Spending Reversals and Fiscal Multipliers under an Interest Rate Peg

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Abstract

This paper revisits the sizes of fiscal multipliers under a pegged nominal interest rate. Empirical evidence shows that a positive government spending shock triggers a buildup of public debt and is followed by a spending reversal in the period that the U.S. nominal interest rate was near zero or the monetary policy was passive. Theoretical analysis illustrates that the short-run impact of government spending shocks depend on expectations about future policy adjustment. If the monetary-fiscal expansion is associated with an anticipated spending reversal, private consumption response can be negative and the output multiplier is not necessarily greater than unity.

JEL Classification: E32, E62, H30, H31

Keywords: government spending, spending reversals, zero lower bound, fiscal multiplier, interest rate peg

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1 Introduction

There is a growing literature on the size of government spending multiplier under a pegged nominal interest rate, especially pegged at the zero lower bound (ZLB). Eggertsson and Woodford (2003), Eggertsson (2010), Woodford (2011) and Christiano et al. (2011) argue that a large government spending multiplier is especially plausible when the zero lower bound on the nominal interest rate binds. Kim (2003) and Davig and Leeper (2011) show that, under passive monetary policy and active fiscal policy, government spending raises both output and consumption. On the other hand, Carlstrom et al. (forthcoming) demonstrates that if the monetary-fiscal expansion is for a fixed duration instead of a stochastic duration, the output multiplier can be much smaller. Erceg and Lindé (2014) argues that although the multiplier is high for small increases in government spending in an endogenous liquidity trap, it may decrease substantially at higher spending levels. These studies have pointed out that there is an expected inflation channel for government spending: a fiscal expansion drives up the current and expected future marginal cost, which leads to an increase in expected inflation and hence reduces the expected real interest rate. The reduction in the real rate leads households to shift consumption toward the present. This effect can be especially strong if the nominal interest rate is pegged at a constant level. According to this channel, a large output multiplier requires a large responses of expected inflation to a fiscal expansion. Yet, Dupor and Li (forthcoming) demonstrates that this large inflation response is inconsistent with empirical evidence from the Federal Reserve's passive policy period as well as the 2009 Recovery Act period. Moreover, using U.S. data, Ramey and Zubairy (2014) finds no robust evidence in support of the New Keynesian model's implication that government spending multipliers are greater when monetary policy is constrained. Crafts and Mills (2012) finds multipliers are smaller than one even when nominal interest rates were close to zero for the U.K..

From another aspect, many studies explore the possibility of fiscal multipliers that depend on debt-to-GDP ratio. Empirically, Perotti (1999), Ilzetzki et al. (2013) and Nickel and Tudyka (forthcoming) find that the impact of government spending shocks exhibit strong non-linear behavior which depends on public indebtedness. Theoretically, Corsetti et al. (2012) points out that most existing studies have imposed a restrictive approach to describe medium-term spending dynamics. Specifically, they usually model an exogenous government spending, ignoring the potential endogenous response of spending to the state of public debt. Corsetti et al. (2012) argues that modeling an endogenous dynamics of government spending significantly changes the short-term effects of fiscal policy. In addition, Leeper et al. (2010) provides evidence that multiple fiscal instruments including government spending are used to stabilize debt by estimating a dynamic stochastic general equilibrium (DSGE) model. Yet, papers that illustrate the importance of public indebtedness on fiscal multipliers have ignored the role of monetary-fiscal policy interactions, especially the influence of an interest rate peg.

The contribution of this paper is to demonstrate how the endogenous government spending dynamics alter the impacts of spending shocks under an interest rate peg. In the first section of our analysis, we revisit the evidence on the impacts of government expenditure shocks for the period when the U.S. monetary policy was near zero lower bound or passive. We use U.S. quarterly data for the period 1939 to 1979 and identify government spending shocks with Blanchard and Perotti (2002) and Ramey (2011) approaches in a VAR, respectively. Some key results are remarkable and robust. First, we find that a positive government expenditure shock leads to a sizable buildup of government debt, followed by a decrease of public expenditure below trend several quarters later. This result can also be found in Corsetti et al. (2012) where they estimate a VAR model for the post-Volcker period. Second, inflation does not exhibit a large response to a government spending shock. This result is consistent with the empirical finding in Dupor and Li (forthcoming). Third, nondurable and durable consumption respond negatively or insignificantly to a positive shock in government spending.

Evidence of such buildup of public debt and spending reversals motivates us to investigate how incorporating endogenous response of spending to public debt alters the effects of government spending shocks, especially when the monetary policy is passive. Specifically, we study how anticipated spending reversals affect the transmission of government spending shocks under a pegged nominal interest rate. For this purpose, we incorporate spending reversals in a standard New Keynesian model where prices are sticky. The main result is that, with spending reversals, a positive shock in government spending does not necessarily generate a large inflation response, nor a positive consumption response, even when the nominal interest rate is pegged. Intuitively, the private sector expects government spending reversals to reduce future inflation. This reduction in expected inflation, together with a pegged nominal interest rates, will lead to an increase in long-run real interest rate, discouraging current private consumption. As a result, the output multiplier can be smaller than one even if the nominal rate is constant.

We also show that our result remains after controlling the wealth effects. Note that spending reversals weaken the hike of tax burden on households resulting from the forthright increase in government spending. In another policy experiment, we modify the size of the shock in an economy without spending reversals, such that the present value of the overall government spending expansion equals to the one in the baseline model. Through this method, we control the size of the overall wealth effects and show that our main result does not change.

The remainder of this paper is organized as follows. Section 2 presents empirical evidence. Section 3 outlines an analytical model and illustrates the mechanism through which spending reversals alter the short-run effects of fiscal expansions. Section 4 presents the full model with endogenous spending reversals and the simulation results. Section 5 concludes.

2 Empirical evidence

In this section, we investigate the VAR evidence on the impacts of government spending shocks under a pegged nominal rate or passive monetary policy. We focus on the dynamics of some key fiscal variables including public debt and government expenditure, as well as inflation and private consumption. We use two distinct identification strategies proposed by Blanchard and Perotti (2002) and Ramey (2011), respectively. Our main findings are robust across these two identification schemes and several VAR specifications.

2.1 Empirical specification

Our benchmark VAR consists of logs of real per capita government spending and GDP, 3 month T-bill rate, the Barro and Redlick (2011) average tax rate, the public debt to GDP ratio, a linear and a quadratic trend; for the Ramey (2011) approach we also include a measure of defense new shocks. The model is estimated recursively using U.S. quarterly data from 1939: Q1 to 1979:Q2. The sample period choice is based on two reasons. First, based on the behavior of 3 month T-bill rate, Ramey and Zubairy (2014) define ZLB times to be 1932: Q2 - 1951: Q1 and 2008: Q4 - 2013: Q4. Moreover, Clarida et al. (2000), among others, provide evidence that the U.S. post war monetary policy was passive before the Volcker-Greenspan era. Thus, 1951: Q2 - 1979: Q2 can be defined as passive monetary period. Second, our choice of sample period is also constrained by data availability. As the dynamics of public debt is in the central of our analysis, we want to have the debt-to-GDP ratio in our benchmark specification, which shorten our sample period to 1939:Q1-1979:Q2.

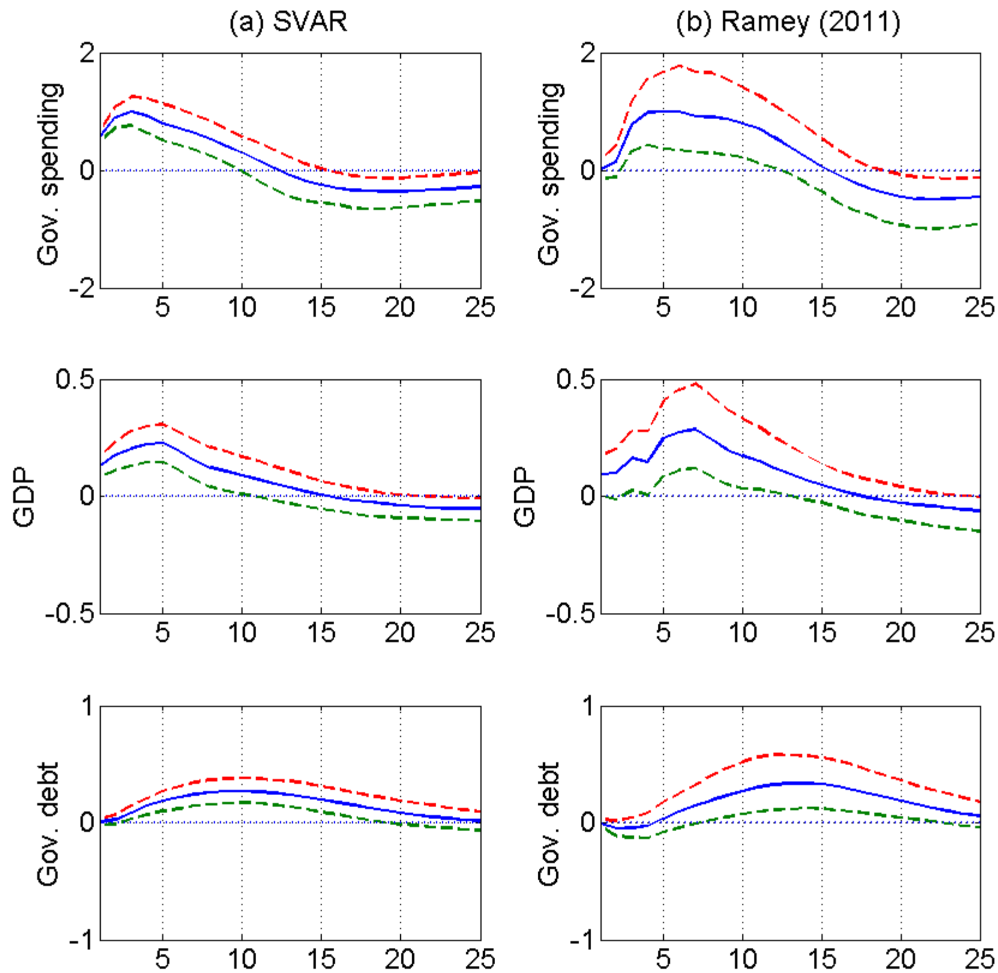
We identify government spending shocks by two distinct methods. First, following Blanchard and Perotti (2002), government expenditure is assumed to be not affected by contemporaneous innovations of other economic variables. Under such assumption, we can identify government spending shocks using Choleski decomposition in which government spending is ordered first in the VAR. The second approach is proposed by Ramey (2011) who constructs a U.S. defense news series and uses it as an approximation to the changes in government spending expectation. The defense news variable is ordered first in her VAR and the impulse response functions are computed by recursive estimation.

In the following subsection, we provide results obtained from both identification methods. In each approach we normalize the log change of government spending to be unity at its peak.

2.2 The benchmark results

Figure 1 shows the benchmark results under both identification schemes. In all figures, horizontal axes indicate quarters after the shock; vertical axes indicate percentage deviation from steady state. The solid line represents the point estimate, and the dashed lines represent a 90% confidence interval from bootstrap sampling based on 500 repetitions. The left column displays the impulse responses from the Blanchard and Perotti (2002), and the right column is from the Ramey (2011) defense news approach.

Figure 1: Effects of Government Spending Shock: Baseline Specification



The top panels display the response of government spending. Under the SVAR approach, government spending dumps on impact, while under the defense news approach, it increases gradually. In both cases, government spending increases persistently in initial quarters, but over time this variable declines below its trend. In other words, there is a reversal follows a positive government spending shock. Corsetti et al. (2012) uses the post-Volcker period data and finds similar results. Output, displayed in the middle panels, rises in initial periods and falls below trend about 4 years later. The bottom panels display the dynamics of public debt-to-GDP ratio. For the SVAR approach, as government spending jumps after the shock, public debt increases significantly and persistently. Under the defense news approach, its response is insignificant in the first year but rises significantly after the initial year, which is because government expenditure increases gradually under this approach. This result implies that the rise of government expenditure is at least partially financed by government debt. Moreover, from both approaches, government spending reversal happens one or two quarters after government debt reaching its peak, which implies that government spending reacts to the level of public debt. This is consistent with Leeper et al. (2010) who use U.S. data to estimate a DSGE model and find that government spending is one of the policy instruments to stabilize public debt.

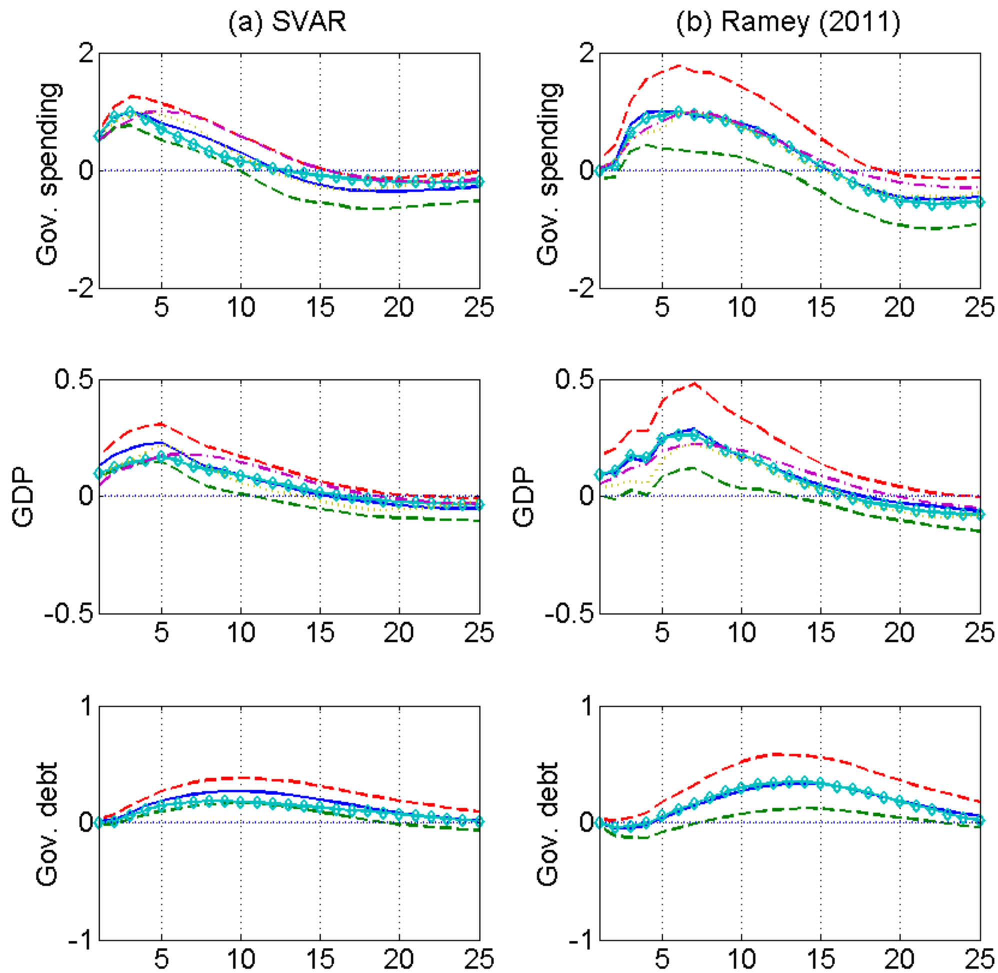
2.2 Robustness

In this sensitivity analysis part, we consider a few variations to the benchmark specification of the VAR model. The robustness checks we implemented are as follows. First, we drop the quadratic trend but keep the linear trend. Second, we drop the variable of public debt-to-GDP ratio. Since we have more data for other variables, we extend our sample period to 1934: Q1 - 1979: Q2.[1] Third, we consider only the period when the nominal interest rate was near zero (1934: Q1-1951:Q1). We have to drop the public debt variable in this case because otherwise the sample period will be too short.

Figure 2 displays the point estimates of the impulse response functions for alternative specifications as well as the 90% confidence bound from the benchmark specification. For all of these specifications, the results remain well in line with our benchmark one.

[1] The sample period is still constrained by the data availability of 3 month T-bill rate.

Figure 2: Effects of Government Spending Shock: Robustness Check



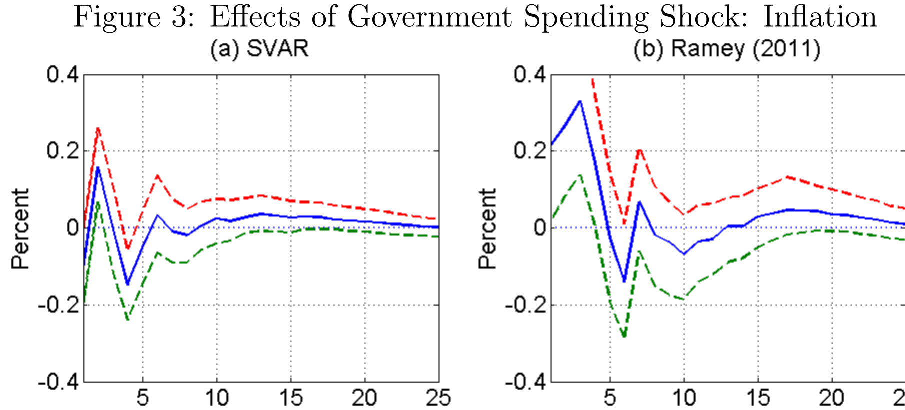
The solid lines are the benchmark results and dashed lines are the 90% confidence interval of the benchmark result. The diamond lines are the IRFs of the specification where we drop the quadratic trend but keep the linear trend. The dot-dashed lines are the IRFs from the specification where we drop the variable of public debt-to-GDP ratio. The dotted lines are the IRFs of the model where we consider only the period when the nominal interest rate was near zero (1934: Q1-1951:Q1).

2.3 Inflation responses

Dupor and Li (forthcoming) show that a sticky price model calibrated to have a large output multiplier requires a large expected inflation response to an increase in government spending. Moreover, they show that this large response is inconsistent with the empirical evidence in the postwar U.S. economy: i) there is no significant increase in inflation in the structural vector autoregression evidence from the Federal Reserve's passive policy period; ii) multiple expected inflation measures during the 2009 Recovery Act period exposed only insignificant responses. In this subsection, we investigate a similar question: whether the inflation exhibits a large response to a positive shock of government spending when the U.S. nominal interest rate was near zero or the monetary policy was passive. Specifically, we add an inflation measure to our baseline VAR model and compute the impulse response function under the two identification schemes.

Figure 3 shows the annualized response of inflation. Under SVAR approach, the response of inflation is not significant. Under the defense news approach, inflation rises in the first year but the size is very small.[2] After the impact periods, inflation does not exhibits a significant response. This result is consistent with the findings in Dupor and Li (forthcoming).

Figure 3: Effects of Government Spending Shock: Inflation



2.4 Consumption Responses

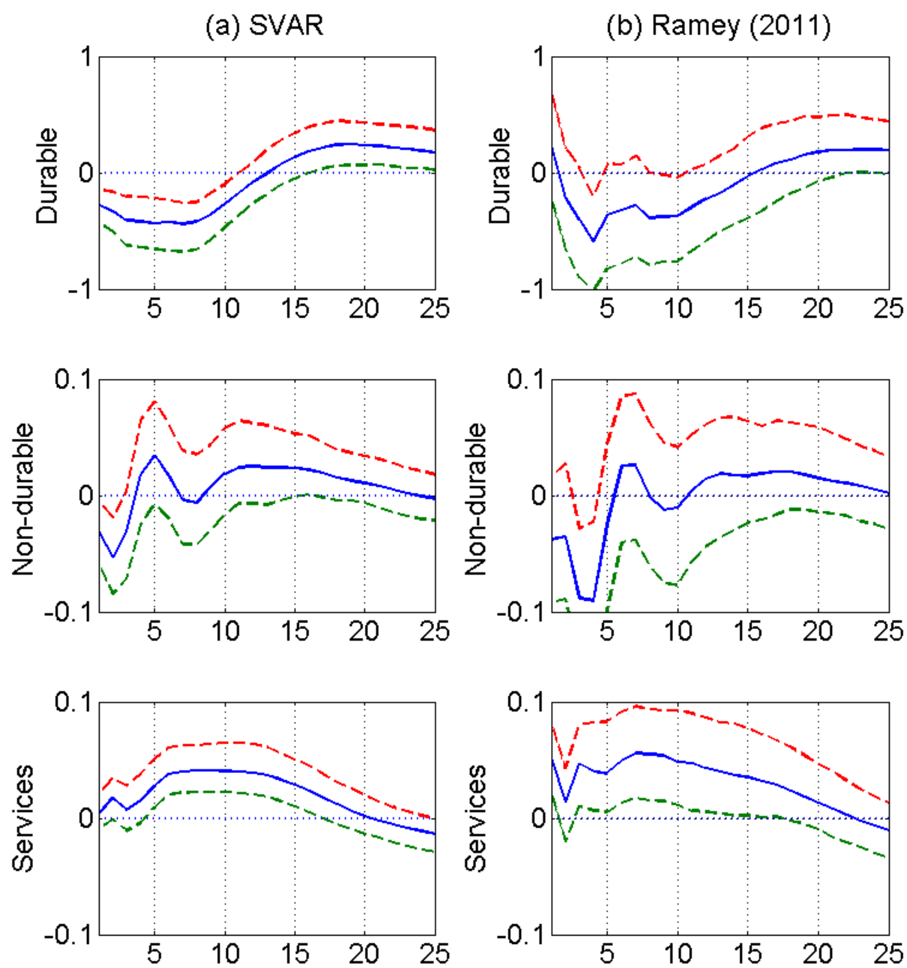
In this subsection, we examine how different components of private consumption respond to government spending shocks. To do this, we rotate in private durable con-

[2]Remember, the peak response of government spending is normalized to one.

sumption, non-durable consumption and services consumption to our baseline VAR model, respectively. Figure 4 shows the computed impulse response functions under the two identification schemes. Consumer durable purchases decline significantly and revert back overtime under the SVAR approach, while they increase insignificantly on impact then fall under the defense news approach. The nondurable consumption falls significantly in initial periods under both identification regimes. Total consumption (not shown) also declines significantly in response to government spending shocks. In contrast, services consumption rises significantly and persistently. It stays above trend even after output has gone below trend. Thus, the responses of total consumption, consumer durable and nondurable goods contradict the prediction of standard New Keynesian sticky price model, while the response of services consumption supports the theory.

In sum, in the U.S. near zero bound or passive monetary policy period, a positive shock of government spending prompts a considerable buildup of public debt and is followed by a spending reversal. This result is robust across alternative identification strategies and model specifications. Moreover, empirical findings suggest that there is no large inflation response to a government spending shock under passive or constrained monetary policy. In addition, except for consumption expenditure of services, other components of private consumption fall, contradicting the prediction of standard New Keynesian sticky price model. Our understanding of these empirical results is the following. First, public debt plays an important role in financing the increase of government expenditure. Second, spending cut is a policy tool to stabilize public debt. Therefore, in our theoretical study, we explicitly taking into account the endogenous dynamics of fiscal variables, especially public debt and government spending. In other words, these empirical findings motivate us to explore the role of government spending reversals in a monetary-fiscal expansion where the nominal interest rate is pegged.

Figure 4: Effects of Government Spending Shock: Private Consumption



3 An analytical model

In this section, we use a simple analytical model to explore how spending reversals may affect the effects of government spending shocks. For simplicity, we abstract from the endogenous spending dynamics but use an exogenous government spending path. In the next section, we will construct our full model with endogenous government spending dynamics.

I consider the following log-linearized sticky price model[3]:

$$i_t - E_t\pi_{t+1} = \sigma(E_t c_{t+1} - c_t) \tag{1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa(\sigma c_t + \nu y_t) \tag{2}$$

$$y_t = (1-s)c_t + s g_t \tag{3}$$

where y_t, c_t, π_t, i_t and g_t are the log deviations of output, consumption, inflation, the nominal interest rate and government expenditure from steady-state values, respectively. The constant $s = \frac{G_{ss}}{Y_{ss}}$ is the steady state government spending and output ratio. For simplicity, I assume the steady state net inflation is zero. I consider a policy experiment in which the central bank announces an interest peg $i_t = 0$ for a deterministic duration T. Government spending is set above steady state $g_t = \bar{g} > 0$ for $t = 1, ..., \frac{T}{2}$ and below steady state $g_t = \frac{2-T}{T}\bar{g} < 0$ for $t = \frac{T}{2} + 1, ..., T$.[4] Hence, government expenditure increases by $\bar{g}$ in total during this period. After the interest rate peg period, the nominal interest rate is set according to a typical Taylor rule:

$$i_t = \phi_\pi \pi_t + \phi_y y_t \tag{4}$$

where $\phi_\pi > 1$ and $\phi_y \geq 0$. As there are no endogenous state variables nor exogenous shocks after the interest rate peg period, the unique equilibrium in the subsequent periods is given by $\pi_t = y_t = c_t = 0$. Plugging $i_t = 0$ and combining equations (1), (2), and (3), the equilibrium in the interest rate peg period can by solved by the following difference equation:

[3]The model set up and notation follow Carlstrom et al. (forthcoming).
[4]I use an even number for T.

$$\beta\sigma E_t\pi_{t+2} - \{\kappa[\sigma + \nu(1-s)] + \sigma(1+\beta)\}E_t\pi_{t+1} + \sigma\pi_t + \sigma\kappa\nu s(E_t g_{t+1} - g_t) = 0 \quad (5)$$

with two terminal conditions:

$$\pi_T = \kappa\nu s g_T \quad (6)$$

and

$$\pi_{T-1} = \kappa\nu s g_{T-1} + \{\kappa[1 + \frac{\nu}{\sigma}(1-s)] + \beta\}\pi_T \quad (7)$$

The perfect foresight solution of this model is:

$$\pi_t = \kappa\nu s \sum_{i=0}^{T-t} C_i g_{t+i} \text{ for t=1,...,T} \quad (8)$$

$$c_t = \frac{\nu s}{[\sigma + \nu(1-s)]} \sum_{i=0}^{T-t-1} (C_{i+1} - \beta C_i) g_{t+i+1} \text{ for t=1,...,T} \quad (9)$$

where,

$$C_0 = 1,\ C_1 = \kappa[1 + \frac{\nu}{\sigma}(1-s)] + \beta$$

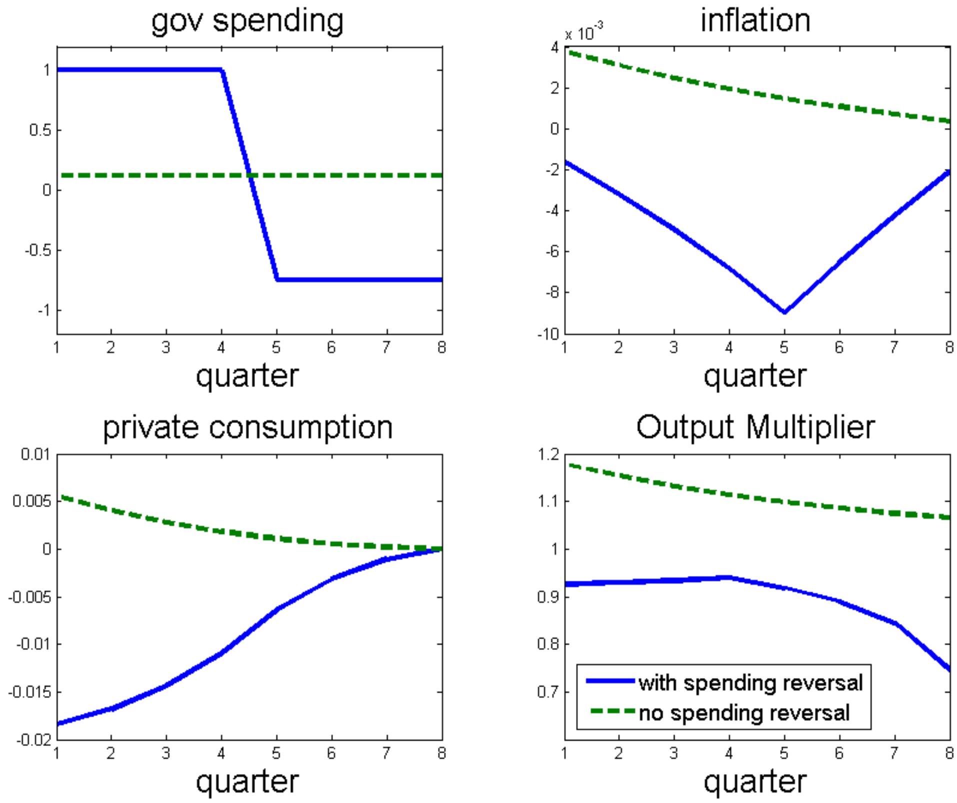
$$C_i = C_{i-1}(\kappa[1 + \frac{\nu}{\sigma}(1-s)] + \beta + 1) - \beta C_{i-2},\ \text{for i =1,...,T-1}$$

From Equation (8) and (9), we find that inflation and private consumption depend on not only current government expenditure but also the anticipated dynamics of government spending. This result plays a central role in our analysis in the next subsection and our full model.

3.1 Impulse responses and fiscal multipliers

The baseline parameter values are set as: $\beta = 0.99$, $\kappa = 0.028$, $\sigma = 2$, $\nu = 0.5$, $s = 0.2$ and $T = 8$. Figure 5 displays the path of government spending and, respectively, the responses of inflation, private consumption and output multiplier in the benchmark experiment. For comparison, I also plot the responses in an experiment without spending reversal. In this alternative experiment, the size of government spending increase is set to $g_t = \frac{\bar{g}}{T}$, for $t = 1, ..., T$, such that total increases in government spending have the same size in these two experiments. Current and future inflation drop in the experiment with a spending reversal while they increase in the comparison experiment. The two experiments also imply markedly different responses of private consumption. The reversal case features a reduction in private consumption, while the comparison case has an increase in consumption. Without spending reversals, an increase in government spending drives up the current and future real marginal costs. If a firm may be unable to adjust its price for several periods, the increase in its expected real marginal costs leads the firm to increase its price today. This shift up will generate inflation which, together with a pegged nominal interest rate, reduces the expected real interest rate. The real rate reduction leads households to shift private consumption toward today, which implies a large output multiplier. On the other hand, the spending reversal in our benchmark experiment drives down future real marginal costs and future inflation. There are two drivers in initial periods: i) the increase in government spending drives up the real marginal costs, which leads to upward pressure on current inflation; ii) the decrease in future inflation leads to downward pressure on current inflation. Therefore, the inflation responses in the initial periods depend on the sizes of these driving forces. If the downward pressure created by the reduction in future inflation dominates the other, the initial inflation would fall. As the nominal interest rate is pegged at zero the real interest rate would rise, which shifts consumption toward the future.

Figure 5: Responses of inflation, private consumption and output



I define the impact and cumulative output multipliers as, respectively:

$$\frac{\Delta Y_1}{\Delta G_1} \equiv \frac{1}{s}\frac{dy_1}{dg_1} \tag{10}$$

$$\frac{\Delta Y}{\Delta G} \equiv \frac{1}{s}\frac{\sum_{t=1}^{T} dy_t}{\sum_{t=1}^{T} dg_t} \tag{11}$$

Table 1 displays the fiscal multipliers. This result shows that the output multipliers are larger than unity in an economy without spending reversals, while they are not necessarily greater than one in an economy with spending reversals, even if the nominal interest rate is pegged at zero.

Table 1: Fiscal Multipliers

	Output Multipliers in:	
	reversal spending	non-reversal spending
impact	0.9263	1.1783
cumulative	0.7154	1.0640

4 Endogenous spending reversals in a New Keynesian Economy

Our full model is a standard New Keynesian model with Calvo-type sticky price. Unproductive government expenditure is financed by lump-sum taxes and one-period nominal government bonds. Moreover, the time path of government spending and taxes is determined by feedback rules where real public debt needs to be stabilized.

4.1 Model

4.1.1 Households

The representative household chooses consumption, C_t, nominal government bonds, B_{t+1}, investment, I_t, and supplies labor, N_t, to maximize life time utility:

$$\sum_{t=0}^{\infty} \beta^t E_0[\frac{{C_t}^{1-\sigma}}{1-\sigma} - \Psi_N \frac{N_t^{1+\theta}}{1+\theta}]$$

subject to

$$P_t(C_t + I_t) + \frac{B_{t+1}}{R_t} = W_t N_t + B_t + P_t r_t^k K_t - T_t + \Phi_t$$

and

$$K_{t+1} = I_t + (1-\delta)K_t - \frac{\sigma_I}{2}(\frac{I_t}{K_t} - \delta)^2 K_t$$

and the transversality condition

$$E_0 lim_{t\to\infty}\frac{B_{t+1}}{R_0 R_1...R_t} \geq 0$$

with $0 < \beta < 1$, $\sigma > 0$, $\theta > 0$, $\Psi_N > 0$ and $0 < \delta < 1$, where P_t is price level of final goods; W_t denotes nominal wages; R_t is the gross risk-free nominal interest rate between $t-1$ and t; K_t is capital and r_t^k is the real return of capital; T_t represents the nominal lump-sum taxes and Φ_t is the nominal profit from intermediate good firms. Following Christiano et al. (2011), the parameter $\sigma_I > 0$ affects the magnitude of capital adjustment costs.

4.1.2 Firms

The final good is produced by competitive firms using the following production function

$$Y_t = [\int_0^1 y_t(i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}, \epsilon > 1$$

where $y_{1t}(i),\ i \in [0,1]$, denotes intermediate good i. $\epsilon > 1$ is the demand elasticity of differentiated goods.

Demand function comes from profit maximization:

$$y_t(i) = (\frac{P_t(i)}{P_t})^{-\epsilon} Y_t$$

where, $P_t(i)$ represents the price of intermediate good i and P_t is the price of the homogeneous final good.

The intermediate good $y_{1t}(i)$, is produced by a monopolist using the following production technology:

$$y_t(i) = K_t(i)^\alpha N_t(i)^{1-\alpha}$$

where $N_t(i)$ and $K_t(i)$ denote the ith monopolist's labor and capital input, respectively. There is no entry or exit into the production and the monopolist is subject to the Calvo-type price-setting. In each period, an intermediate firm has probability $1 - a$ to optimize its price, $P_t(i)$, otherwise, the firm sets

$$P_t(i) = P_{t-1}(i)$$

The discounted profits of the ith intermediate production firm are given by

$$E_t \sum_{j=0}^{\infty} \beta^{t+j} \lambda_{t+j} [P_{t+j}(i) y_{t+j}(i) - (1 - v)(W_{t+j} N_{t+j}(i) + P_{t+j} r^k_{t+j} K_{t+j}(i))]$$

as in Christiano et al. (2011), $v = \frac{1}{\epsilon}$ denotes an employment subsidy that corrects the inefficiency created by the presence of monopoly power, in steady state. λ_{t+j} is the multiplier on the household budget constraint.

Firm i maximizes its discounted profits subject to the Calvo-type price-setting friction, the demand function, and the production function.

4.1.3 Government

As long as the nominal interest rate is not pegged, the central bank determines the nominal interest rate by a Taylor rule

$$R_t = R_{t-1}^{\rho_r} \pi_t^{\phi_1(1-\rho_r)/\beta} (Y_t)^{\phi_2(1-\rho_r)/\beta}$$

where $\rho_r \in (0,1)$, $\phi_1 > 1$ and $\phi_2 \geq 0$; $\pi_t = \frac{P_t}{P_{t-1}}$.

Government spending is financed by lump-sum taxes and one-period nominal bond. The government budget constraint is

$$\frac{D_{t+1}}{R_t} = D_t + P_t G_t - T_t$$

Following Corsetti et al. (2012), real government spending and real lump-sum taxes are influenced by real government debt and determined by the following feedback rules

$$G_t = (1-\phi_{gg})G_{ss} + \phi_{gg}G_{t-1} + \phi_{gd}\frac{D_t}{P_{t-1}} + \varepsilon_t$$

$$T_t^r = \frac{T_t}{P_t} = G_{ss}^{1-\phi_{tg}} G_t^{\phi_{tg}} + \phi_{td}\frac{D_t}{P_{t-1}}$$

where G_t is real government spending and G_{ss} is its steady state level; D_t is one-period nominal government debt; T_t is nominal lump-sum taxes and T_t^r is the real value of taxes; ε_t is an exogenous shock to government spending. In equilibrium, we have $D_t = B_t$. The ϕ-parameters represent the endogenous responsiveness of government expenditure and taxes to spending and debt. We assume $\phi_{gd} \leq 0$ and $\phi_{td} \geq 0$ such that the government will cut its spending and increase taxes in response to a buildup of public debt.

4.1.4 Equilibrium

The resource constraint for the economy is

$$C_t + I_t + G_t = Y_t$$

A "monetary equilibrium" is a collection of stochastic processes

$$\{C_t, N_t, W_t, P_t, Y_t, R_t, r_t^k, P_t(i), y_t(i), N_t(i), B_t, I_t, K_{t+1}, \pi_t, G_t, D_t, T_t\}$$

such that for given $\{\varepsilon_t\}$ the household and firm problems are satisfied, the monetary and fiscal policy rules are satisfied, markets clear, and the resource constraints are satisfied.

4.2 Policy experiment and the effects of government spending shocks

In this section I consider a modest change to the policy experiment. The duration of nominal interest rate peg is no longer deterministic, but instead stochastic. The rationale of this stochastic interest rate peg is that the interest rate peg is not an intended policy by the central bank, but is a policy response to an exogenous shock. For example, Eggertsson (2010) uses a discount rate shock to drives down the shadow Taylor rule rate to be below zero. As the exogenous shock has the stochastic feature, it is more realistic to model a stochastic interest rate peg instead of a deterministic one. The fiscal policy expansion, however, is still deterministic. The deterministic fiscal expansion is more reasonable than a stochastic one, since a fiscal stimulus is often designed with certain schedule. In this experiment, at the first quarter when nominal interest rate is pegged, the exogenous component of government spending, ε_t, increases by 1% of the steady state government spending.

4.2.1 Parameterization

Table 2 displays the parameter choices. Discount factor β is set to 0.99. Coefficient of risk aversion and the inverse of Frisch elasticity are set to 1. Probability of price fixed is assumed to be 0.845, implying the slope of the Phillips curve to be 0.03 a value widely used in the literature[5]. We assume capital share and capital depreciation rate to be 0.36 and 0.02, respectively. Following the same criteria in Christiano et al. (2011), σ_I is set to 17. For Taylor rule, we use $\rho_r = 0.9$, $\phi_1 = 1.5$ and $\phi_2 = 0$, which are all within the range of the literature. Regarding fiscal policy, we assume that changes in government expenditure are financed in equal part by lump-sum taxes and government debt, $\phi_{tg} = 0.5$. This parameter affects the sizes of public debt buildup and the spending reversal. ϕ_{gg} is set to 0.9 capturing government spending persistence. The steady state ratios of government spending, private consumption and investment to GDP are set to 0.2, 0.51 and 0.29, respectively. These values are the same as in Christiano et al. (2011). The probability of staying in the pegged interest rate state is set to 0.9. In standard New Keynesian models, there is an upper bound of this probability to ensure a unique equilibrium and the output multiplier would be greater as this probability approaches its upper bound. Finally, as in Corsetti et al. (2012), we set $\phi_{gd} = -0.02$ and $\phi_{td} = 0.02$ such that a higher public debt implies lower government spending and higher taxes.

[5]See, for example, Christiano et al. (2011).

Table 2: Baseline parameter values

Parameter		Value
Discount factor	β	0.99
Coefficient of risk aversion	σ	1.0
Inverse of Frisch elasticity	θ	1.0
Probability of price fixed	a	0.845
Capital share	α	0.36
Capital depreciation rate	δ	0.02
Capital adjustment costs	σ_I	17
Monetary policy: smoothing	ρ_r	0.9
Monetary policy: to inflation	ϕ_1	1.5
Monetary policy: to output gap	ϕ_2	0.0
Spending autocorrelation	ϕ_{gg}	0.9
Debt sensitivity of spending	ϕ_{gd}	-0.02
Debt sensitivity of taxes	ϕ_{td}	0.02
Tax finance	ϕ_{tg}	0.5
Prob. of stay pegged	p	0.9
Steady state ratio: spending	$\frac{G_{ss}}{Y_{ss}}$	0.2
Steady state ratio: consumption	$\frac{C_{ss}}{Y_{ss}}$	0.51
Steady state ratio: investment	$\frac{I_{ss}}{Y_{ss}}$	0.29

4.2.2 Simulation

We solve the model by log-linearization around a zero inflation and zero public debt steady state. The simulation reflects the following policy experiment. At time $t = 1$, the central bank pegs the nominal interest rate at zero. Starting from $t = 2$, there are t possible states: pegged interest rate state and a number of non-pegged rate states. In each period, if the interest rate remains pegged, there is probability p such that the central banks keeps its pegged rate in the next period and with probability $1 - p$ the monetary policy follows the Taylor rule. If the monetary policy returns to the Taylor rule, it will follow the Taylor rule for sure in the next period. At any time t, each non-pegged rate state is distinct because the endogenous state variables, $D_t,\ K_t,\ R_{t-1},\ etc.$, make the exit time from the pegged state matters. At time $t = 1$, the exogenous component of government spending, ε_t, is set to be 0.01. To calculate the expected paths of inflation, consumption and output, we first need to calculate the values in each possible state from time $t = 1$ to $t = M$[6]. Then, the expected paths of a variable can be calculated as:

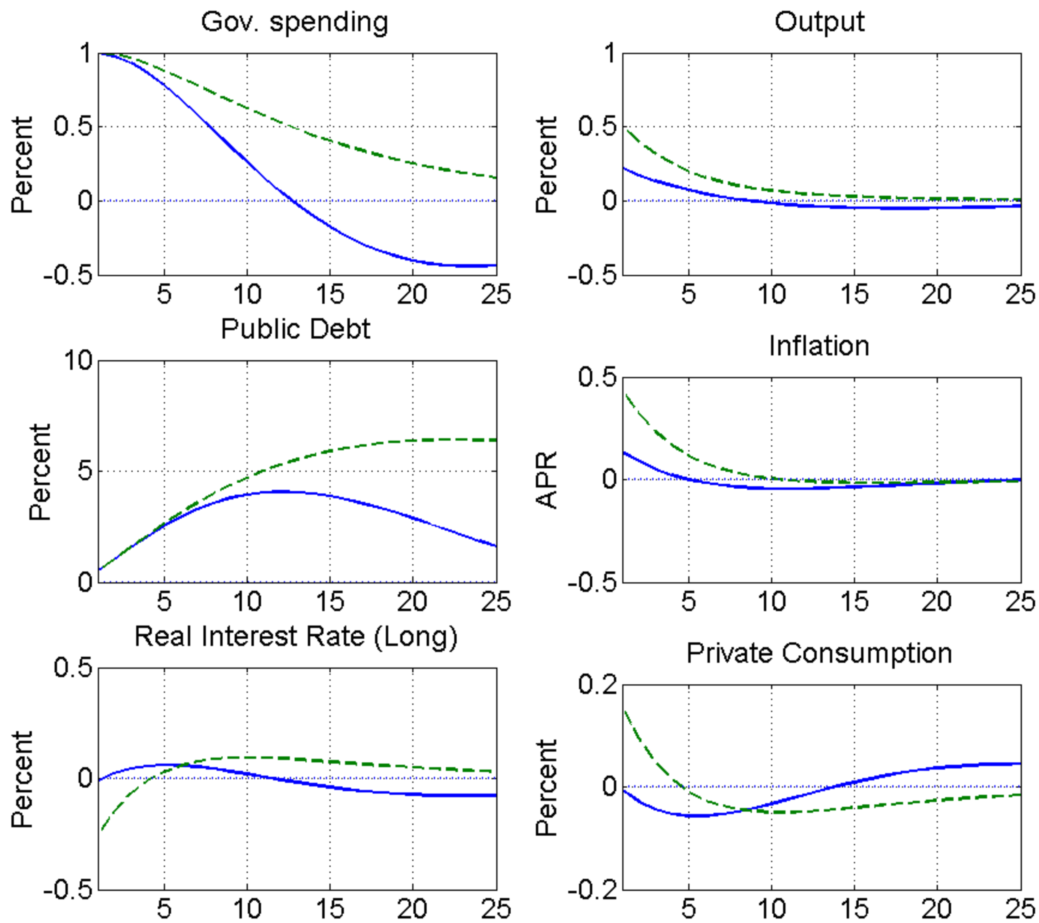
$$E_1 x_t = p^{t-1} x_t^0 + (1-p) \sum_{i=1}^{t-1} p^{i-1} x_t^{t-i}$$

where $E_1 x_t$ denotes the expected value of a variable at time $t = 1$; x_t^0 is the value of a variable when the economy is still in the pegged interest rate state; x_t^1 represents the value of the first quarter that the economy gets out the interest peg state; x_t^2 represents the value of the second quarter that the economy goes back to "normal" state, etc..

We also calculate the response of the economy under an alternative regime when there is no endogenous feedback effect on government spending, i.e. no spending reversals, $\phi_{gd} = 0$. Figure 6 displays the expected responses of selected variables. The solid lines display the dynamics of the model economy under our baseline specification, while the dashed lines show the responses of the alternative model. Under the baseline model, government spending jumps on impact but declines in response to the rise of public debt; and it falls below steady state about 3 years later, shortly after the quarter that public debt reaches its peak. In contrast, under the alternative specification, government spending remains above trend and is financed by larger taxes. The two regimes also imply considerable different dynamics of output and private consumption. Our baseline model generates a smaller increase in output on impact, and it falls below trend several quarters after the shock. Most importantly, in our baseline model, private consumption declines on impact and remains below trend until government spending falls below its steady state level; while it jumps on impact and falls gradually in the alternative regime.

[6] M is large enough to ensure the economy returns to steady state.

Figure 6: Expected responses of government spending, output, public debt, inflation, real interest rate and private consumption



The dynamics of government spending under each model together with the pegged nominal rate generate a distinct pattern of long-run real interest rates, which in turn governs intertemporal consumption choices. To be specific, under our baseline fiscal regime, inflation exhibits a smaller increase in initial periods and more importantly, a persistent decline in the medium term. Due to the pegged nominal interest rate, the ex ante future short-term real interest rate increases, which is immediately reflected in current long-run real rates[7]. In contrast, inflation exhibits a large and persistent

[7] We follow Corsetti et al. (2012) and define the long-term real interest rate as the real yield on a bond of infinite duration.

increase in the absence of endogenous spending reversals, which indicates a decline in the real rate. In other words, the long-run real rate increases in our baseline model, while it declines sharply in the alternative regime. Higher long-run real rates shift private consumption toward the future and thus results in a smaller jump in total output.

Table 3 displays the impact multiplier and the discounted expected cumulative multipliers $E_1 \frac{\Delta Y}{\Delta G} \equiv \frac{1}{s} \frac{E_1 \sum_{t=1}^{T} \beta^{t-1} dx_t}{\sum_{t=1}^{T} \beta^{t-1} dg_t}$ for both regimes. I also calculate the impact and discounted cumulative inflation elasticities: $\frac{\Delta \pi_1}{\Delta G_1} \equiv \frac{d\pi_1}{dg_1}$ and $E_1 \frac{\Delta \pi}{\Delta G} \equiv \frac{E_1 \sum_{t=1}^{T} \beta^{t-1} d\pi_t}{\sum_{t=1}^{T} \beta^{t-1} dg_t}$. Under our baseline model, the impact output multiplier is slightly above one but the discounted cumulative multipliers are below one, while the output multipliers are much larger and above one under the alternative regime. Moreover, the consumption multipliers are negative and inflation elasticities are small with spending reversals, while they are positive and greater if government spending does not react to public debt.

Table 3: Fiscal multipliers

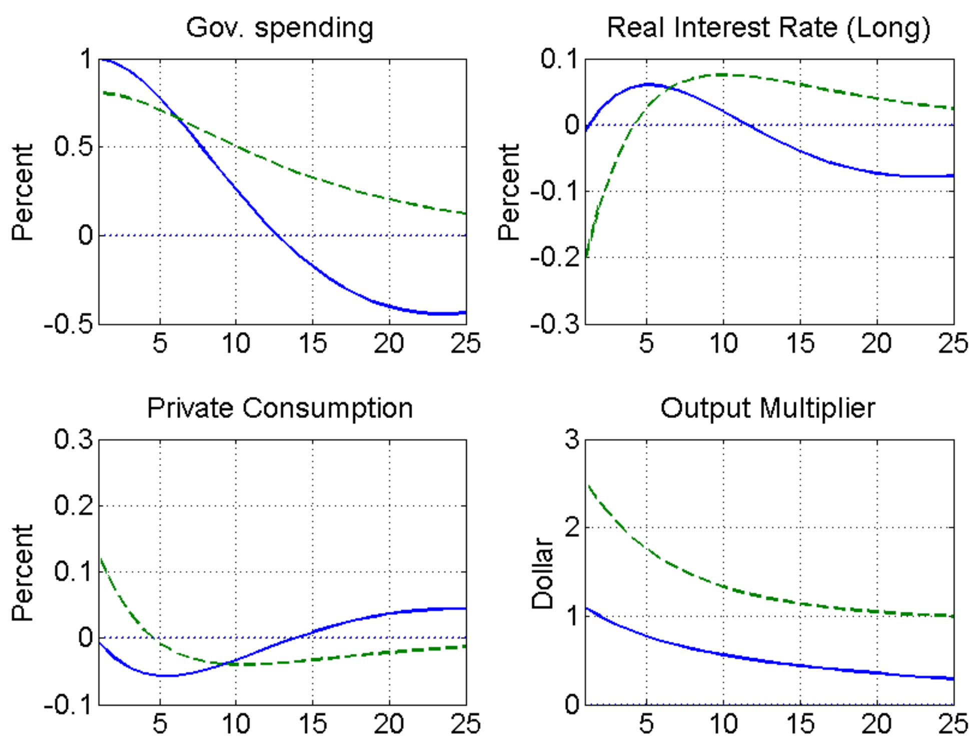
	Output Multiplier		Consumption Multiplier		Inflation Elasticity	
Spending Reversals	Yes	No	Yes	No	Yes	No
Impact	1.098	2.528	-0.012	0.307	0.034	0.108
1-year cumulative	0.836	1.901	-0.068	0.159	0.020	0.075
2-years cumulative	0.631	1.463	-0.107	0.057	0.009	0.051

4.2.3 The wealth effects

As the overall tax burden on households is smaller in the case with spending reversals, one natural question is that whether the difference in the responses of economic variables, especially private consumption, comes from the difference in wealth effects. To answer this question, we conduct the following experiment. In the alternative model, we modify the size of the initial shock such that the present value of the total government spending expansion equals to the one in our baseline model. Figure

7 displays the response of long-run real rate, private consumption as well as the discounted cumulative output multiplier. We find that our main result remains. After controlling the wealth effects, the difference of consumption response between this two regimes comes from the intertemporal substitution channel. That is, if households anticipate that government spending to fall below trend in response to a buildup of public debt, the expected inflation responds only weakly to a positive spending shock. As a result, the long-run real interest rate does not necessarily fall even the nominal interest rate is pegged. Households, therefore, may not shift consumption toward today. In addition, output multiplier would not be larger than unity.

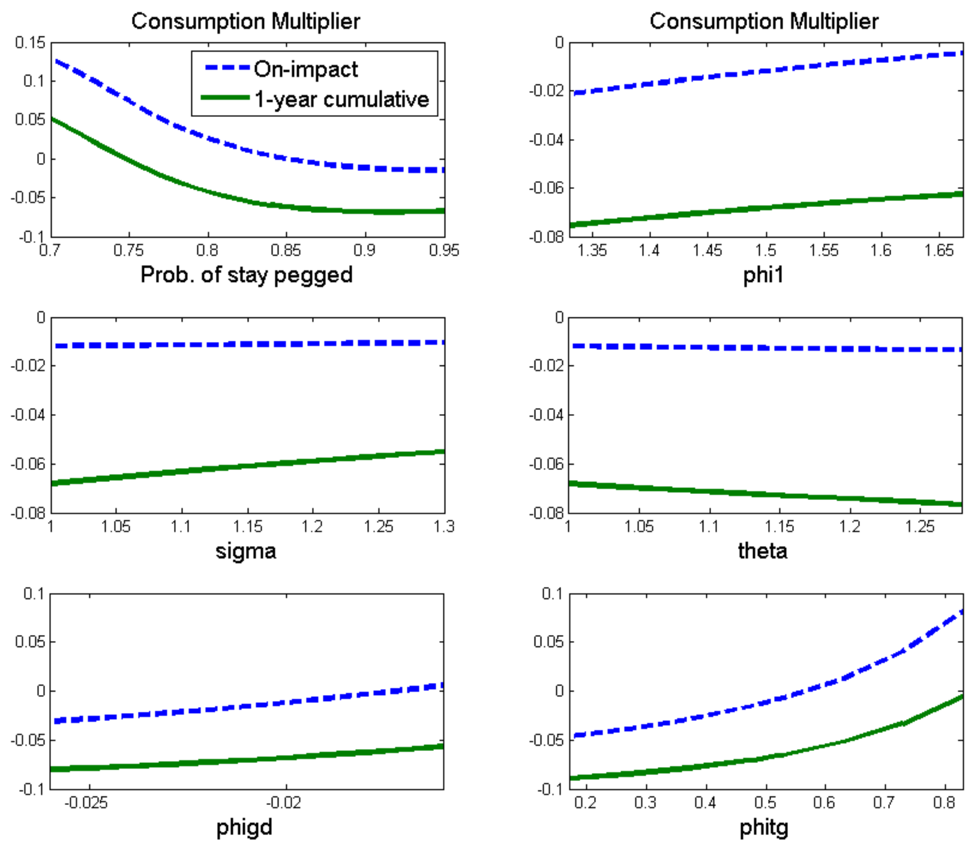
Figure 7: Control wealth effects



4.3 Sensitivity

We conducted several sensitivity analysis by varying the probability of staying in the pegged state, p, sensitivity of Taylor-rule rate to inflation, ϕ_1, coefficient of risk averse, σ, the inverse of Frisch elasticity, θ, sensitivity of spending to government debt, ϕ_{gd}, and the percentage of tax finance, ϕ_{tg}. The first two parameters govern the expected monetary policy; the third and fourth parameters determine households' preference; and the last two affect the endogenous dynamics of fiscal policy. Figure 8 displays the consumption multipliers. First, consumption multiplier declines as p increases. If p increases, the expected nominal interest rate becomes more "sticky". Thus, the rise in future short-run real interest rate becomes more persistent, which further pushes up current long-term real interest rate and discourages current consumption. Second, consumption multiplier rises as the Taylor-rule monetary policy becomes more sensitive to inflation. As ϕ_1 increases, the monetary policy responds more aggressively to inflation once it returns to normal time. This would dampen the response of real interest rates as well as private consumption. Third, as the inverse of elasticity of intertemporal substitution becomes larger, consumption smoothing behavior prevents private consumption from shifting toward the future. As a result, consumption multipliers would be less negative. Fourth, if labor supply is less elastic to real wage, real marginal costs respond more aggressively to demand, which generates larger fluctuation in inflation and real rates. Thus, private consumption declines by more in initial periods. Next, if government spending responds less aggressively to public debt, the size of the spending reversal would be smaller. As a result, private consumption would be larger. Finally, if the increase in government spending is financed by contemporaneous tax by less (ϕ_{tg} decreases), consumption multiplier would become more negative. The size of debt buildup rises as less spending is financed by contemporaneous tax, which indicates a greater size of spending reversal. Therefore, the long-run real interest rate increases by more and private consumption declines by more.

Figure 8: Sensitivity



5 Conclusion

This paper examines the sizes of fiscal multipliers under a pegged nominal interest rate. U.S. empirical evidence shows that a positive government spending shock triggers a rise of public debt and is followed by a spending reversal, when the nominal interest rate was close to zero or the monetary policy was passive. Moreover, inflation exhibits a insignificant response and private consumption responds negatively to a positive spending shock. From theoretical analysis, we show that if the monetary-fiscal expansion is associated with an anticipated spending reversal, private consumption response is negative and the output multiplier can be smaller than one. This result is not due to the mitigated wealth effects and robust across a wide range of parameter values.

Data Appendix

The federal debt to GDP ratio is from FRED data base. We use linear interpolation to convert the annual data into quarterly frequency. Total consumption and its components are from the data appendix of Ramey (2011). The average marginal tax rate data is taken from the paper of Barro and Redlick (2011). We follow Ramey (2011) and convert the annual tax series to quarterly by assuming that the tax rate does not change within each calender year. All the other data are from the online appendix of Ouyang, Ramey and Zubairy (2012) and Ramey and Zubairy (2014).

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