frequencies in *both* sub-samples. On the other hand, the importance of monetary policy shocks has changed over time: they are very important in explaining the variance of GDP at business cycle frequencies in the first sub-sample, similarly to the results previously reported in Section 2 for the full sample, but they play a limited role at both frequencies in the second sub-sample.

3.7.2 Robustness to the inclusion of taxes

It is well known from basic macroeconomic models that the intertemporal government budget constraint has to be satisfied, and therefore, it might be important to include taxes in our empirical analysis. Table 3.5, Panel A, reports the contribution of the government spending shocks to output fluctuations at both business and medium cycle frequencies when net taxes are added to the baseline VAR. That is, we estimate the same VAR as equation (3.1) except that now $Z_t = (G_t, T_t, X_t', r_t)'$, where T_t are tax receipts net of transfers and all other variables are as defined in Section 2.[20] By comparing Table 3.5 and Table 3.1, it is clear that our results for output are unaffected by the addition of taxes, and government spending shocks play an important role primarily in explaining medium cycle frequencies.[21]

3.7.3 Other monetary policy identification schemes

An additional concern is that we identified the monetary policy shock as a shock to the federal funds rate in a VAR that does not include other monetary variables. We therefore consider alternative VARs that include nonborrowed reserves, total reserves and money supply (M1) following the benchmark recursive identification schemes discussed in **?**) in Section 4.2. In a first experiment, reported in Table 3.5, Panel B(i), we estimate the same VAR as in equation (3.1), except that $Z_t = (G_t, X_t', r_t, tr_t, nbr_t, m_t)'$, where tr_t is total reserves, nbr_t is nonborrowed reserves plus extended credit, m_t is a measure of money supply (M1), and the other variables are as defined in Section 2.[22] Following **?**), these additional monetary variables are ordered after the federal funds rate (r_t), so that the information set of the monetary authority includes current and lagged values of G_t and X_t, and lagged values of the other monetary variables. In a second experiment, reported in Table 3.5, Panel B(ii), the monetary policy shock is identified as a shock to nonborrowed reserves in a VAR with the following ordering: $Z_t = (G_t, X_t', nbr_t, r_t, tr_t, m_t)'$. The results reported in

[20] The tax variable is defined exactly as in Blanchard and Perotti (2002).

[21] Mertens and Ravn (2008) study the effects of tax changes identified on the basis of narrative evidence of Romer and Romer (2007), and conclude that tax shocks account for close to 20 % of variation in output at business cycle frequencies.

[22] Due to limited data availability for nonborrowed reserves, total reserves and M1, in this subsection the VAR is estimated for data spanning 1959:1-2006:4.

Panel B show that the percentage contribution of the government spending shock at both business and medium cycle frequencies is extremely robust to the inclusion of additional monetary variables. Looking at monetary policy, overall the contribution of the monetary policy shocks identified as shocks to nonborrowed reserves rather than a shock to the federal funds rate is smaller, a finding consistent with ?), Table 3. However, consistently with our previous results, we note that, again, the contribution of the monetary policy shock is more substantial at business cycle than at medium cycle frequencies.

3.7.4 Alternative de-trending procedures

The benchmark VAR specification in Section 2 assumes a linear deterministic time trend. However, linearly de-trending output with a constant time trend might induce low frequency movements in the presence of a substantial productivity slowdown such as that of 1973. One might be concerned that it is the government shock that captures those low frequency movements, since it is the most important shock at medium cycles. For these reasons, we also consider a VAR estimated with a break in trend:

$$Z_t = K + \Gamma_1 t + \Gamma_2 d_t t + A\left(L\right) Z_{t-1} + B\left(L\right) \varepsilon_t^R + u_t \tag{3.6}$$

where d_t is a dummy variable equal to one after 1973:1 and zero otherwise. The dummy variable captures the break in trend associated with the great productivity slowdown (see Baily and Gordon (1988)). The contributions of the government spending shock at the business and medium cycle frequencies become 2.3 and 21.3 respectively, thus showing that our main conclusions are also robust to breaks in trends associated with the productivity slowdown of 1973.[23]

[23] We also verified that our main results are robust to estimating a stochastic rather than a deterministic trend, using a VAR where $Z_t = \left(\Delta G_t,\, \Delta\left(Y_t - h_t\right),\, h_t,\, c_t - Y_t,\, i_t - Y_t,\, Y_t - h_t - w_t,\, \pi_t,\, r_t\right)'$.

3.8 Conclusions

This paper establishes two novel stylized facts. First, we show that fiscal policy shocks are relatively more important in explaining medium cycle fluctuations in output whereas monetary policy shocks are relatively more important in explaining business cycle fluctuations. This finding is important as there is a wide literature on DSGE models that also finds that the contribution of fiscal shocks is negligible in explaining output fluctuations at business cycles. However, our results imply that, by focusing on business cycle fluctuations, this literature is missing the effects of fiscal shocks at medium cycles. These empirical results are robust to different monetary policy identification schemes, the inclusion of taxes, and time variation due to the Great Moderation and the productivity slowdown of 1973.

Second, we show that failing to take into account that both monetary and fiscal policy shocks simultaneously affect macroeconomic variables incorrectly attributes some of the macroeconomic fluctuations to the wrong source. It would be interesting to investigate whether the differences that we find when we jointly consider monetary and fiscal policy could be attributed to differences in policy rules or differences in the identified shocks, and to evaluate the extent of the interaction between monetary and fiscal authorities. However, an answer to these questions would require a theoretical structural model. We therefore leave these issues to future research.

Finally, our empirical results add an interesting new stylized fact to the current debate on the effects of fiscal policy shocks. We show that the shock identified by Ramey (2008) affects both business and medium cycle frequencies equally, whereas the shock identified by Perotti (2007) mainly affects medium cycle frequencies. Furthermore, we find that including a proxy for monetary policy helps alleviate some of the differences between the two approaches.

3.9 Tables and Figures

Table 3.1: Spectral Decomposition.

	Business Cycle component $(\frac{\pi}{16}-\frac{\pi}{3})$	Medium Cycle component $(\frac{\pi}{100}-\frac{\pi}{16})$
A. Percentage contribution of $\varepsilon_{g,t}$		
GDP	3.7	35.9*
Hours	5.0	26.4*
Consumption	4.4	33.6*
Investment	2.7	6.6
Wages	3.3	17.6
Inflation	3.8	20.6
B. Percentage contribution of $\varepsilon_{r,t}$		
GDP	20.3	10.6
Hours	19.5	7.8
Consumption	23.1	21.1
Investment	21.1	26.0
Wages	6.0	11.8
Inflation	19.8	12.9

Note: Panel A (top) shows the contribution of the government spending shock at the business and medium cycle frequencies. Panel B (bottom) shows the contribution of the monetary policy shock at the same frequencies. (*) denotes that the contribution at medium cycle frequencies is significantly different from the contribution at business cycle frequencies at the 10% significance level.

Table 3.2: Forecast Error Variance Decomposition.

	4 quarters ahead	8 quarters ahead	20 quarters ahead	40 quarters ahead
A. Percentage variance due to $\varepsilon_{g,t}$				
GDP	4.8	9.9*	30.3*	35.0*
Hours	2.5	10.1*	13.0*	7.4*
Consumption	6.1	13.7*	32.1*	23.2*
Investment	0.7	0.8	3.8	5.1*
Wages	2.4	4.1	5.7	12.8
Inflation	4.3	5.0	3.1	7.6
B. Percentage variance due to $\varepsilon_{r,t}$				
GDP	5.9	15.7	15.2	12.5
Hours	7.4	14.4	10.9	10.7
Consumption	9.4	20.1	16.8	12.3
Investment	6.2*	19.0	22.4	22.4
Wages	2.6*	6.8	12.7	11.5
Inflation	5.4*	6.0*	18.2	15.3

Note: Panel A (top) reports the contribution of government spending shocks. Panel B (bottom) reports the contribution of monetary policy shocks. (*) in the top panel denotes that the selected FEVDs of $\varepsilon_{g,t}$ are significantly different from the benchmark FEVD at 4 quarters ahead at the 10% significance level. (*) in panel B denotes that the selected FEVDs of $\varepsilon_{r,t}$ are significantly different from the benchmark FEVD at 40 quarters ahead at the 10% significance level.

Table 3.3: Forecast Error Variance Decompositions: Perotti's recursive ordering and Ramey's narrative identifications.

	4 quarters ahead	8 quarters ahead	20 quarters ahead	40 quarters ahead
A. Percentage variance due to $\varepsilon_{Perotti,t}$				
GDP	6.3	12.1	27.1	27.0
Hours	3.9	11.1	10.7	6.1
Consumption	5.6	14.3	31.0	20.5
Wages	2.3	4.1	4.9	7.2
B. Percentage variance due to $\varepsilon_{Ramey,t}$				
GDP	0.2	2.1	3.4	2.9
Hours	0.8	2.0	1.9	3.9
Consumption	1.1	0.7	0.5	1.4
Wages	0.3	0.9	1.8	2.1

Note: Panel A (top) reports the contribution of government spending shock identified by equation (3.4). Panel B (bottom) reports the contribution of government spending shock identified by equation (3.5).

Table 3.4: Sub-sample Robustness Analysis.

	Business Cycle component $(\frac{\pi}{16} - \frac{\pi}{3})$	Medium Cycle component $(\frac{\pi}{100} - \frac{\pi}{16})$
Sub-sample I (1954:3-1984:1)		
Percentage contribution of $\epsilon_{g,t}$	7.1	26.5
Percentage contribution of $\epsilon_{r,t}$	41.5	24.9
Sub-sample II (1984:2-2006:4)		
Percentage contribution of $\epsilon_{g,t}$	10.1	10.3
Percentage contribution of $\epsilon_{r,t}$	1.2	5.4

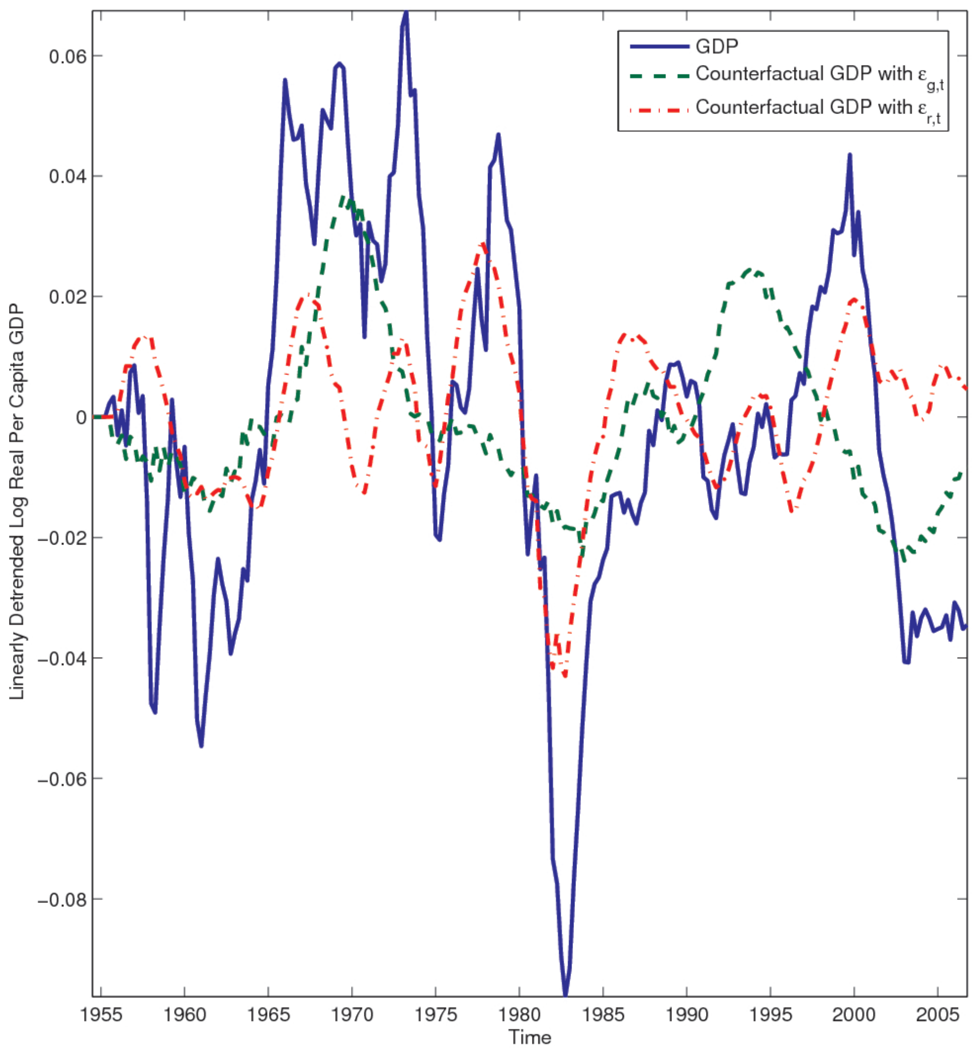
Note: The top panel shows the contribution of government spending shock and monetary shocks in explaining GDP at the business and medium cycle frequencies for the first sub-sample (1954:3-1984:1), and the bottom panel shows the contribution of both shocks in explaining GDP for the second sub-sample (1984:2-2006:4).

Table 3.5: Robustness Analyses.

	Business Cycle component $(\frac{\pi}{16} - \frac{\pi}{3})$	Medium Cycle component $(\frac{\pi}{100} - \frac{\pi}{16})$
A. Including net taxes in the VAR		
Percentage contribution of $\varepsilon_{g,t}$	4.1	30.9
Percentage contribution of $\varepsilon_{r,t}$	21.1	13.8
B. Additional monetary variables in the VAR		
(i) Monetary policy shock identified as a shock to the FFR		
Percentage contribution of $\varepsilon_{g,t}$	2.9	29.2
Percentage contribution of $\varepsilon_{r,t}$	9.3	7.3
(ii) Monetary policy shock identified as a shock to Non-borrowed reserves		
Percentage contribution of $\varepsilon_{g,t}$	2.9	29.2
Percentage contribution of $\varepsilon_{nbr,t}$	3.5	0.9

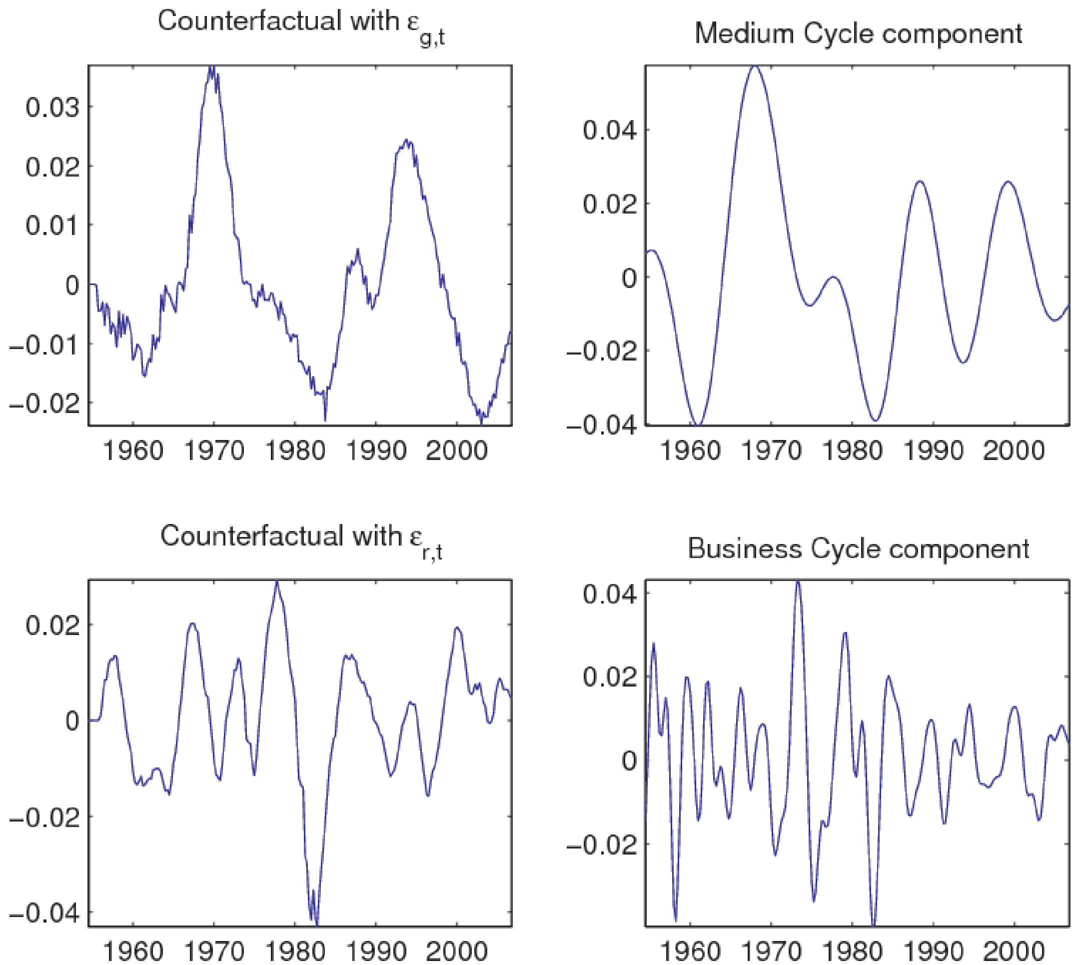
Note: Panel A (top) reports the contribution of the government spending shock to output fluctuations at business and medium cycle frequencies when net taxes are added to the baseline VAR. Panel B (bottom) reports the contribution of the government spending shock to output fluctuations at business and medium cycle frequencies when additional monetary variables (nonborrowed reserves, total reserves and money supply) are added to the baseline VAR. The monetary policy shock is identified either as a shock to the federal funds rate – Panel B(i) – or as a shock to nonborrowed reserves – Panel B(ii).

Figure 3.1: Historical Counterfactual Decomposition of GDP.



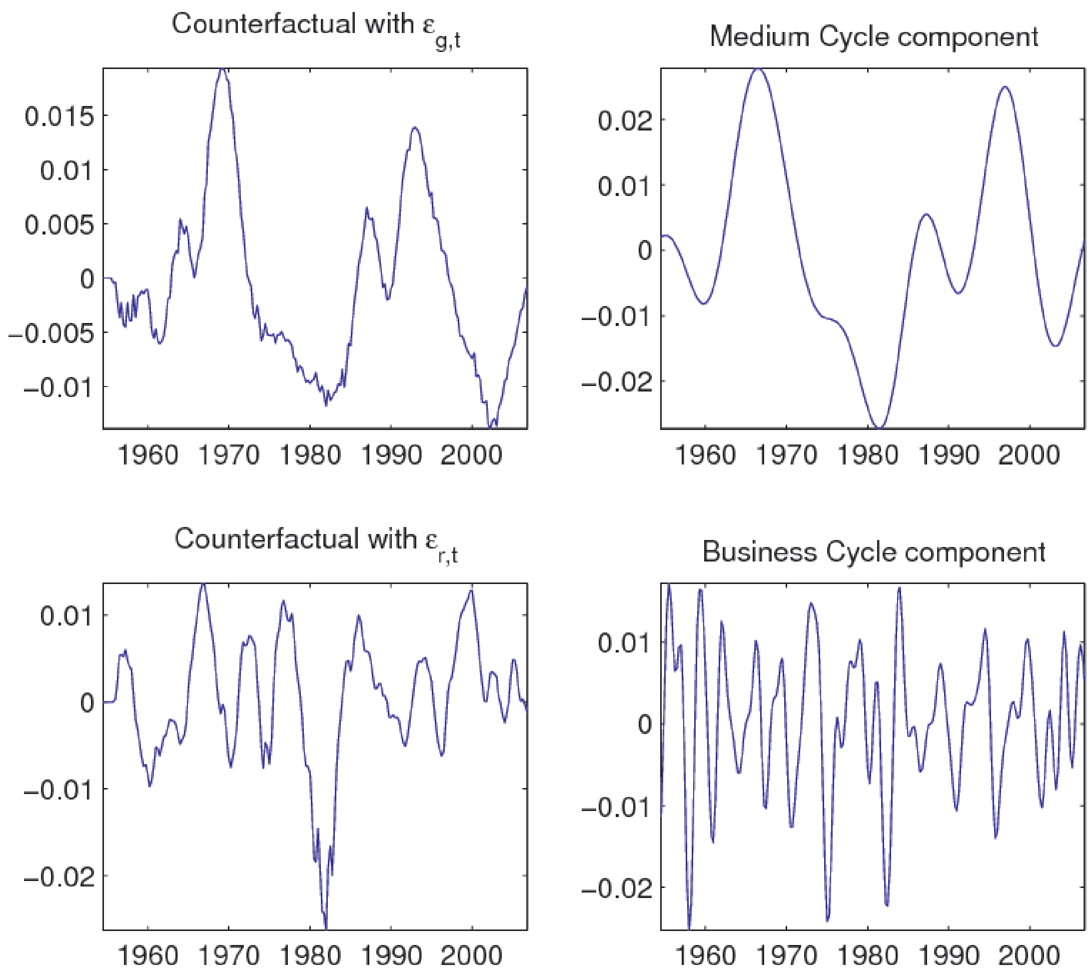
Note: The solid line is GDP, the dashed line is the GDP counterfactual associated with only government spending shocks, and the dotted line is the GDP counterfactual associated with only monetary policy shocks.

FIGURE 3.2: Historical Counterfactual Decomposition of GDP at Various Frequencies.



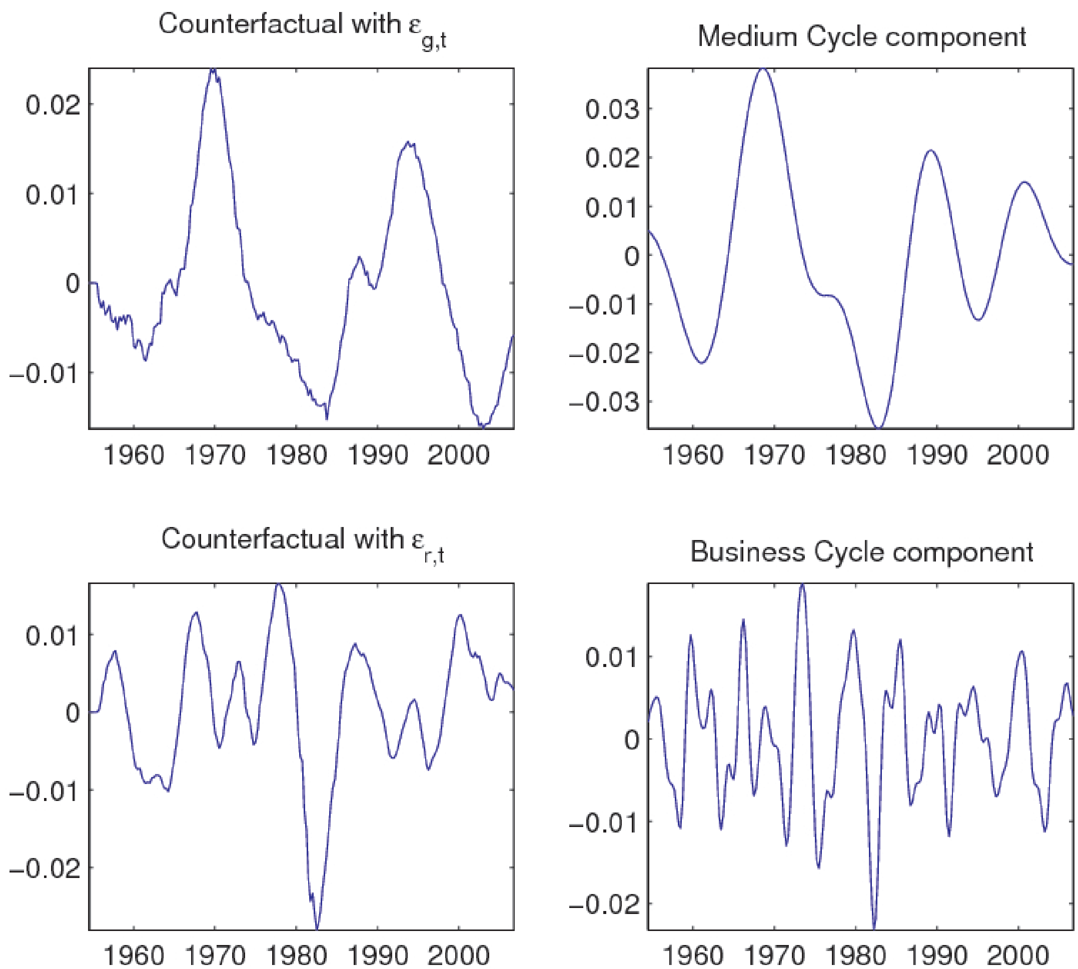
Note: The figure plots counterfactual analyses associated with the two shocks (left panels, fiscal policy on top and monetary policy on bottom), and the business and medium cycle components of GDP (right panels).

Figure 3.3: Decomposition of Hours at Various Frequencies.



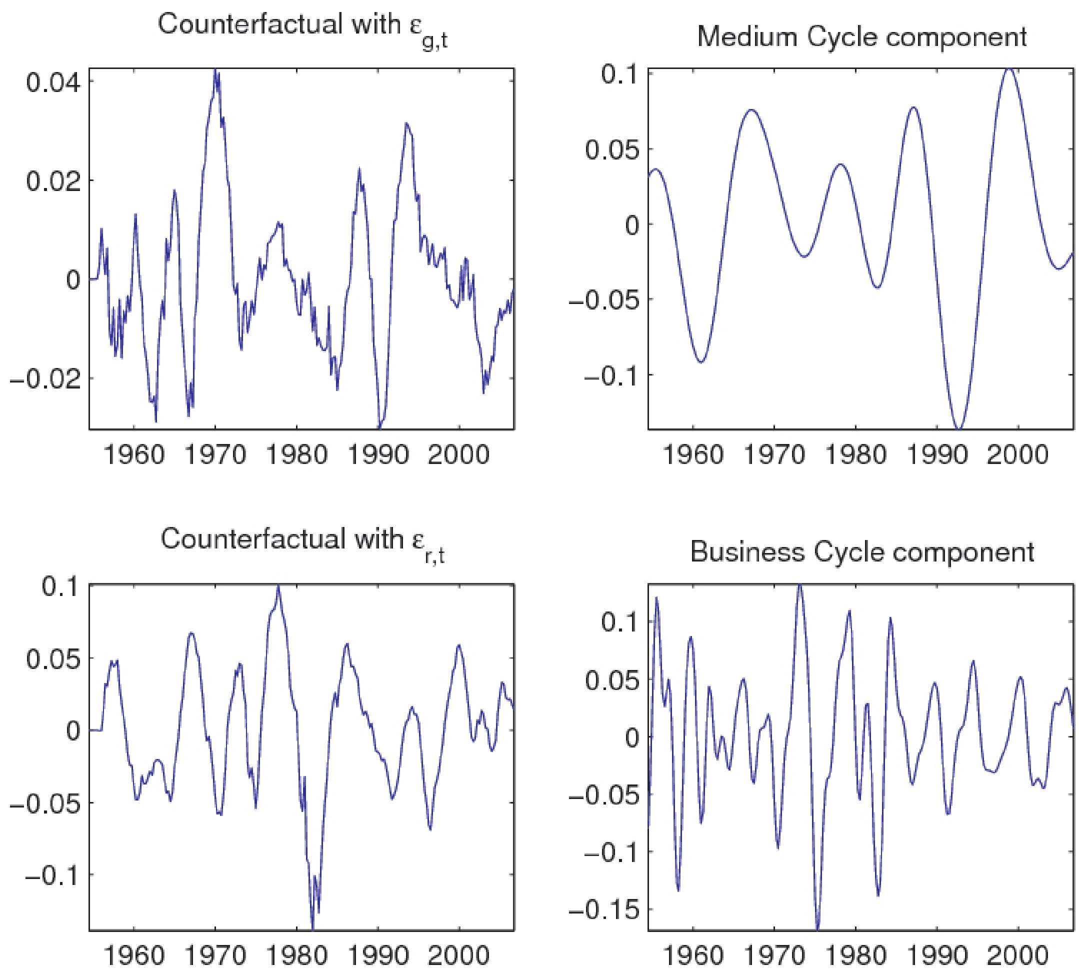
Note: The figure plots counterfactual analyses associated with the two shocks (left panels, fiscal policy on top and monetary policy on bottom), and the business and medium cycle components of hours (right panels).

Figure 3.4: Decomposition of Consumption at Various Frequencies.



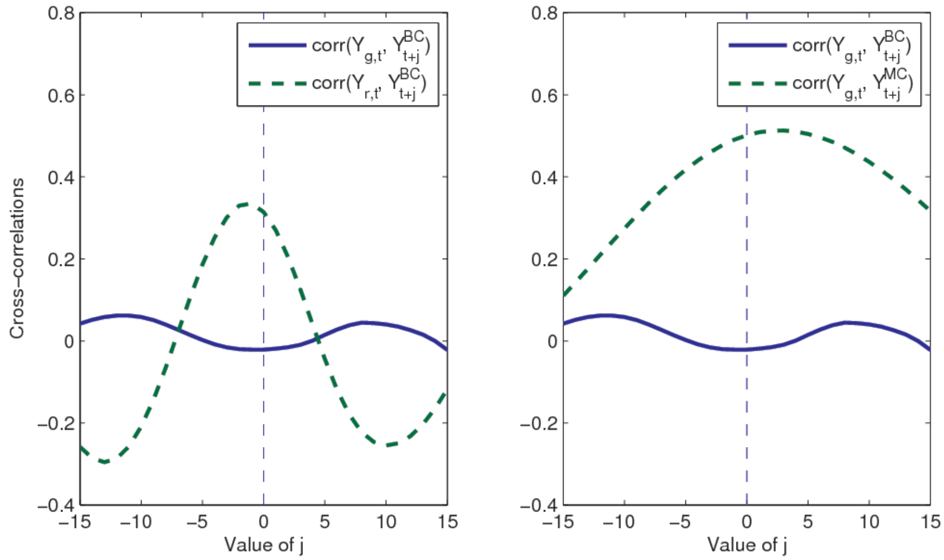
Note: The figure plots counterfactual analyses associated with the two shocks (left panels, fiscal policy on top and monetary policy on bottom), and the business and medium cycle components of consumption (right panels).

Figure 3.5: Decomposition of Investment at Various Frequencies.



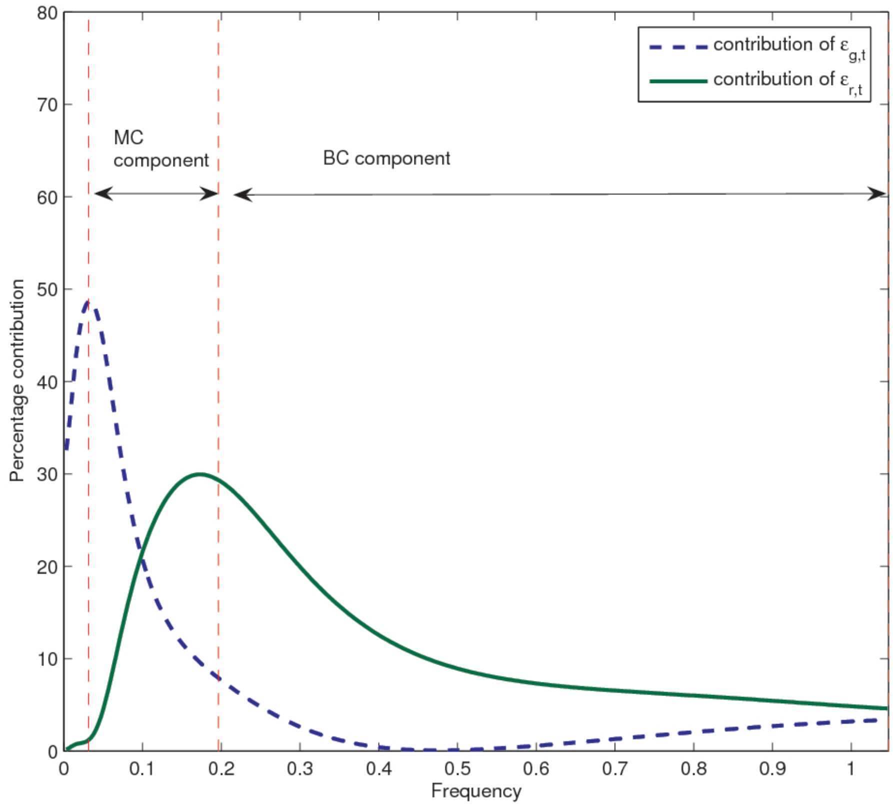
Note: The figure plots counterfactual analyses associated with the two shocks (left panels, fiscal policy on top and monetary policy on bottom), and the business and medium cycle components of investment (right panels).

Figure 3.6: Cross-correlations of Counterfactuals and Business/Medium Cycle Components of GDP.



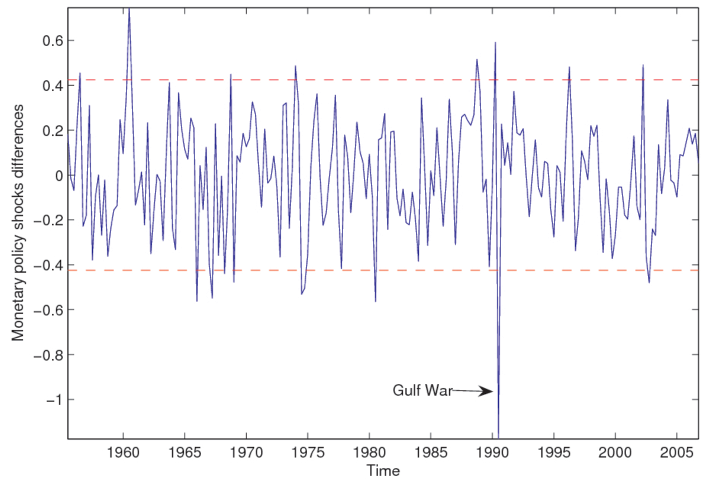
Note: In the left panel, the solid line is the cross-correlation between counterfactual GDP due to government spending shock ($Y_{g,t}$) and the business cycle component of GDP (Y_{t+j}^{BC}); the dashed line is correlation between counterfactual GDP due to monetary shock ($Y_{r,t}$) and Y_{t+j}^{BC}. In the right panel, the solid line is the cross-correlation between counterfactual GDP due to government spending shock ($Y_{g,t}$) and Y_{t+j}^{BC}; the dashed line is correlation between $Y_{g,t}$ and the medium cycle component of GDP (Y_{t+j}^{MC}). The x-axis denotes different values of j.

FIGURE 3.7: Robustness to Definitions of Business-Medium Cycle.



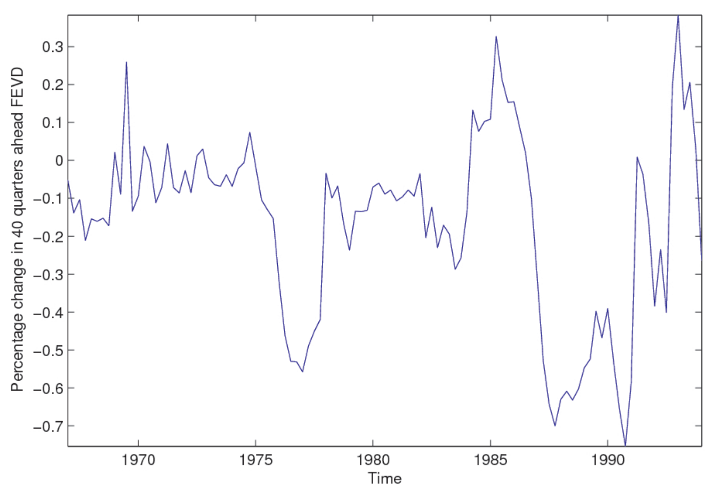
Note: The figure plots the fraction of variance of GDP due to each shock at different frequencies. The dashed line is the contribution of the government spending shock and the solid line is the contribution of the monetary policy shock.

Figure 3.8: Time Series of Monetary Policy Shocks Differences.



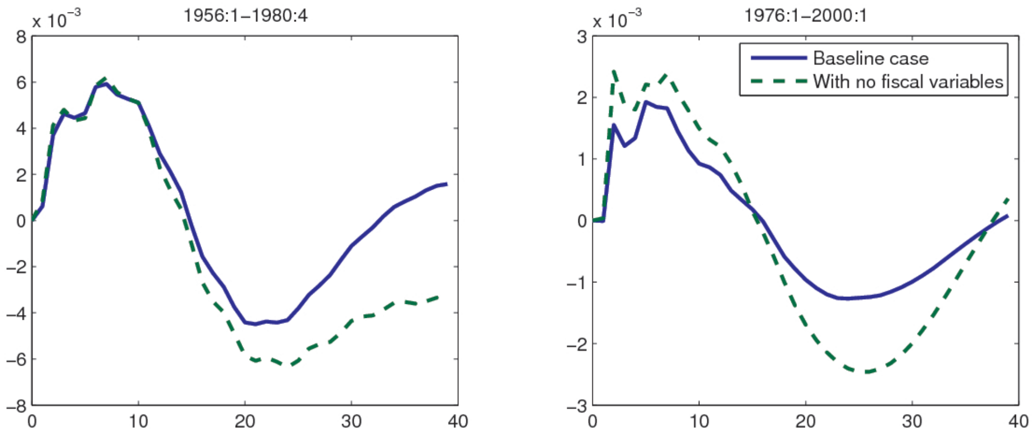
Note: The figure plots the difference between the monetary policy shocks estimated with and without government spending, $\widehat{\varepsilon}_{r,t} - \widetilde{\varepsilon}_{r,t}$. The dotted line shows 90% confidence bands for the null hypothesis that the two shocks are equal, in expectation.

Figure 3.9: Percentage Change in 40 quarters ahead FEVD of Monetary Policy Shocks when including Fiscal Policy Variables.



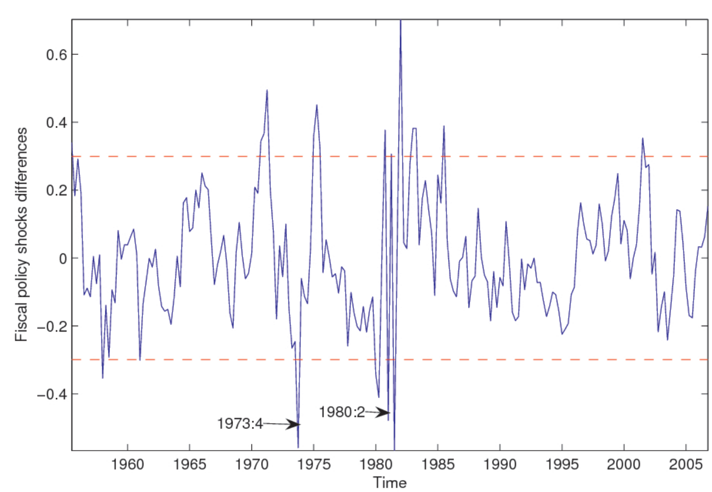
Note: The figure plots the percentage difference between the FEVD of GDP due to monetary policy shocks estimated in VARs with and without government spending, for a centered rolling window of 100 quarters.

Figure 3.10: Impulse Responses of GDP to the Monetary Policy Shock, with and without Fiscal Variables.



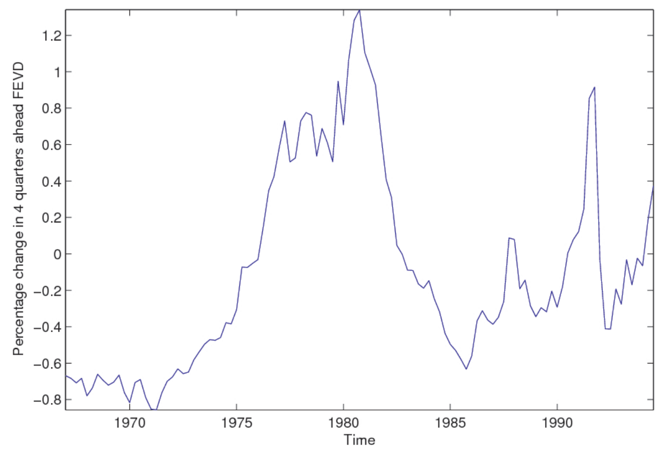
Note: The solid line shows the response for the baseline VAR and the dashed line shows the response for the VAR without government spending.

Figure 3.11: Time Series of Fiscal Policy Shocks Differences.



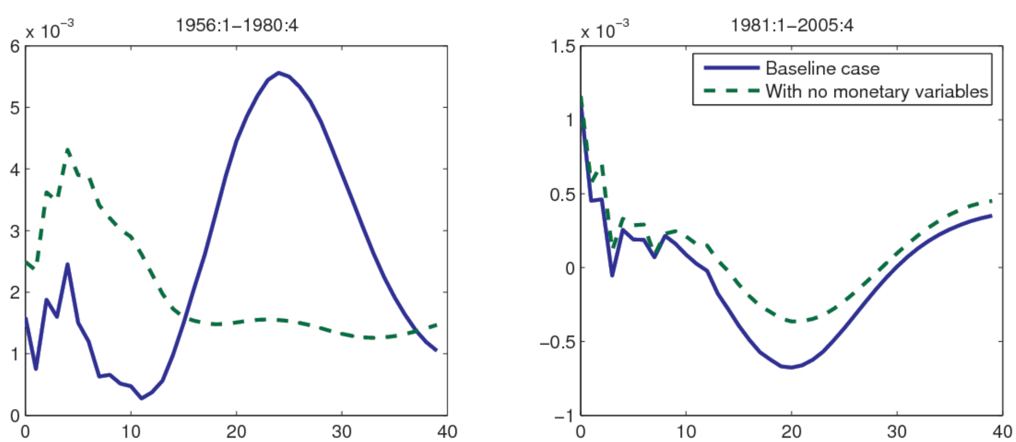
Note: The figure plots the difference between the fiscal policy shocks estimated with and without the federal funds rate in the VAR, $\widehat{\varepsilon}_{g,t} - \overline{\varepsilon}_{g,t}$. The dotted line shows 90% confidence bands for the null hypothesis that the shocks are equal, in expectation.

Figure 3.12: Percentage Change in 4 quarters ahead FEVD of Fiscal Policy Shocks when including Monetary Policy Variables.



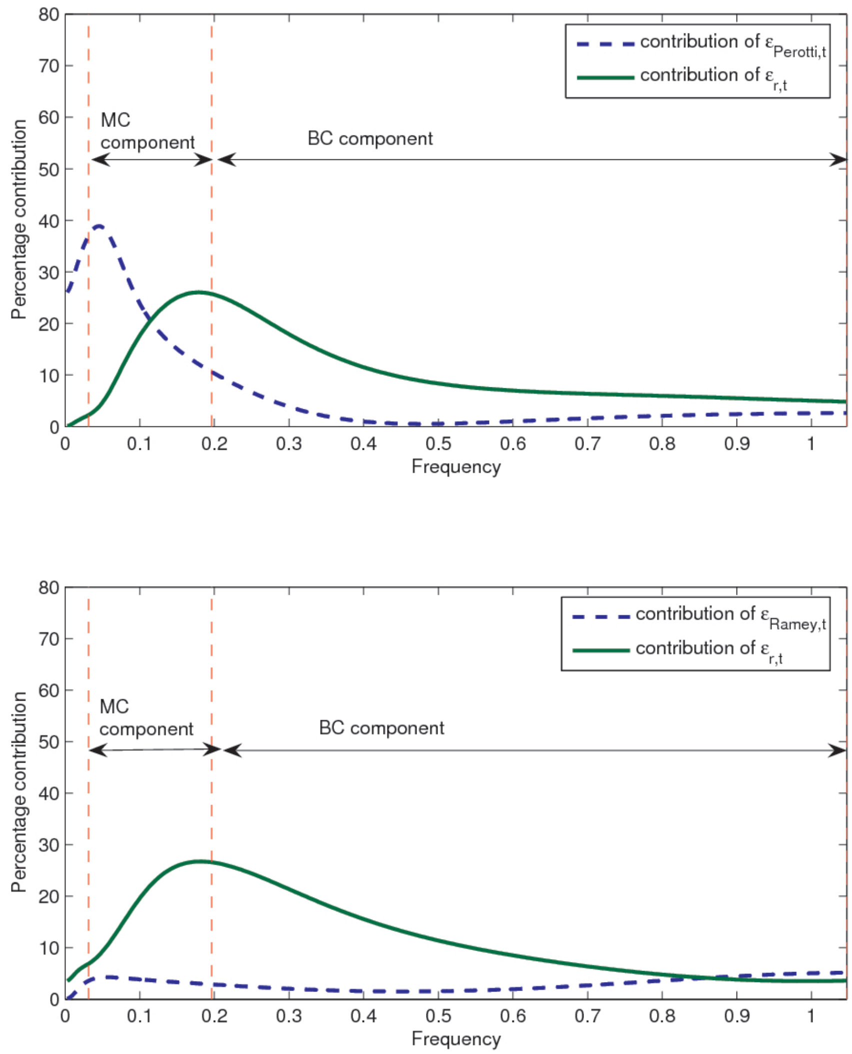
Note: The figure plots the percentage difference between the FEVD of GDP due to fiscal policy shocks estimated in VARs with and without federal funds rate, for a centered rolling window of 100 quarters.

Figure 3.13: Impulse Responses of GDP to a Government Spending Shock, with and without Monetary Variables.



Note: The solid line shows the response for the baseline VAR and the dashed line shows the response for the VAR without the Federal Funds rate.

FIGURE 3.14: Comparison of Perotti's (2007) and Ramey's (2008) Fiscal Shocks.



Note: The figure plots the fraction of variance of GDP due to each shock at different frequencies. The dashed line is the contribution of the fiscal policy shock and the solid line is the contribution of the monetary policy shock. The upper panel identifies the government spending shock via equation (3.4) whereas the lower panel focuses on equation (3.5).

Appendix A

Appendix for Chapter 1

A.1 Complete set of symmetric competitive equilibrium conditions in a model with deep habits

$$x_t^c = c_t - b^c s_{t-1}^C \tag{A.1}$$

$$x_t^g = g_t - b^g s_{t-1}^G \tag{A.2}$$

$$k_{t+1} = (1-\delta)k_t + i_t \left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right)\right] \tag{A.3}$$

$$U_x(x_t^c, h_t) = \lambda_t \tag{A.4}$$

$$-U_h(x_t^c, h_t) = \frac{\lambda_t w_t}{\tilde{\mu}_t} \tag{A.5}$$

$$\lambda_t q_t = \beta E_t \lambda_{t+1} \left[r_{t+1}^k u_{t+1} - a(u_{t+1}) + q_{t+1}(1-\delta)\right] \tag{A.6}$$

$$\lambda_t = \lambda_t q_t \left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right) - \left(\frac{i_t}{i_{t-1}}\right)\mathcal{S}'\left(\frac{i_t}{i_{t-1}}\right)\right] + \beta E_t \lambda_{t+1} q_{t+1} \left(\frac{i_{t+1}}{i_t}\right)^2 \mathcal{S}'\left(\frac{i_{t+1}}{i_t}\right) \tag{A.7}$$

$$r_t^k = a'(u_t) \tag{A.8}$$

$$f_t^1 = \left(\frac{\tilde{\eta}-1}{\tilde{\eta}}\right)\tilde{w}_t\lambda_t\left(\frac{w_t}{\tilde{w}_t}\right)^{\tilde{\eta}} h_t^d + \tilde{\alpha}\beta E_t\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\tilde{\eta}-1}\left(\frac{\tilde{w}_{t+1}}{\tilde{w}_t}\right)^{\tilde{\eta}-1} f_{t+1}^1 \tag{A.9}$$

$$f_t^2 = -U_h(x_t^c, h_t)\left(\frac{w_t}{\tilde{w}_t}\right)^{\tilde{\eta}} h_t^d + \tilde{\alpha}\beta E_t\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\tilde{\eta}}\left(\frac{\tilde{w}_{t+1}}{\tilde{w}_t}\right)^{\tilde{\eta}} f_{t+1}^2 \tag{A.10}$$

$$f_t^1 = f_t^2 \tag{A.11}$$

$$\lambda_t = \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}} \tag{A.12}$$

$$\frac{1 - mc_t - \tilde{\nu}_t^c}{\rho^c - 1} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[b^c\tilde{\nu}_{t+1}^c + \frac{\rho^c}{\rho^c - 1}\left\{1 - mc_{t+1} - \tilde{\nu}_{t+1}^c\right\}\right] \tag{A.13}$$

$$\frac{1 - mc_t - \tilde{\nu}_t^g}{\rho^g - 1} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\left[b^g\tilde{\nu}_{t+1}^g + \frac{\rho^g}{\rho^g - 1}\left\{1 - mc_{t+1} - \tilde{\nu}_{t+1}^g\right\}\right] \tag{A.14}$$

$$1 - mc_t = \tilde{\nu}_t^i \tag{A.15}$$

$$\eta\left(\tilde{\nu}_t^c x_t^c + \tilde{\nu}_t^g x_t^g + \tilde{\nu}_t^i(y_t - c_t - i_t)\right) + \alpha\pi_t\left(\pi_t - \pi_{t-1}\right) - y_t = \alpha\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\pi_{t+1}\left(\pi_{t+1} - \pi_t\right)\right] \tag{A.16}$$

$$y_t = c_t + g_t + i_t + a(u_t)k_t \tag{A.17}$$

$$F(u_t k_t, h_t^d) - \psi = c_t + g_t + i_t + a(u_t)k_t + \frac{\alpha}{2}(\pi_t - \pi_{t-1})^2 \tag{A.18}$$

$$\mathrm{mc}_t F_2(u_t k_t, h_t^d) = w_t \tag{A.19}$$

$$\mathrm{mc}_t F_1(u_t k_t, h_t^d) = r_t^k \tag{A.20}$$

$$h_t = \tilde{s}_t h_t^d \tag{A.21}$$

$$\tilde{s}_t = (1 - \tilde{\alpha})\left(\frac{\tilde{w}_t}{w_t}\right)^{-\tilde{\eta}} + \tilde{\alpha}\left(\frac{w_{t-1}}{w_t}\right)^{-\tilde{\eta}}\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\tilde{\eta}}\tilde{s}_{t-1} \tag{A.22}$$

$$w_t^{1-\tilde{\eta}} = (1 - \tilde{\alpha})\tilde{w}_t^{1-\tilde{\eta}} + \tilde{\alpha}w_{t-1}^{1-\tilde{\eta}}\left(\frac{\pi_{t-1}}{\pi_t}\right)^{1-\tilde{\eta}} \tag{A.23}$$

$$\tau_t = g_t \tag{A.24}$$

$$s_t^C = \rho^c s_{t-1}^C + (1-\rho^c)c_t \tag{A.25}$$

$$s_t^G = \rho^g s_{t-1}^G + (1-\rho^g)g_t \tag{A.26}$$

and the exogenous process for government spending and Taylor monetary rule.

A.2 Complete set of symmetric competitive equilibrium conditions in a model with superficial habits

$$k_{t+1} = (1-\delta)k_t + i_t\left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right)\right] \tag{A.1}$$

$$U_c(c_t - bc_{t-1}, h_t) = \lambda_t \tag{A.2}$$

$$-U_h(c_t - bc_{t-1}, h_t) = \frac{\lambda_t w_t}{\tilde{\mu}_t} \tag{A.3}$$

$$\lambda_t q_t = \beta E_t \lambda_{t+1}\left[r_{t+1}^k u_{t+1} - a(u_{t+1}) + q_{t+1}(1-\delta)\right] \tag{A.4}$$

$$\lambda_t = \lambda_t q_t\left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right) - \left(\frac{i_t}{i_{t-1}}\right)\mathcal{S}'\left(\frac{i_t}{i_{t-1}}\right)\right] + \beta E_t \lambda_{t+1} q_{t+1}\left(\frac{i_{t+1}}{i_t}\right)^2 \mathcal{S}'\left(\frac{i_{t+1}}{i_t}\right) \tag{A.5}$$

$$r_t^k = a'(u_t) \tag{A.6}$$

$$f_t^1 = \left(\frac{\tilde{\eta}-1}{\tilde{\eta}}\right)\tilde{w}_t\lambda_t\left(\frac{w_t}{\tilde{w}_t}\right)^{\tilde{\eta}} h_t^d + \tilde{\alpha}\beta E_t\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\tilde{\eta}-1}\left(\frac{\tilde{w}_{t+1}}{\tilde{w}_t}\right)^{\tilde{\eta}-1} f_{t+1}^1 \tag{A.7}$$

$$f_t^2 = -U_h(c_t - bc_{t-1}, h_t)\left(\frac{w_t}{\tilde{w}_t}\right)^{\tilde{\eta}} h_t^d + \tilde{\alpha}\beta E_t\left(\frac{\pi_{t+1}}{\pi_t}\right)^{\tilde{\eta}}\left(\frac{\tilde{w}_{t+1}}{\tilde{w}_t}\right)^{\tilde{\eta}} f_{t+1}^2 \tag{A.8}$$

$$f_t^1 = f_t^2 \tag{A.9}$$

$$\lambda_t = \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}} \tag{A.10}$$

$$1 - mc_t = \tilde{\nu}_t \tag{A.11}$$

$$(\eta\tilde{\nu}_t - 1)y_t + \alpha\pi_t(\pi_t - \pi_{t-1}) = \alpha\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\pi_{t+1}(\pi_{t+1} - \pi_t)\right] \tag{A.12}$$

$$y_t = c_t + g_t + i_t + a(u_t)k_t \tag{A.13}$$

$$F(u_t k_t, h_t^d) - \psi = c_t + g_t + i_t + a(u_t)k_t + \frac{\alpha}{2}(\pi_t - \pi_{t-1})^2 \tag{A.14}$$

$$\mathrm{mc}_t F_2(u_t k_t, h_t^d) = w_t \tag{A.15}$$

$$\mathrm{mc}_t F_1(u_t k_t, h_t^d) = r_t^k \tag{A.16}$$

$$h_t = \tilde{s}_t h_t^d \tag{A.17}$$

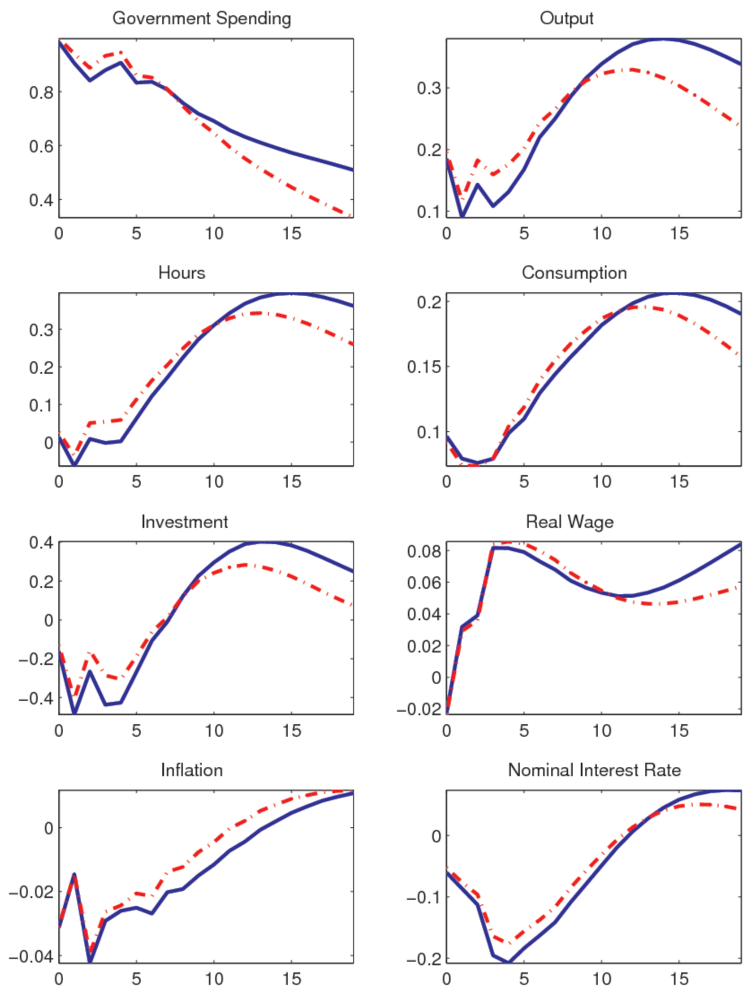
$$\tilde{s}_t = (1 - \tilde{\alpha}) \left(\frac{\tilde{w}_t}{w_t} \right)^{-\tilde{\eta}} + \tilde{\alpha} \left(\frac{w_{t-1}}{w_t} \right)^{-\tilde{\eta}} \left(\frac{\pi_t}{\pi_{t-1}} \right)^{\tilde{\eta}} \tilde{s}_{t-1} \tag{A.18}$$

$$w_t^{1-\tilde{\eta}} = (1 - \tilde{\alpha}) \tilde{w}_t^{1-\tilde{\eta}} + \tilde{\alpha} w_{t-1}^{1-\tilde{\eta}} \left(\frac{\pi_{t-1}}{\pi_t} \right)^{1-\tilde{\eta}} \tag{A.19}$$

$$\tau_t = g_t \tag{A.20}$$

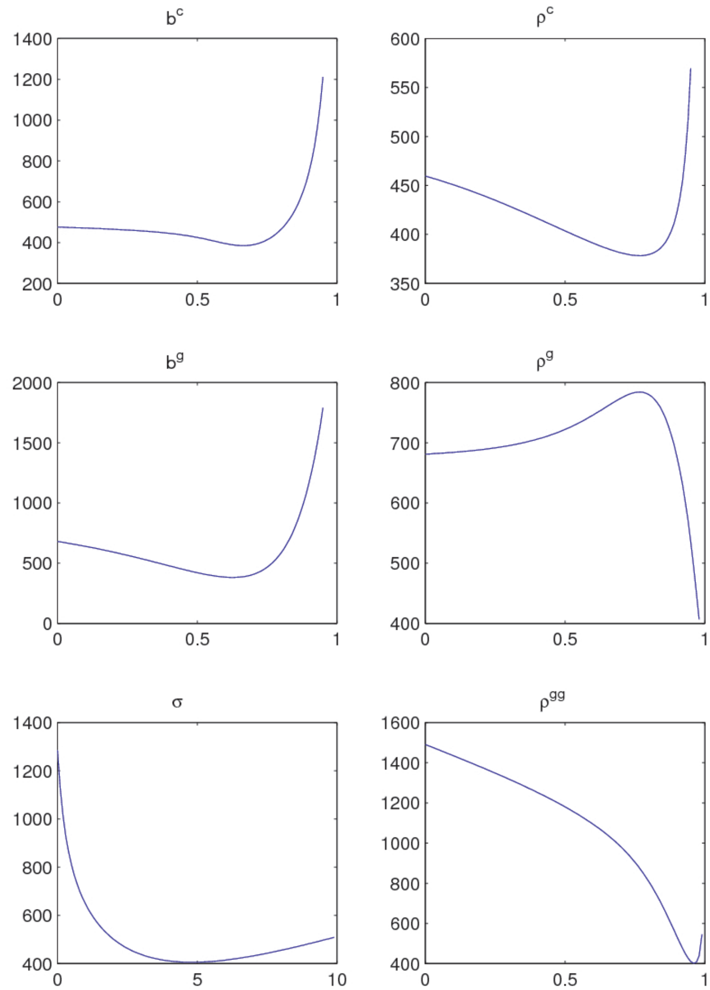
and the exogenous process for government spending and Taylor monetary rule.

Figure A.1: Impulse response functions with and without the Ramey variable



Note: Impulse response function to a one standard deviation government spending shock as identified in the baseline SVAR (solid line) and impulse response function to government spending shock identified similarly but *no* Ramey variable included on the right hand side of the VAR equation (dashed line), which would be similar to the case shown in Fatas and Mihov (2001) and Blanchard and Perotti (2002).

Figure A.2: Identification of parameters



Note: This figure shows a graphical exercise to see if the parameters being estimated are identified. The objective function $L_n(\theta)$, as defined in Section 4, is plotted on the y-axis while θ is varied on the x-axis. In this figure all parameters are fixed at the estimated values for the baseline model with deep habits, while one parameter in θ is varied at a time.

Appendix B

Appendix for Chapter 2

B.1 Complete Set of Symmetric Equilibrium Conditions

$$x_t^c = c_t - b^c s_{t-1}^C \tag{A-1}$$

$$x_t^g = g_t - b^g s_{t-1}^G \tag{A-2}$$

$$k_{t+1} = (1-\delta)k_t + i_t \left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right)\right] \tag{A-3}$$

$$d_t U_x(x_t^c, h_t) = \lambda_t \tag{A-4}$$

$$- d_t U_h(x_t^c, h_t) = \frac{\lambda_t w_t}{\tilde{\mu}_t}, \tag{A-5}$$

$$\lambda_t q_t = \beta E_t \lambda_{t+1} \left[(1-\tau_{t+1}^k) r_{t+1}^k u_{t+1} - a(u_{t+1}) + q_{t+1}(1-\delta) + \delta q_{t+1} \tau_{t+1}^k u_{t+1}\right] \tag{A-6}$$

$$\lambda_t = \lambda_t q_t \left[1 - \mathcal{S}\left(\frac{i_t}{i_{t-1}}\right) - \left(\frac{i_t}{i_{t-1}}\right) \mathcal{S}'\left(\frac{i_t}{i_{t-1}}\right)\right] + \beta E_t \lambda_{t+1} q_{t+1} \left(\frac{i_{t+1}}{i_t}\right)^2 \mathcal{S}'\left(\frac{i_{t+1}}{i_t}\right) \tag{A-7}$$

$$(1-\tau_t^k) r_t^k + \delta q_t \tau_t^k = a'(u_t) \tag{A-8}$$

$$(\tilde{\eta} - 1)(1-\tau_t^w) h_t + \tilde{\alpha} \pi_t^w (\pi_t^w - \bar{\pi}) - \tilde{\eta} \frac{h_t}{\tilde{\mu}_t} = \tilde{\alpha} \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1}^w (\pi_{t+1}^w - \bar{\pi})\right] \tag{A-9}$$

$$\lambda_t = \beta R_t E_t \frac{\lambda_{t+1}}{\pi_{t+1}}, \tag{A-10}$$

$$\frac{1 - mc_t - \tilde{\nu}_t^c}{\theta^c - 1} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[b^c \tilde{\nu}_{t+1}^c + \frac{\theta^c}{\theta^c - 1} \left\{ 1 - mc_{t+1} - \tilde{\nu}_{t+1}^c \right\} \right] \tag{A-11}$$

$$\frac{1 - mc_t - \tilde{\nu}_t^g}{\theta^g - 1} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \left[b^g \tilde{\nu}_{t+1}^g + \frac{\theta^g}{\theta^g - 1} \left\{ 1 - mc_{t+1} - \tilde{\nu}_{t+1}^g \right\} \right] \tag{A-12}$$

$$1 - mc_t - \tilde{\nu}_t^i = 0 \tag{A-13}$$

$$\eta \left(\tilde{\nu}_t^c x_t^c + \tilde{\nu}_t^g x_t^g + \tilde{\nu}_t^i (y_t - c_t - g_t) \right) + \alpha \pi_t (\pi_t - \bar{\pi}) - y_t = \alpha \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1} (\pi_{t+1} - \bar{\pi}) \right] \tag{A-14}$$

$$z_t F(u_t k_t, h_t) - \psi = c_t + g_t + i_t + a(u_t) k_t + \frac{\alpha}{2} (\pi_t - \pi)^2 + \frac{\tilde{\alpha}}{2} \left(\pi_t^w - \bar{\pi} \right)^2 w_t \tag{A-15}$$

$$y_t = z_t F(u_t k_t, h_t) - \psi - \frac{\alpha}{2} (\pi_t - \pi)^2 \tag{A-16}$$

$$\mathrm{mc}_t z_t F_2(u_t k_t, h_t) = w_t \tag{A-17}$$

$$\mathrm{mc}_t z_t F_1(u_t k_t, h_t) = r_t^k \tag{A-18}$$

$$b_t = R_{t-1} \frac{b_{t-1}}{\pi_t} + g_t + tr_t - \tau_t \tag{A-19}$$

$$\tau_t = \tau_t^w w_t h_t + \tau_t^k (r_t^k u_t k_t - \delta q_t u_t k_t) \tag{A-20}$$

$$s_t^C = \theta^c s_{t-1}^C + (1 - \theta^c) c_t \tag{A-21}$$

$$s_t^G = \theta^g s_{t-1}^G + (1 - \theta^g) g_t \tag{A-22}$$

and equations (2.2), (2.8), (2.13), (2.14), (2.15), (2.16), (2.17) and (2.19) from the text.

B.2 Steady State

$$q = 1,\ u = 1$$

$$R = \frac{\pi}{\beta}$$

$$r^k = (\frac{1}{\beta} - 1 + \delta - \delta\tau^k)/(1 - \tau^k)$$

$$share_i = I/Y = \delta\theta/r^k$$

$$share^c = C/Y = 1 - share^i - share^g$$

$$\gamma_1 = (1 - \tau^k)r^k + \delta\tau^k,\ \gamma_2 = \sigma^u\gamma_1$$

$$\tilde{\mu} = \frac{\tilde{\eta}}{(\tilde{\eta} - 1)(1 - \tau^w)}$$

$$mc = \frac{share^c + share^i + share^g}{\eta\,(share^c aa^c/bb^c + share^g aa^g/bb^g - share^i)} + 1$$

$$aa^c = (1 - b^c),\ bb^c = (\beta b^c(\theta^c - 1))/(\beta\theta^c - 1) - 1$$

$$aa^g = (1 - b^g),\ bb^g = (\beta b^g(\rho^g - 1))/(\beta\rho^g - 1) - 1$$

$$\nu^c = (mc - 1)/bbc,\ \nu^g = (mc - 1)/bbg,\ \nu^i = (mc - 1)$$

$$K = (r^k/mc/\theta)^{\frac{1}{\theta - 1}} H$$

$$I = \delta K$$

$$w = mc(1 - \theta)(K/H)^\theta$$

$$\psi = K^\theta H^{1-\theta} - (r^k K + wH)$$

$$Y = K^\theta H^{1-\theta} - \psi$$

$$s^c = C,\ s^g = G$$

$$a = (1 - h)w/((1 - H)w + \tilde{\mu}(C - b^c s^c))$$

$$\lambda = (1-a)(c(1-b^c))^{(1-a)(1-\sigma)-1}(1-h)^{a(1-\sigma)}$$

$$\tau = \tau^w wH + \tau^k(r^k - \delta)K$$

$$tr = b\left(1 - \frac{R}{\pi}\right) - G + \tau$$

B.3 Data used in estimation

The following quarterly series were used in the estimation. In order to construct real per-capita values, GDP deflator (given by Table 1.1.6, Line 1) and civilian non-institutional population, over 16 (given by LNU00000000Q, at Bureau of Labor Statistics) are used. The table and line numbers refer to the NIPA tables on the Bureau of Economic Analysis website. The data for consumption, investment, government spending and debt were linearly detrended to get stationary series.

- **Consumption**: Sum of personal consumption expenditures on non-durables goods (Table 1.1.5, Line 3) and services (Table 1.1.5, Line 5) divided by the GDP deflator and by population.

- **Inflation**: First difference of GDP deflator.

- **Federal funds rate**: Monthly federal funds rate series from St. Louis FRED website was averaged to create quarterly series.

- **Investment**: Sum of gross private domestic investment (Table 1.1.5, Line 6) and personal consumption expenditures on nondurable goods (Table 1.1.5, Line 4), divided by the GDP deflator and by population.

- **Government spending**: Government consumption expenditures and gross investment (Table 1.1.5, Line 20) divided by the GDP deflator and by population.

- **Debt**: Market value of federal debt held by public from the Dallas Fed website divided by the GDP deflator and by population. The quarterly series is constructed by summing up the monthly series. The series of debt initialized by the Dallas Fed series and constructed from secondary deficit data from NIPA matches up in levels and the correlation is 0.99.

- **Capital and labor tax rate**: The method of Jones (2002) was used to construct these series. The first step is to construct the average personal income tax rate,

$$\tau_p = \frac{FIT + SIT}{W + PRI/2 + CI}$$

where FIT denotes federal income taxes (Table 3.2, Line 3), SIT denotes state and local income taxes (Table 3.3, Line 3), W denotes wages and salaries (Table 1.12, Line 3), PRI denotes proprietor's income (Table 1.12, Line 9) and CI denotes capital income which is the sum of rental income (Table 1.12, Line 12), corporate profits (Table 1.12, Line 13), net interest (Table 1.12, Line 18) and $PRI/2$. The labor tax rate, τ^w, is then calculated as,

$$\tau^w = \frac{\tau^p[W + PRI/2] + CSI}{EC + PRI/2}$$

where CSI is total contributions to government social insurance (Table 3.1, Line 7) and EC denotes total compensation of employees (Table 1.12, Line 2). The capital tax rate, τ^k is calculated as,

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

The tax rates are constructed as average tax rates using the methodology in Mendoza, Razin, and Tesar (1994) and Jones (2002), primarily because they are easily constructed on a quarterly basis using data on actual tax payments and national accounts, and in addition allow us to distinguish between taxes on labor and capital income. Other tax rate series include Barro and Sahasakul (1983) marginal tax rate series on personal income, where they average tax rates over the number of returns for each class of adjusted gross income. However, this does not differentiate between tax rates on capital and labor income. McGrattan (1994) linearly interpolates annual tax rates constructed following Joines (1981) to obtain quarterly observations. The main difference between Jones (2002) and their tax rate series is that they estimate the personal income tax rate as a marginal tax rate from tax records, rather than as an average rate from the national accounts. While much easier to construct, Mendoza, Razin, and Tesar (1994) show that average tax rates in different countries tend to follow the same dynamics as marginal tax rates.[1]

B.4 Multipliers Implied by the Priors

To evaluate the economic content of the priors of the parameters being estimated, Table B.1 shows their implications for the fiscal multipliers, that are the focus of the paper. The table reports the median and 95 percentile present value multipliers for 500 random draws from the prior distribution of the parameters. Since deep habits are introduced as a transmission mechanism, notice that the median impact multiplier for government spending is larger than 1. However, as the confidence bands illustrate that the priors do not exclude the possibility of a much smaller spending multiplier. In general, tax multipliers are smaller than spending multiplier at early horizons. Also, note that the confidence bands are large, particularly for longer horizons, which reflects the disperse priors for fiscal rule parameters.

[1] Following Jones (2002), since the labor tax rate series has a trend and its idiosyncratic with no counterpart in the model, it is removed by linearly detrending the series. Mendoza, Razin, and Tesar (1994) also show that in many different countries, the capital tax series is stationary but the labor tax series has an upward trend.

Table B.1: Present Value Multipliers Implied by the Priors

	Quarter 1	Quarter 4	Quarter 12	Quarter 20
Government Spending Multiplier				
$\frac{PV\Delta Y_{t+k}}{PV\Delta G_{t+k}}$	1.06	0.93	0.41	0.12
	[0.7, 1.8]	[0.5,1.9]	[-0.2, 1.7]	[-0.65, 1.4]
Labor Tax Multiplier				
$\frac{PV\Delta Y_{t+k}}{PV\Delta T^w_{t+k}}$	0.10	0.22	0.40	0.25
	[0.0,0.3]	[0.0, 0.5]	[-1.0, 0.9]	[-6.2, 1.5]
Capital Tax Multiplier				
$\frac{PV\Delta Y_{t+k}}{PV\Delta T^k_{t+k}}$	0.45	0.61	0.73	0.59
	[0.3, 0.8]	[0.3, 1.1]	[-0.3, 1.6]	[-5.0, 1.9]

Note: This table shows the present discounted value of the cumulative change in output over the present value cumulative change in the fiscal variable of interest, over the k quarters, for 500 random draws from the prior distribution of the parameters. The reported numbers are the median multipliers and the 95 percentiles are given below in brackets.

B.5 Fit of the Model

In order to assess the goodness of fit of the model, Figure B.1 shows the data used in the estimation, along with the posterior mean of the smoothed series implied by the estimated model. The fit of the model is nearly perfect for most variables, notably government spending and tax rates. The model predicts consumption relatively smoother than is observed. The only significant discrepancy is inflation where the model implies less overall volatility.

Table B.2 also reports the standard deviations computed from data and those implied by the model. It also reports the 90 percent probability intervals that account for both parameter uncertainty and small sample uncertainty. Relative to the data, the model over-predicts the standard deviation of output a little, and approximately matches the relative standard deviation of consumption, inflation and hours. There

Table B.2: Moment Comparison

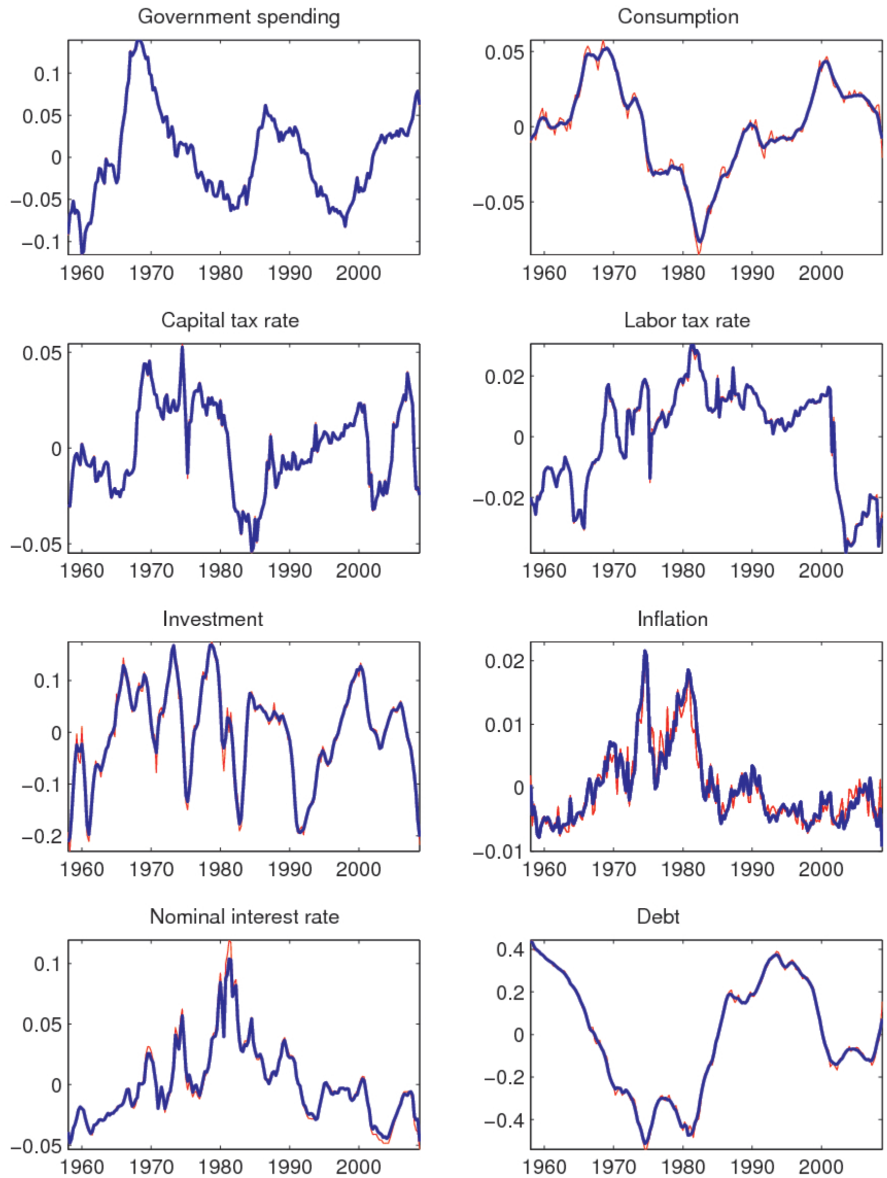
	Data	Model	
		Median	[5,95]
Std. Dev. of Output (%)	3.62	4.65	[3.24, 5.31]
Standard Deviation/ Standard Deviation of Output			
Consumption	0.83	0.86	[0.77, 0.97]
Investment	2.94	4.50	[3.19, 5.64]
Inflation	0.16	0.18	[0.13, 0.21]
Nominal Interest Rate	0.87	0.52	[0.32, 0.74]
Government Spending	1.41	0.85	[0.64, 1.18]
Capital tax rate	0.89	1.13	[0.70, 1.88]
Labor tax rate	0.45	0.83	[0.41, 1.01]
Hours	1.02	1.15	[0.74, 1.70]

For randomly chosen 1000 draws, I generate 500 samples of the observable series implied by the model with the same length as the data-set (204 observations) after discarding the first 80 initial observations. The table reports the median and 5th and 95th percentile together with the corresponding moment in the data.

is some tendency to over-predict the volatility of investment, and tax rates and under predict the volatility of nominal interest rate and government spending. Note that the estimated model does not perfectly match these moments, since I am employing a likelihood based estimation procedure, which tries to match the entire structure of the data series, including second moments, autocorrelations and cross-correlations.

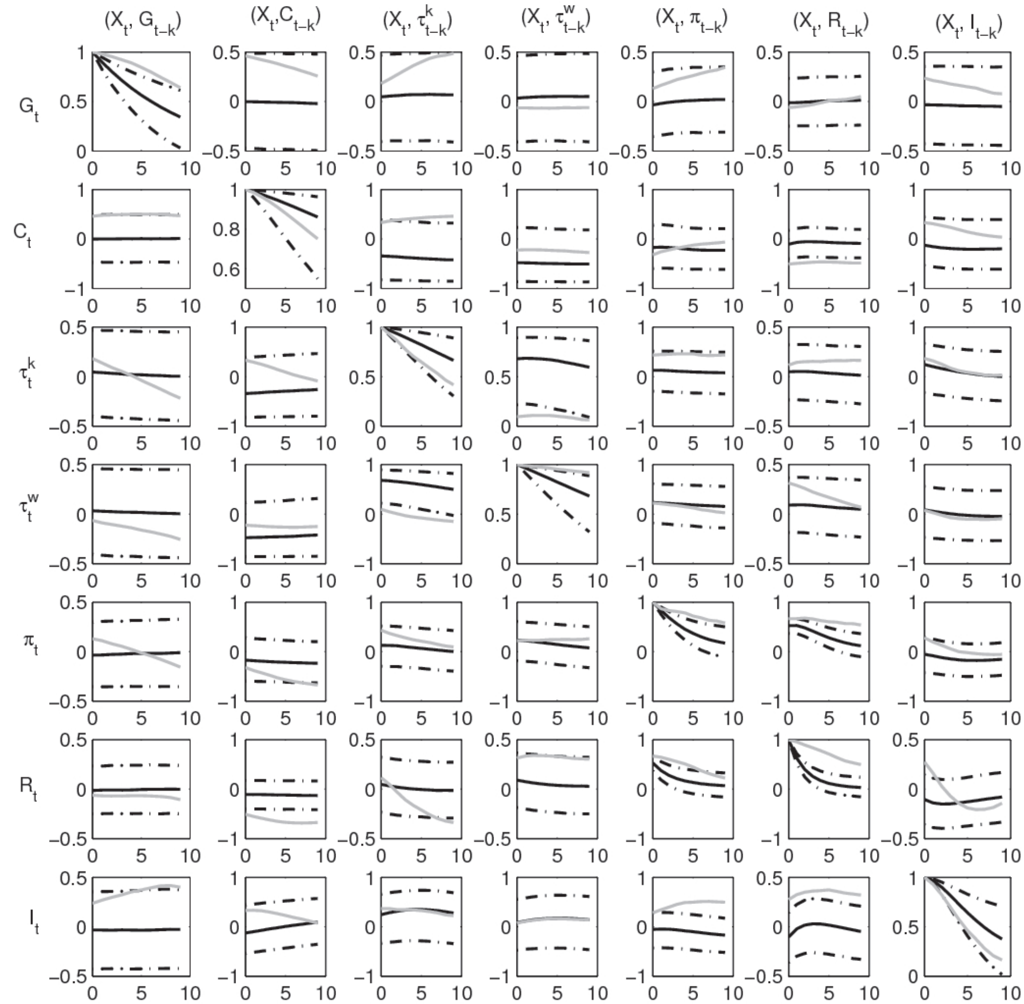
Figure B.2 shows the autocorrelations and cross-correlations generated by the model and in the data for selected observable variables. The model predictions are the black lines, where the solid black line is the median and the dashed lines are the 90 percent posterior intervals. The data is represented by the grey lines. The diagonal of the figure shows that the model is able to capture the decaying autocorrelation structure of the variables quite well. Generally, the data cross-correlations fall within the confidence bands. These error bands, however, are quite large, accounting for both parameter and small sample uncertainty.

Figure B.1: Model fit



Note: The thin red line is the data used in the estimation and the thick blue line is posterior mean of the smoothed version of the same series.

FIGURE B.2: Cross-correlations



Note: The black line represent the median cross-correlations implied by the model along with the 90% confidence bands (dash-dotted line). The grey lines are the data cross-correlations. Each column gives the correlation between X_t and the variable specified, where X_t is given in each row. The x-axis gives the values of k.

B.6 Model Comparison to Alternative Specification of Fiscal Rules

I compare the baseline model with the processes for government spending and transfers given by Equations (2.15) and (2.16), with one where both government spending and transfers have exogenous AR(1) processes and do not respond to the state of the economy (so that $\rho_{g,y} = \rho_{tr,y} = 0$). Exogenous processes for fiscal variables, especially government spending are a common assumption in the literature.

I also compare the baseline model to the case where the government spending process is given by Equation (2.15) but I allow transfers to additionally respond to the level of lagged debt, so that the process for transfers, instead of Equation (2.16), is given by,

$$\hat{tr}_t = \rho_{tr}\hat{tr}_{t-1} + \rho_{tr,y}\hat{y}_{t-1} + \rho_{tr,b}\hat{b}_{t-1} + \epsilon_t^{tr}.$$

In order to compare the estimated baseline model with different specifications of fiscal rules, I report the log marginal likelihood for two alternative models relative to the baseline model, in Table B.3. These were computed using the modified harmonic mean proposed by Geweke (1999). According to this criterion, eliminating any feedback from the economy to government spending and transfers worsens the fit of the model, even though the marginal likelihood penalizes over-parametrization. The log marginal likelihood difference between the baseline case and allowing transfers to respond to the level of debt, in addition to the tax rates, is close to three. As argued in Rabanal and Rubio-Ramirez (2005), this difference cannot be accepted as decisive evidence in favor of one model over the other.

Table B.3: Model Comparison

Specification	**Log Marginal Likelihood** (Difference from Baseline)
Exogenous processes for tr_t and g_t	-63.5
Also allow tr_t to respond to b_{t-1}	3.1

Note: The table shows the log marginal likelihood for different model specifications minus that for the baseline model.

Appendix C

Appendix for Chapter 3

Table C.1: Data Series Description and Sources

Label	Frequency	Description	Source
GDP	Q	Gross domestic product	BEA (Table 1.1.5)
GCD	Q	Personal consumption expenditures on durable goods	BEA (Table 1.1.5)
GCN	Q	Personal consumption expenditures on nondurable goods	BEA (Table 1.1.5)
GCS	Q	Personal consumption expenditures on services	BEA (Table 1.1.5)
GPI	Q	Gross private domestic investment	BEA (Table 1.1.5)
GGE	Q	Government consumption expenditures and gross investment	BEA (Table 1.1.5)
GDPQ	Q	Real gross domestic product	BEA (Table 1.1.6)
P16	Q	Civilian non-institutional population, over 16	BLS (LNU00000000Q)
LBMNU	Q	Non-farm business hours worked	BLS (PRS85006033)
LBCPU	Q	Hourly non-farm business compensation	BLS (PRS85006103)
FYFF	M	Federal funds rate	St. Louis FRED
GGFR	Q	Federal tax receipts	BEA (Table 3.2)
GGAID	Q	Federal grants in aid	BEA (Table 3.2)
GGFTP	Q	Federal transfer payments to persons	BEA (Table 3.2)
GGFINT	Q	Federal interest payments	BEA (Table 3.2)
GGSR	Q	State and local tax receipts	BEA (Table 3.3)
GGST	Q	State and local transfer payments to persons	BEA (Table 3.3)
GGSINT	Q	State and local net interest payments to persons	BEA (Table 3.3)
TRARR	M	Total reserves	Federal Reserve Board
NONBORTAF	M	Non-borrowed reserves of depository institutions	Federal Reserve Board
M1SL	M	M1 money stock	Federal Reserve Board

Table C.2: Data Series in the VAR.

Label	Description	Construction
GDPDEF	GDP deflator	GDPQ/GDP
NETTAX	Tax receipts net of transfers	GGFR+GGSR-GGAID-GGFTP-GGFINT-GGSINT
G_t	Real per-capita govt. spending	GGE/(P16*GDPDEF)
Y_t	Real per-capita GDP	GDPQ/P16
h_t	Per-capita hours worked	LBMNU/P16
c_t	Real per-capita consumption	(GCN+GCS)/(P16*GDPDEF)
i_t	Real per-capita investment	(GPI+GCD)/(P16*GDPDEF)
w_t	Real wages	LBCPU/GDPDEF
π_t	Inflation	Δ GDPDEF
r_t	Fed Funds rate	FYFF
T_t	Real net taxes	NETTAX/(P16*GDPDEF)
tr_t	Total reserves	TR
nbr_t	Non-borrowed reserves	NBR
m_t	M1 money supply	M1

Note: the VAR includes all series in log-levels, except for r_t, which is in levels.

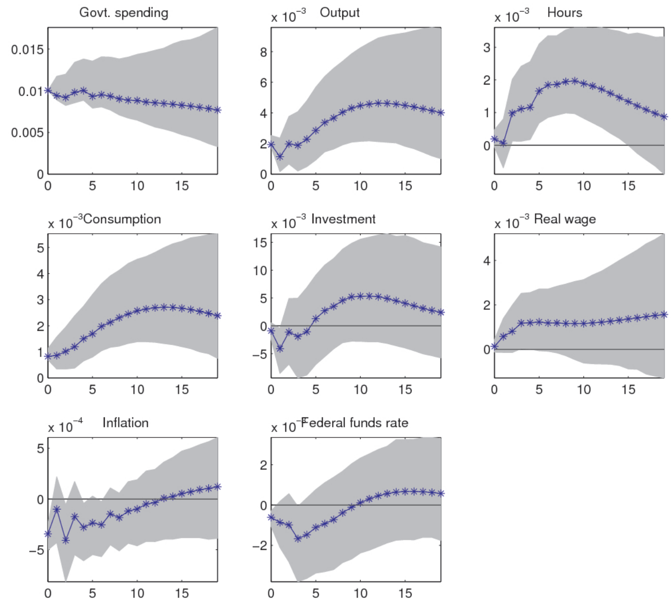


FIGURE C.1: Impulse Responses to the Government Spending Shock. The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

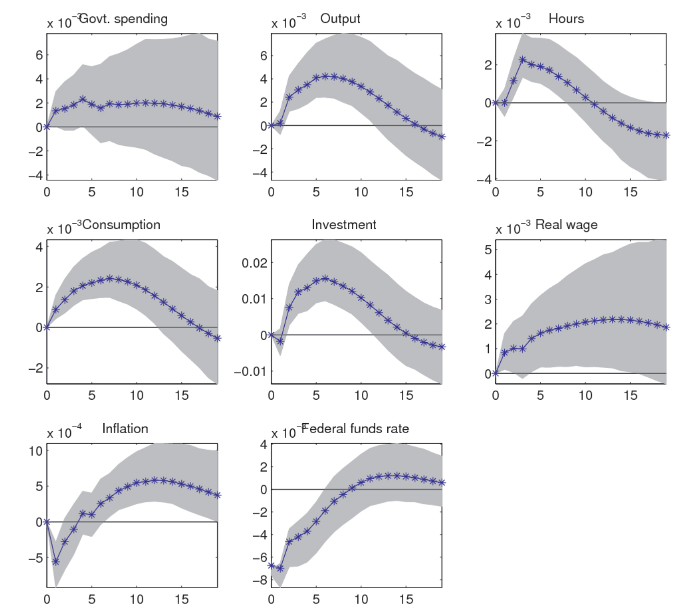


FIGURE C.2: Impulse Responses to the Monetary Policy Shock The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

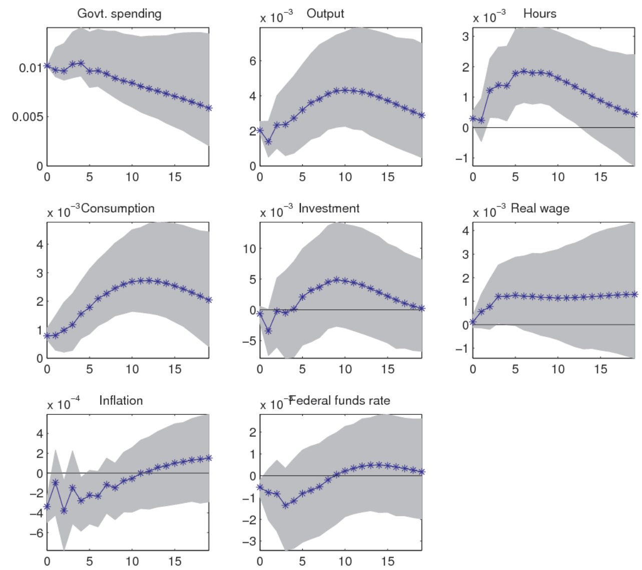


FIGURE C.3: Impulse Responses to a Government Spending Shock identified as $\varepsilon_{Perotti,t}$ in a VAR with monetary variables. The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

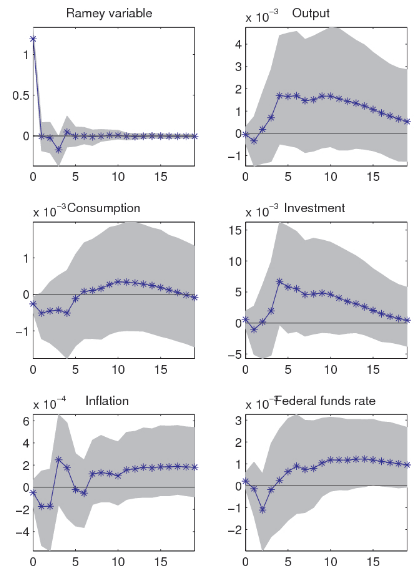


FIGURE C.4: Impulse Responses to a Government Spending Shock identified as $\varepsilon_{Ramey,t}$ in a VAR with monetary variables. The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

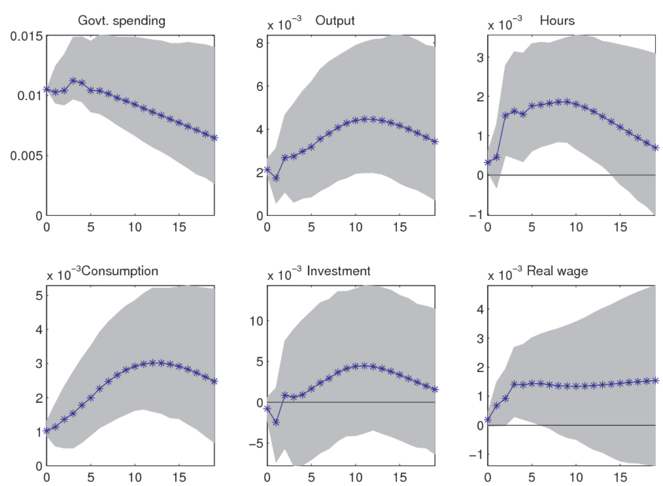


FIGURE C.5: Impulse Responses to a Government Spending Shock identified as $\varepsilon_{Perotti,t}$, in a VAR with no monetary variables. The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

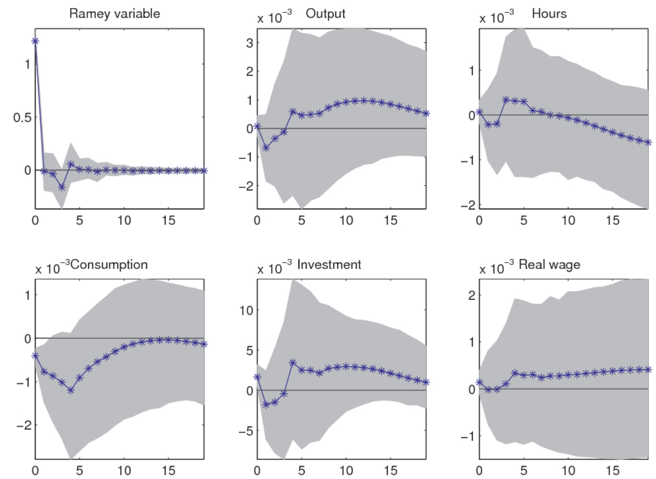


FIGURE C.6: Impulse Responses to a Government Spending Shock identified as $\varepsilon_{Ramey,t}$, in a VAR with no monetary variables. The shaded regions are 95% confidence bands obtained by Monte Carlo simulations.

Bibliography

Altig, D., L. Christiano, M. Eichenbaum, and J. Linde (2005): "Firm-Specific Capital, Nominal Rigidities and the Business Cycle," NBER Working Papers 11034, National Bureau of Economic Research.

Andreasen, M. M. (2008): "How to Maximize the Likelihood Function for a DSGE Model," CREATES Research Papers 2008-32, School of Economics and Management, University of Aarhus.

Aschauer, D. A. (1985): "Fiscal Policy and Aggregate Demand," *American Economic Review*, 75(1), 117–27.

Baily, M. N., and R. J. Gordon (1988): "The Productivity Slowdown, Measurement Issues, and the Explosion of Computer Power," *Brookings Papers on Economic Activity*, 19(1988-2), 347–432.

Barsky, R. B., M. S. Kimball, F. T. Juster, and M. D. Shapiro (1997): "Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study," *The Quarterly Journal of Economics*, 112(2), 537–79.

Baxter, M., and R. G. King (1993): "Fiscal Policy in General Equilibrium," *American Economic Review*, 83(3), 315–34.

Bilbiie, F. (2006): "Non-Separable Preferences, Fiscal Policy Puzzles and Inferior Goods," Mimeo.

Bils, M. (1987): "The Cyclical Behavior of Marginal Cost and Price," *American Economic Review*, 77(5), 838–55.

Blanchard, O., and R. Perotti (2002): "An Empirical Characterization Of The Dynamic Effects Of Changes In Government Spending And Taxes On Output," *The Quarterly Journal of Economics*, 117(4), 1329–1368.

Bouakez, H., and N. Rebei (2007): "Why does Private Consumption Rise After a Government Spending Shock?," *Canadian Journal of Economics*, 40(3), 954–979.

Braun, A. R. (1994): "Tax Disturbances and Real Economic Activity in the Postwar United States," *Journal of Monetary Economics*, 33(3), 441–462.

Burnside, C., M. Eichenbaum, and J. D. M. Fisher (2004): "Fiscal Shocks and Their Consequences," *Journal of Economic Theory*, 115(1), 89–117.

Chernozhukov, V., and H. Hong (2003): "An MCMC Approach to Classical Estimation," *Journal of Econometrics*, 115(2), 293–346.

Christiano, L., M. Eichenbaum, and S. Rebelo (2009): "When is the Government Spending Multiplier Large?," Manuscript, Northwestern University.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005): "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113(1), 1–45.

Chung, H., and E. Leeper (2007): "What Has Financed Government Debt?," CAEPR Working Papers 2007-015, Center for Applied Economics and Policy Research, Economics Department, Indiana University Bloomington.

Clarida, R., J. Gali, and M. Gertler (2000): "Monetary Policy Rules And Macroeconomic Stability: Evidence And Some Theory," *The Quarterly Journal of Economics*, 115(1), 147–180.

Coenen, G., and R. Straub (2005): "Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area," *International Finance*, 8(3), 435–470.

Cogan, J. F., T. Cwik, J. B. Taylor, and V. Wieland (2009): "New Keynesian versus Old Keynesian Government Spending Multipliers," NBER Working Papers 14782, National Bureau of Economic Research.

Comin, D., and M. Gertler (2006): "Medium-Term Business Cycles," *American Economic Review*, 96(3), 523–551.

Corsetti, G., A. Meier, and G. J. Muller (2009): "Fiscal Stimulus with Spending Reversals," CEPR Discussion Papers 7302, C.E.P.R. Discussion Papers.

Davig, T., and E. M. Leeper (2009): "Monetary-Fiscal Policy Interactions and Fiscal Stimulus," NBER Working Papers 15133, National Bureau of Economic Research.

Del-Negro, M., F. Schorfheide, F. Smets, and R. Wouters (2005): "On the Fit and Forecasting Performance of New-Keynesian models," Working Paper Series 491, European Central Bank.

Devereux, M. B., A. C. Head, and B. J. Lapham (1996): "Monopolistic Competition, Increasing Returns, and the Effects of Government Spending," *Journal of Money, Credit and Banking*, 28(2), 233–54.

Edelberg, W., M. Eichenbaum, and J. D. Fisher (1999): "Understanding the Effects of a Shock to Government Purchases," *Review of Economic Dynamics*, 2(1), 166–206.

Eggertsson, G. (2009): "Can Tax Cuts Deepen Recessions?," Manuscript, Federal Reserve Bank of New York.

Fatas, A., and I. Mihov (2001): "The Effects of Fiscal Policy on Consumption and Employment: Theory and Evidence," CEPR Discussion Papers 2760, C.E.P.R. Discussion Papers.

Favero, C., and F. Giavazzi (2007): "Debt and the Effects of Fiscal Policy," NBER Working Papers 12822, National Bureau of Economic Research.

Forni, L., L. Monteforte, and L. Sessa (2009): "The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro area," *Journal of Public Economics*, 93(3-4), 559–585.

Gali, J., M. Gertler, and J. D. Lopez-Salido (2007): "Markups, Gaps, and the Welfare Costs of Business Fluctuations," *The Review of Economics and Statistics*, 89(1), 44–59.

Gali, J., J. D. Lopez-Salido, and J. Valles (2007): "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association*, 5(1), 227–270.

Geweke, J. (1999): "Using Simulation Methods for Bayesian Econometric Models: Inference, Development,and Communication," *Econometric Reviews*, 18(1), 1–73.

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988): "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 78(3), 402–17.

Hall, A., A. Inoue, J. Nason, and B. Rossi (2007): "Information Criteria for Impulse Response Function Matching Estimation of DSGE Models," Discussion paper.

Hall, R. E. (1988): "Intertemporal Substitution in Consumption," *Journal of Political Economy*, 96(2), 339–57.

Joines, D. H. (1981): "Estimates of Effective Marginal Tax Rates on Factor Incomes," *Journal of Business*, 54(2), 191–226.

Jones, J. B. (2002): "Has Fiscal Policy Helped Stabilize the Postwar U.S. Economy?," *Journal of Monetary Economics*, 49(4), 709–746.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2009): "Investment Shocks and Business Cycles," NBER Working Papers 15570, National Bureau of Economic Research, Inc.

Leeper, E. M. (1991): "Equilibria Under 'Active' and 'Passive' Monetary and Fiscal Policies," *Journal of Monetary Economics*, 27(1), 129–147.

Leeper, E. M., M. Plante, and N. Traum (2009): "Dynamics of Fiscal Financing in the United States," NBER Working Papers 15160, National Bureau of Economic Research.

Leeper, E. M., T. B. Walker, and S.-C. S. Yang (2008): "Fiscal Foresight: Analytics and Econometrics," NBER Working Papers 14028, National Bureau of Economic Research.

——— (2009): "Fiscal Foresight and Information Flows," NBER Working Papers 14630, National Bureau of Economic Research.

Linnemann, L. (2006): "The Effect of Government Spending on Private Consumption: A Puzzle?," *Journal of Money, Credit and Banking*, 38(7), 1715–1735.

Linnemann, L., and A. Schabert (2003): "Fiscal Policy in the New Neoclassical Synthesis," *Journal of Money, Credit and Banking*, 35(6), 911–29.

Lopez-Salido, D., and P. Rabanal (2006): "Government Spending and Consumption-Hours Preferences," la Caixa Working Paper 2, la Caixa Working Papers.

McConnell, M. M., and G. Perez-Quiros (2000): "Output Fluctuations in the United States: What Has Changed since the Early 1980's?," *American Economic Review*, 90(5), 1464–1476.

McGrattan, E. R. (1994): "The Macroeconomic Effects of Distortionary Taxation," *Journal of Monetary Economics*, 33(3), 573–601.

Mendoza, E. G., A. Razin, and L. L. Tesar (1994): "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption," *Journal of Monetary Economics*, 34(3), 297–323.

Mertens, K., and M. O. Ravn (2008): "The Aggregate Effects of Anticipated and Unanticipated U.S. Tax Policy Shocks: Theory and Empirical Evidence," CEPR Discussion Papers 6673, C.E.P.R. Discussion Papers.

Monacelli, T., and R. Perotti (2008): "Fiscal Policy, Wealth Effects, and Markups," NBER Working Papers 14584, National Bureau of Economic Research, Inc.

Mountford, A., and H. Uhlig (2002): "What are the Effects of Fiscal Policy Shocks?," CEPR Discussion Papers 3338, C.E.P.R. Discussion Papers.

Ni, S. (1995): "An Empirical Analysis on the Substitutability between Private Consumption and Government Purchases," *Journal of Monetary Economics*, 36(3), 593–605.

Perotti, R. (2002): "Estimating the Effects of Fiscal Policy in OECD Countries," Economics Working Papers 015, European Network of Economic Policy Research Institutes.

——— (2007): "In Search of the Transmission Mechanism of Fiscal Policy," in *NBER Macroeconomics Annual 2007, Volume 22*.

Rabanal, P., and J. F. Rubio-Ramirez (2005): "Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach," *Journal of Monetary Economics*, 52(6), 1151–1166.

Ramey, V. (2008): "Identifying Government Spending Shocks: It's All in the Timing," Mimeo, UCSD.

Ramey, V. A., and M. D. Shapiro (1998): "Costly Capital Reallocation and the Effects of Government Spending," *Carnegie-Rochester Conference Series on Public Policy*, 48(1), 145–194.

Ravn, M., S. Schmitt-Grohe, and M. Uribe (2006): "Deep Habits," *Review of Economic Studies*, 73(1), 195–218.

——— (2007): "Explaining the Effects of Government Spending Shocks on Consumption and the Real Exchange Rate," NBER Working Papers 13328, National Bureau of Economic Research, Inc.

Ravn, M. O., S. Schmitt-Grohe, M. Uribe, and L. Uuskla (2009): "Deep Habits and the Dynamic Effects of Monetary Policy Shocks," CEPR Discussion Papers 7128, C.E.P.R. Discussion Papers.

Romer, C., and J. Bernstein (2009): "The Job Impact of the American Recovery and Reinvestment Plan," January 9, 2009, Obama Transition Team.

Romer, C. D., and D. H. Romer (1989): "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz," in *NBER Macroeconomics Annual 1989, Volume 4*, NBER Chapters, pp. 121–184. National Bureau of Economic Research, Inc.

——— (2004): "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94(4), 1055–1084.

——— (2007): "The Macroeconomic Effects of Tax Changes: Estimates Based on a New Measure of Fiscal Shocks," NBER Working Papers 13264, National Bureau of Economic Research.

Rotemberg, J. J. (1982): "Sticky Prices in the United States," *Journal of Political Economy*, 90(6), 1187–1211.

Rotemberg, J. J., and M. Woodford (1992): "Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity," *Journal of Political Economy*, 100(6), 1153–1207.

Rotemberg, J. J., and M. Woodford (1999): "The Cyclical Behavior of Prices and Costs," in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford.

Schmitt-Grohe, S., and M. Uribe (2004): "Solving Dynamic General Equilibrium Models using a Second-Order Approximation to the Policy Function," *Journal of Economic Dynamics and Control*, 28(4), 755–775.

——— (2005): "Optimal Fiscal and Monetary Policy in a Medium-Scale Macroeconomic Model: Expanded Version," NBER Working Papers 11417, National Bureau of Economic Research.

——— (2006): "Comparing Two Variants of Calvo-Type Wage Stickiness," NBER Working Papers 12740, National Bureau of Economic Research.

——— (2007): "Optimal Simple and Implementable Monetary and Fiscal Rules," *Journal of Monetary Economics*, 54(6), 1702–1725.

Smets, F., and R. Wouters (2007): "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97(3), 586–606.

Stock, J. H., and M. W. Watson (1999): "Business cycle fluctuations in us macroeconomic time series," vol. 1 of *Handbook of Macroeconomics*, chap. 1, pp. 3–64. Elsevier.

——— (2003): "Has the Business Cycle Changed and Why?," in *NBER Macroeconomics Annual 2002, Volume 17*, NBER Chapters, pp. 159–230. National Bureau of Economic Research, Inc.

Uhlig, H. (2009): "Some Fiscal Calculus," Manuscript, University of Chicago.

Yang, S.-C. S. (2007): "Tentative evidence of tax foresight," *Economics Letters*, 96(1), 30–37.

Biography

Sarah Zubairy was born in Albuquerque, NM on February 27, 1983. She graduated with a Bachelor's degree majoring in Mathematics with honors, and with minors in Economics and Physics, in 2004 from the University of Rochester, Rochester NY. She received her Masters of Arts in Economics in 2005 from Duke University and will be graduating with a doctorate degree in Economics in Spring 2010. While at Duke, she was a Dissertation Intern at the Federal Reserve Bank of St. Louis, for Summer 2007, and was a Committee on the Status of Women in the Economics Profession (CSWEP) Summer Fellow at the Federal Reserve Bank of New York, during Summer 2009. In addition, she won the Katherine Stern Dissertation fellowship for the academic year 2009-2010.