Government Production, Complementarity and the Effects of Government Spending Shocks

Zipeng Zhou *†

July 5, 2016

Abstract

This paper reconsiders the effect of government spending on the private sector economy through input and output channels of government production. I introduce a long-run benign government producer to an otherwise standard two-sector business cycle model with price rigidity. I model government production, distinguishing between different categories of inputs, including employment, intermediate goods and capital goods and different categories of outputs. Specific inputs and outputs are classified according to their elasticity of substitution with private consumption. Given the average level of complementarity/substitutability between private consumption, labor supply, and government outputs, I explore the effects of shocks to the different components of government production. The results indicate that a fiscal policy which can fine-tune the allocation of government inputs and the categories of government outputs is able to span the whole range of theoretical results on the responses of private consumption, private output, real wage and private labor to a government spending shock.

Key words: Government input; Government output; Complementarity level; Calvo Model; Consumption

JEL Codes: E13, E23, E32, E20, E62, H1, H4, H5

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*I deeply thank Professor Jinhui Bai, for his invaluable time, advice and encouragement throughout the progress of this paper. I also deeply thank Professor Behzad T. Diba and Professor Matthew B. Canzoneri for their helpful comments. The usual disclaimer applies.

†Zipeng Zhou: International School of Economics and Management, Capital University of Economics and Business

Email: zipengzhou@qq.com

Contact address: International School of Economics and Management, Capital University of Economics and Business, Fengtai Qu, Beijing, China, 100070

1 Introduction

The responses of the private economy to government spending shocks are important for their obvious policy implications. This paper reconsiders the effect of fiscal policy using a two-sector neoclassical model with price rigidity. I focus on the relationship between private variables (e.g. private consumption, private labor employment, real wage and private output) and different categories of government production to investigate the responses of the private economy to government spending shocks. Particularly, I allow consumer utility to depend on private consumption, government outputs and labor supply in order to reveal the importance of the complementarity/substitutability between them. Government is introduced in this paper as a producer of government outputs. Government spending is defined as the expenditure on government inputs. Distinguishing between different government inputs, intermediate goods, labor and capital, can capture the subtle interaction channels between government spending and private production. Distinguishing the degree of complementarity between different categories of government outputs and private consumption provides additional channels for government spending shocks to affect the private economy. These channels can play a central role in understanding the relationship between the private economy and government spending. Despite their potential, they have rarely been studied in a neoclassical model with a government producer and price rigidity.

Historically, there are two strands of theories which have been advanced in research related to fiscal spending responses. One is Keynesian IS-LM analysis, which claims that an increase in government spending directly boosts aggregate demand and leads to an accommodating expansion in employment and output. The other one is the real business cycle (RBC) model, which argues that an increase in government spending works through a negative wealth effect on households that creates expansions in employment and private output.

Recently, there have been some attempts to build models incorporating private economy responses to government spending shocks. These models have been related to the complimentarity/substitutability between government spending and private labor supply or private consumption. Linnemann [2006] builds a neoclassical model in which leisure and consumption enter into the utility function. Increases in government spending crowds out the private purchasing power and creates a negative wealth effect. As leisure falls because the negative wealth effect, the substitutability between private consumption and leisure indicates the marginal utility of consumption must increase, making the household want to consume more. Later, Monacelli and Perotti [2009] study the role of substitution between leisure and government spending in a business cycle model with price rigidity. They show that substitution between leisure and government spending can generate large responses of private consumption and real wages to changes in government spending. Linnemann and Schabert [2003] formulate a New-Keynesian model in which they find that government spending causes increased private consumption for sufficiently low values of the elasticity of substitution between private consumption and government spending. Ercolani [2007], however, shows that substitution between private consumption and government spending emerges on the average level. Such substitutability, together with the negative wealth effect, makes private consumption fall after a government spending shock.

Previous literature does not fully capture two important aspects of government spending in reality. First, it assumes that government spending is on homogeneous goods. In fact, as discussed by Finn [1998] and Cavallo [2005], distinguishing between government expenditure on labor and goods can change the conclusions drawn from models that assume an aggregate value of government spending. Baxter and King [1993] reach the same conclusion using an RBC model. Compensation to government employees functions as a government transfer, which dampens the negative wealth effect of government spending.

Second, the previous literature usually ignores the distinctions between government inputs and outputs. In reality, government inputs and government outputs are different. For example, government inputs include labor, intermediate goods and capital while government outputs include education, social security system, national defense and public services. Government outputs can produce certain externalities for private consumption. For example, holding national conferences, carnivals or sporting events can attract travelers to visit the host city and spend money on relevant products. Similarly, making information technology knowledge universal can boost the consumption of high tech-equipment in general. Government output can also produce negative externalities. Providing more public health services can crowd out the need for private hospitals, or providing more public transportation services can reduce the need for private vehicles. In aggregate, government spending will be either a substitute or complement for private consumption. Distinguishing different categories of government outputs, however, is helpful to explain the channels through which government production can affect the private economy.

Since different categories of government inputs and outputs have different interaction properties with the private economy, the shocks to different parts of government production provide extra channels for fiscal policies to affect the economy. This perspective is consistent with the observation that there is no general consensus on the empirical relationship between the private economy and government spending. Blanchard and Perotti [2002], Gali et al. [2007] and Ravn et al. [2012], have found that government spending shocks generate positive responses of private consumption, real wages and real output. Ramey and Shapiro [1998], Edelberg et al. [1999], Burnside et al. [2004], and Ramey [2011] argue instead that the data support the opposite conclusion. According to Ramey [2012], the estimates of the aggregate output multiplier of the government spending vary from 0.5 to 2.

The model I introduce here accommodates these diverse findings by disaggregating the components of government spending and government production. I assume a nested CES-GHH preference to embody the complementarities/substitutabilities between private consumption, labor supply, and government production. The GHH preference structure was introduced by Greenwood et al. [1988], and is used extensively in the business cycle literature as a framework to match a series of empirical regularities. Government outputs and private consumption are combined in a constant elasticity of substitution (CES) form in the preference. I assume in the long run government determines the purchases of inputs and the production of outputs to optimize the household's utility. In the short run, there are shocks to the components of government inputs and outputs which are determined by exogenous fiscal policies. This paper discusses the effects of different fiscal shocks on the private economy through different channels of government production. The results indicate that if fiscal policies can fine-tune input purchases and output production then they can generate a wide range of responses from private consumption, real wages, private employment and private production.

The paper proceeds as follows: In section 2, I discuss the intuition behind the model. In section 3, I set up and calibrate the model economy in the long run with flexible prices. In section 4, I outline the model economy in the short run with government input and output shocks and Calvo staggered price and wage. Section 5 presents the simulation results. Section 6 concludes.

2 Intuition

In the standard neoclassical model, government spending is assumed to be homogeneous and wasteful. An increase in government spending crowds out the purchasing power of households. Due to the negative wealth effect, households choose to consume less and work more hours. The labor supply curve shifts out to the right, while labor demand curve remains unchanged. Consequently, real wages decrease, private employment increases and private outputs increase. The assumptions of wasteful and homogenous government spending, however, fail to take into account the fact that government spending is used to purchase the inputs for government production. Taking the U.S. government for example, 60% of government expenditure is for compensation to government employees, 30% is for consumption of intermediate goods and the remainder is for capital consumption. More importantly, government spending also produces productive outputs, including education, national defense, social security, and the legislation system.

Distinguishing between different categories of government inputs and outputs will change the predictions from standard neoclassical models. Increasing the compensation to government employees, for example, transfers wealth from the government sector to households, which dampens the negative wealth effect. It also crowds out employment in the private sector. A necessary condition for private output to increase is that the labor supply shifts out. This paper argues that two mechanisms can make that happen. The first mechanism works through the complementarity channel between labor supply and private consumption. The second mechanism works through the complementarity channel between private consumption and certain categories of government outputs. Both mechanisms require an environment with certain level of price rigidity.

With these two mechanisms, increasing government employment or certain categories of government output can increase the marginal utility of private consumption, as well as the demand of consumption goods. Therefore, in a price staggered environment, private firms encounter an outward shift of the demand curve. Firms that cannot change their prices meet this extra demand by increasing production, hence shifting out the derived demand for labor. In the short run, as labor increases, private output increases and the marginal dis-utility of labor increases, therefore real wages will rise and the cost of consuming private goods increases. A fine-tuned government spending, then, can produce a new temporary equilibrium with more private output, more private consumption, a higher wage and more private employment.

The degree of complementarity between private consumption and different components of government production determine the effects of fiscal policies. For example, federal defense expenditures probably have a small level of complementarity with private consumption. In the empirical research, therefore, they have little effect on the private economy. On the contrary, if fiscal policy promotes the production of government outputs which have a higher level of complementarity with the private economy, such as holding national sporting events, legalizing marijuana, and controlling environmental pollution near tourist destinations, then the fiscal stimulus effect on the private economy will be stronger.

3 Model Economy With Flexible Prices

This section describes and calibrates the model economy without any frictions of price setting. Households, private firms and government are the agents in this economy. Households consume private and government outputs. Monopolistic firms produce private outputs with labor and capital. The government produces government outputs with labor, capital and intermediate goods purchased from private sector. I assume that the government in this flexible price model economy optimizes its production to maximize the utility of households. Because there is no tax distortion in this economy, so this model economy with a benign government is equivalent to a economy with a competitive government producer and the households determine the quantity of government output according to the competitive price of government outputs.

3.1 Households

There is a continuum of households indicated by the index τ. Each household has monopoly power over the supply of its labor. Each households τ maximizes an inter-temporal utility function given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t^\tau$$

where β is the discount factor and the instantaneous utility function is separable in consumption c_t^τ, government output $y_{g,t}^\tau$, labor n_t^τ and real cash balances $\frac{m_t^\tau}{p_t}$:

$$U_t^\tau = \frac{1}{1-\sigma_n}\left[\left((c_t^\tau)^{1-\sigma_g} + \psi_g (y_{g,t}^\tau)^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}} - \psi_n \frac{(n_t^\tau)^{1+\theta}}{1+\theta}\right]^{1-\sigma_n} + \frac{1}{1-\sigma_m}\left(\frac{m_t^\tau}{p_t}\right)^{1-\sigma_m} \tag{1}$$

The household maximizes his utility function subject to an intertemporal budget constraint which is given by:

$$IBC_t \equiv \frac{m_{t-1}^\tau}{p_t} + \frac{B_{t-1}^\tau}{p_t} + IN_t^\tau - c_t^\tau - \frac{p_{g,t}}{p_t} y_{g,t} - i_t^\tau - \frac{m_t^\tau}{p_t} - b_t \frac{B_t^\tau}{p_t} - \frac{T_t}{P_t} \tag{2}$$

where $y_{g,t}$ is government output. $p_{g,t}$ is the price of government output. The household's total income is given by:

$$IN_t^\tau = (w_t^\tau n_t^\tau + A_t^\tau) + r_{p,t}^k k_{p,t-1}^\tau + Div_t^\tau + r_{g,t}^k k_{g,t-1}^\tau \tag{3}$$

where $n_t^\tau = n_{g,t}^\tau + n_{p,t}^\tau$ and $i_t^\tau = i_{g,t}^\tau + i_{p,t}^\tau$.

It is assumed, as in Christiano et al. [2005], that there exist state-contingent securities that insure households against variations in household specific labor income.

As a result, the first component in the household's income will be equal to aggregate labor income. Furthermore, the marginal utility of wealth will be identical across different types of households.

3.1.1 Consumption and Saving Behavior

First, households maximize the objective utility function with respect to consumption c_t, the holding of bonds B_t, the cash balances m_t and the government output $y_{g,t}$ over an infinite life horizon:

$$\max_{c_t, B_t, m_t, y_{g,t}} W \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[U_t^\tau + \lambda_t IBC_t\right] \tag{4}$$

This optimization problem gives us the following first order conditions with respect to consumption, labor, cash balance and government outputs.

$$u_1 = \left[\left((c_t^\tau)^{1-\sigma_g} + \psi_g (y_{g,t}^\tau)^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}} - \psi_n \frac{(n_t^\tau)^{1+\theta}}{1+\theta}\right]^{-\sigma_n} \left((c_t^\tau)^{1-\sigma_g} + \psi_g (y_{g,t}^\tau)^{1-\sigma_g}\right)^{\frac{\sigma_g}{1-\sigma_g}}$$

$$\lambda_t = u_1 (c_t^\tau)^{-\sigma_g} \tag{5}$$

$$\lambda_t = \beta(1+r_t)\lambda_{t+1} \tag{6}$$

$$\left(\frac{m_t}{p_t}\right)^{-\sigma_m} = \lambda_t \frac{nr_t}{1+nr_t} \tag{7}$$

$$\frac{p_{g,t}}{p_t}\lambda_t = u_1 \psi_g (y_{g,t}^\tau)^{-\sigma_g} \tag{8}$$

where $1+nr_t = (1+r_t)(1+\pi_t)$ (nr_t is the nominal interest rate, r_t is the real interest rate and π_t is the inflation rate).

3.1.2 Labor Supply and Wage setting equation

The household also maximizes function W with respect to the nominal wage w_t^τ:

$$\max_{w_t^\tau} W \equiv \sum_{t=0}^{\infty} \beta^t [U_t^\tau + \lambda_t IBC_t] \tag{9}$$

Here I assume the labor supply has a bundler. The bundler hires labor from each household and combines it into final labor. The demand for the labor of a particular household τ is determined by:

$$n_t^\tau = \left(\frac{w_t^\tau}{w_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} n_t \tag{10}$$

This maximization problem of function W results in the following labor supply equation:

$$n_t^\theta = \frac{1}{1+\lambda_w}\lambda_t w_t \frac{1}{\psi_n}\left[\left(c_t^{1-\sigma_g} + \psi_g y_{g,t}^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}} - \psi_n \frac{n_t^{1+\theta}}{1+\theta}\right]^{\sigma_n} \tag{11}$$

In equilibrium, all households have the same wage w_t^τ. Therefore, w_t^τ is equal to w_t in equation (11). As the aggregate function shows

$$w_t = \left[\int_0^1 (w_t^\tau)^{-1/\lambda_w} \, d\tau\right]^{-\lambda_w} \tag{12}$$

3.1.3 Investment and Capital Accumulation

Finally, households own both private capital stock and government capital stock. They rent out the private capital stock to firm-producers at a given rental rate $r^k_{p,t}$. They also rent out the government capital stock to government-producers at a given rental rate $r^k_{g,t}$. They can increase the supply of capital stock by investing in additional private capital, $i_{p,t}$, or government capital, $i_{g,t}$. Both investments have the same unit cost in terms of consumption.

The law of motion of capital accumulation is given by:

$$k_{p,t} = k_{p,t-1}(1 - \delta_p) + i_{p,t} \tag{13}$$

$$k_{g,t} = k_{g,t-1}(1 - \delta_g) + i_{g,t} \tag{14}$$

Household chooses next period capital stock $k_{x,t}$ and investment $i_{x,t}$ in order to maximize their intertemporal utility function subject to the intertemporal budget constraint and the capital accumulation equation. letting $x = g \ or \ p.$:

$$\max_{k_{x,t}, i_{x,t}} H \equiv \sum_{t=0}^{\infty} \beta^t [U_t^\tau + \lambda_t IBC_t + \lambda_t q_{x,t}(k_{x,t-1}(1 - \delta_x) + i_{x,t} - k_{x,t})] \tag{15}$$

where δ_x is the depreciation rate and $q_{x,t}$ is the Tobin's q, i.e. the price of one unit of capital stock.

This optimization problem results in the following first order conditions:

$$q_{x,t} = \beta \frac{\lambda_{t+1}}{\lambda_t} [q_{x,t+1}(1 - \delta_x) + r^k_{x,t+1}] \tag{16}$$

$$q_{x,t} = 1 \tag{17}$$

3.2 Firms

The country produces a single final good and a continuum of intermediate goods indexed by j, where j is distributed over the unit interval ($j \in [0, 1]$).

3.2.1 Final-good sector

The final good is produced using intermediate goods according to the following technology which is similar to the aggregate labor supply in equation (11):

$$y_{p,t} = [\int_0^1 (y^j_{p,t})^{1/1+\lambda_p} \,\mathrm{dj}]^{1+\lambda_p} \tag{18}$$

where $y^j_{p,t}$ denotes the quantity of intermediate good of type j that is used in final goods production at date t, and $\lambda_{p,t}$ determines the mark-up in the goods market.

The cost minimization conditions in the final good sector can be written as:

$$y^j_{p,t} = \left[\frac{p^j_t}{p}\right]^{-\frac{1+\lambda_p}{\lambda_p}} y_{p,t}$$

Perfect competition in the final goods market implies the price of the final goods could be also be written as

$$p_t = [\int_0^1 (p^j_t)^{-1/\lambda_p} \,\mathrm{dj}]^{-\lambda_p} \tag{19}$$

3.2.2 Intermediate Good Producers

Each intermediate good, j, is produced by firm, j, using the following technology:

$$y^j_{p,t} = Z_{p,t} k^{\alpha}_{p,j,t-1} n^{1-\alpha}_{p,j,t} \tag{20}$$

where A_t is the productivity factor and $k_{p,j,t-1}$,$n_{p,j,t}$ are the indexed quantity of capital stock and labor used by the intermediate firm. The total costs of the intermediate firm are given by the sum of the wages and the rent. The firm minimizes this total costs subject to its production function:

$$\min_{n_{j,t},k_{p,j,t-1}} TC_t \equiv w_t n_{p,j,t} + r^k_{p,t} k_{p,j,t-1} + mc_t [y^j_{p,t} - (Z_{p,t} k^{\alpha}_{p,j,t-1} n^{1-\alpha}_{p,j,t})] \tag{21}$$

The results of this minimization problem are the following:

$$w_t = mc_t (1-\alpha) \frac{y_{p,t}}{n_{p,t}}$$

$$r^k_{p,t} = mc_t \alpha \frac{y_{p,t}}{k_{p,t-1}}$$

And then:

$$\frac{w_t n_{p,j,t}}{r^k_t kp,j,t-1} = \frac{1-\alpha}{\alpha} \tag{22}$$

$$mc_t = \frac{1}{Z_{p,t}} (w_t)^{1-\alpha} (r^k_t)^{\alpha} \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} \tag{23}$$

Nominal profits of firm j are given by:

$$\Pi^j_t = (p^j_t - mc_t)[\frac{p^j_t}{p}]^{-\frac{1+\lambda_p}{\lambda_p}} y_{p,t} \tag{24}$$

Each firm j has market power for its own good and maximizes its profits with respect to the price it sets:

$$\max_{p^j_t} \Pi^j_t \tag{25}$$

subject to

$$y^j_{p,t} = [\frac{p^j_t}{p_t}]^{-\frac{1+\lambda_p}{\lambda_p}} y_{p,t}$$

The solution of this maximization problem gives a price, p^j_t, which is a mark-up of the marginal cost:

$$p^j_t = (1+\lambda_p) mc_t \tag{26}$$

3.3 Government

The government producer is cost-efficient. Its purpose in the model economy is to maximize the utilities of the households. The production of government output is financed by lump-sum tax. I also assume government is cost-efficient. Therefore, it is equivalent to a model with a competitive government producer instead, in which the profit of government sector is zero. I assume the government prouduction function take a three-factor CES functional form:

$$y_{g,t} = Z_{g,t} im^{d_1}_t k^{d_2}_{g,t} n^{1-d_1-d_2}_{g,t} \tag{27}$$

where im are the intermediate goods and services from the private sector. k_g is the capital stock of the government sector. n_g is the labor hired from the competitive labor market. Government spending is given by

$$T_t = p_t w_t n_{g,t} + p_t(im_t + i_{g,t})$$

Non-distortion and zero-profit of the government sector imply the price of the public outputs can be written as

$$p_{g,t} = \frac{p_t(r^k_{g,t})^{d_2}(w_t)^{1-d_1-d_2}}{Z_{g,t} d_1^{d_1} d_2^{d_2}(1-d_1-d_2)^{1-d_1-d_2}} \tag{28}$$

3.4 Market Equilibrium

The final goods market is in equilibrium if the supply of final goods equals the demand by households and the purchases of intermediate goods for the government:

$$y_{p,t} = c_t + i_{p,t} + im_t + i_{g,t} \tag{29}$$

At the macro level, I consider that all the intermediate firms are symmetric. Moreover, because the capital-labor ratio, will be identical across intermediate goods producers and equal to the aggregate capital-labor ratio and because the marginal cost is independent on the intermediate goods produced, the same technology will be used to characterize the production function of the final good:

$$y_{p,t} = Z_{p,t} k_{t-1}^{\alpha} n_{p,t}^{1-\alpha} \tag{30}$$

$$\frac{w_t n_{p,t}}{r^k_{p,t} k_{p,t-1}} = \frac{1-\alpha}{\alpha} \tag{31}$$

and the price of the final good will be a mark-up of the marginal cost:

$$p_t^j = (1+\lambda_p) mc_t \tag{32}$$

The inflation rate is defined as:

$$\pi_t = \frac{p_{t+1} - p_t}{p_t} \tag{33}$$

The money market must also be in equilibrium. Here, I choose to model the process of money as an AR(1) autoregressive process with a constant:

$$m_t = (1-\rho)\eta + \rho m_{t-1} + v_t \tag{34}$$

where η is the constant, and ρ is the intertemporal correlation coefficient. η will fix the money and the price since the steady state money demand is equal to:

$$m^* = \frac{\eta}{1-\rho}$$

3.5 Calibration for the Economy with Flexible Price

The parameters for this model are drawn from three different sources. The first category is drawn from previous literature. The second category is derived from estimation, and the last category is derived from calibration. To make the model economy consistent with the U.S. economy, the calibration part uses quarterly data set from 1960:I–2006:IV in NIPA.

Table1 shows the parameters used in the model and their values λ_w and λ_p determine the monopolistic levels of labor supply or production for households and firms separately. Following Canzoneri et al. [2006], I set the value of λ_w and λ_p both equal to 0.2. σ_g (or σ_n) determines the elasticity of substitution between private consumption and government outputs (or labor). Higher σ_g (or σ_n) means government outputs (or labor) and private consumption goods have a higher degree of complementarity. Monacelli and Perotti [2009] assumes σ_n in a range from 1.25 to 3.0. In this paper, I take the average of these values and assume $\sigma_n = 2.0$. In fact, Basu and Kimball [2002] estimate the elasticity of substitution between labor and private consumption and find the value is around 0.35. This value is consistent with $\sigma_n = 2.0$ which indicates that labor and private consumption are complements. Regarding σ_g, Ercolani [2007] finds that government outputs and private consumption are substitutes to each other. Therefore, I make σ_g equal to 0.7. θ is the parameter which governs Frisch elasticity of labor supply, I take its value from Monacelli and Perotti [2009] and make it equal to 0.8. σ_m is the parameter governing elasticity of cash demand, I take its value from Pierre et al. [2003] and set it equal to 1.2.

Table 1: Calibration Results

parameter	Value	Description	target
From Literature			
λ_w	0.2	wage mark up	
λ_p	0.2	price mark up	
θ	0.8	Frisch elasticity of labor supply	
σ_n	2.0	elasticity of substitution in labor	
σ_m	1.2	elasticity of cash demand	
σ_g	0.7	inverse of elasticity of substitution in government outputs	
From Estimation			
α	0.3	share of the capital of the private production	
d_1	0.3	intermediate goods share of public production	
d_2	0.1	capital share of public production	
δ_p	0.025	depreciation rate of private capital	
δ_g	0.02	depreciation rate of public capital	
From Calibration			
β	0.99	discount factor	$\frac{k_p}{y_p} = 8.4$
η	18	cash supply in the economy	p=1 at steady state
ψ_g	0.56	weight of public goods in utility function	$\frac{n_g}{n_p} = 0.22$
ψ_n	5.0	weight of labor in utility function	$n = 0.33$

Notes: The data set is from 1960:I-2006:IV in NIPA.

I assume that the private sector and the government have Cobb-Douglas production functions. All of the estimations are based on the data set from the US government 1960:I–2006:IV in NIPA.

In the model economy, $\beta = 0.99$, $\eta = 18$, $\psi_g = 0.12$ and $\psi_n = 1.3$. These parameters are calibrated according to the target ratios shown in the last column of Table1.

Table 2 shows the comparison between the steady state of the model economy and the U.S. economy. .

Table 2: Steady States of the Model and Real Economy

parameter	Description	Model Econ	Real Econ
$\frac{k}{y_p}$	The ratio of private capital to the output	7.8	8.4*
n	Total Labor Supply	0.33	0.33*
$\frac{n_g}{n_p}$	ratio of private labor to public employment	0.22	0.22*
$\frac{g}{GDP}$	government expenditure share in GDP	0.20	0.21
$\frac{i_p}{GDP}$	share of investment to GDP	0.17	0.22
$\frac{c}{GDP}$	share of consumption to GDP	0.63	0.60

*Notes:*1.* indicates the average real world ratio is used as the targets to calibrate the model. 2.The data set is from 1960:I-2006:IV.

4 The Model Economy with Calvo Price

In this section, I introduce Calvo price and wage setting to represent the staggered prices in the model economy. I first build the Calvo price and wage settings in a standard way. Then, I discuss several fiscal policy strategies which can fine-tune the production of government outputs.

4.1 Calvo Price Setting For the Private Firms

Using the same assumptions as discussed by Calvo [1983], firms are not allowed to change their prices unless they receive a random price-change signal. The probability that a given price can be re-optimized in any particular period is constant and equal to $(1-\xi_p)$. The profit optimization problem of the producers that are allowed to re-optimize at time t is the following:

$$\max_{\tilde{p}_t^j} D = \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} y_{t+i}^j \left[\frac{\tilde{p}_t^j}{p_{t+i}} \left(\frac{p_{t+i-1}}{p_{t-1}} \right)^{\gamma_p} - mc_{t+i} \right] \tag{35}$$

where the cost minimization condition in the final good sector is

$$y_{t+i}^j = \left[\frac{\tilde{p}_t^j}{p_{t+i}} \right]^{-\frac{1+\lambda_p}{\lambda_p}} y_{t+i}$$

This results in the following first order condition:

$$\frac{\tilde{p}_t^j}{(1+\lambda_p)} \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} y_{t+i} p_{t+i}^{1/\lambda_p} (\frac{p_{t+i-1}}{p_{t-1}})^{\gamma_p} = \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} p_{t+i}^{\frac{1+\lambda_p}{\lambda_p}} y_{t+i} mc_{t+i} \tag{36}$$

Equation (36) shows that the price set by firm j is a markup of the future marginal costs. If prices are perfectly flexible ($\xi_p = 0$), the mark-up in period t is equal to $(1+\lambda_{p,t})$ as in equation (26).

Given equation (36), the law of motion of the aggregate price index is:

$$p_t^{-1/\lambda_p} = \xi_p \left[p_{t-1} \left(\frac{p_{t-1}}{p_{t-2}} \right)^{\gamma_p} \right]^{-1/\lambda_p} + (1-\xi_p) \tilde{p}_t^{-1/\lambda_p} \tag{37}$$

I consider the two sums of the equation (36) separately and I make each sum equal to a new variable at time t, then solve the resulting equation recursively. For the first sum, I will follow these steps. I consider the first sum of equation (36) as the variable $SUM1_t$:

$$SUM1_t = \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} y_{t+i} p_{t+i}^{1/\lambda_p} p_{t+i-1}^{\gamma_p}$$

This equation will be the following in a recursive way:

$$SUM1_t = \beta \xi_p SUM1_{t+1} + \lambda_t y_t p_t^{1/\lambda_p} p_{t-1}^{\gamma_p} \tag{38}$$

Then we do the same for the second sum:

$$SUM2_t = \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{t+i} p_{t+i}^{\frac{1+\lambda_p}{\lambda_p}} y_{t+i} mc_{t+i}$$

giving another recursive equation:

$$SUM2_t = \beta \xi_p SUM2_{t+1} + \lambda_t y_t p_t^{\frac{1+\lambda_p}{\lambda_p}} mc_t \tag{39}$$

Given equations (38) and (39), equation (36) becomes:

$$\frac{\tilde{p}_t^j p_{t-1}^{-\gamma_p}}{(1+\lambda_p)} SUM1_t = SUM2_t \tag{40}$$

4.1.1 The dynamics of the Calvo Staggered Price

In simulating this economy, I will have to consider four endogenous variables in the price setting equation: p_t, $\tilde{p}_t$, $SUM1_t$ and $SUM2_t$. I will replace equation (19) by the equations (37), (38), (39) and (40):

$$p_t^{-1/\lambda_p} = \xi_p \left[p_{t-1} \left(\frac{p_{t-1}}{p_{t-2}} \right)^{\gamma_p} \right]^{-1/\lambda_p} + (1-\xi_p) \tilde{p}_t^{-1/\lambda_p}$$

$$SUM1_t = \beta \xi_p SUM1_{t+1} + \lambda_t y_t p_t^{1/\lambda_p} p_{t-1}^{\gamma_p}$$

$$SUM2_t = \beta \xi_p SUM2_{t+1} + \lambda_t y_t p_t^{\frac{1+\lambda_p}{\lambda_p}} mc_t$$

$$\frac{\tilde{p}_t^j p_{t-1}^{-\gamma_p}}{(1+\lambda_p)} SUM3_t = SUM4_t$$

where β, γ_p, ξ_p, λ_p are parameters.

4.2 The Model with Calvo-Wage Setting

Here I will consider the model with the sticky wage assumptions. Households act as price-setters in the labor market. Following Erceg et al. [2000] and Canzoneri et al. [2006], I assume that wages can only be optimally adjusted after some random wage-change signal is received. The probability that a particular household can change its nominal wage in period t is constant and equat to $(1-\xi_w)$. A household τ which receives such a signal in period t will thus set a new nominal wage $\tilde{w}_t^\tau$, taking into account the probability that it will not be re-optimized in the near future. For the households who can not re-optimize, their wages adjust according to:

$$w_t^{\tau} = \left(\frac{p_{t-1}}{p_{t-2}}\right)^{\gamma_w} w_{t-1}^{\tau}$$

where γ_w is the degree of wage indexation. When γ_w is equal to 0, there is no indexation and the wages that can not be re-optimized remain constant. When γ_w is equal to 1, there is perfect indexation to past inflation.

Here, the maximization problem of the households becomes:

$$\max_{\tilde{w_t^{\tau}}} L = \sum_{i=0}^{\infty} \beta^i \xi_w^i \left[U_t^{\tau}(n_{t+i}^{\tau})\right] \tag{41}$$

where the particular demand for labor is determined by

$$n_{t+i}^{\tau} = \left[\frac{\tilde{w_t^{\tau}}(\frac{p_{t+i-1}}{p_{t-1}})^{\gamma_w}}{w_{t+i}}\right]^{-\frac{1+\lambda_w}{\lambda_w}} n_{t+i} \tag{42}$$

Household τ chooses $\tilde{w}_t$ to maximize the utility function, subject to

$$IBC_t \equiv \frac{m_{t-1}^{\tau}}{p_t} + \frac{B_{t-1}^{\tau}}{p_t} + IN_t^{\tau} - c_t^{\tau} - \frac{p_{g,t}}{p_t} y_{g,t} - i_t^{\tau} - \frac{m_t^{\tau}}{p_t} - b_t \frac{B_t^{\tau}}{p_t} - \frac{T_t}{P_t}$$

$$IN_{t+i}^{\tau} = \left(\frac{\tilde{w_t}^{\tau}(\frac{p_{t+i-1}}{p_{t-1}})^{\gamma_w}}{p_{t+i}} n_{t+i}^{\tau} + A_{t+i}^{\tau}\right) + r_{p,t+i}^k k_{p,t+i-1}^{\tau} + Div_{t+i}^{\tau} + r_{g,t+i}^k k_{g,t+i-1}^{\tau}$$

This maximization with staggered wage problem is the following:

$$\max_{\tilde{w_t^{\tau}}} L = \sum_{i=0}^{\infty} \beta^i \xi_w^i \left[U_t^{\tau}(n_{t+i}^{\tau}) + \lambda_{t+i} \tilde{w}_t^{\tau} p_{t+i}^{-1} (\frac{p_{t+i-1}}{p_{t-1}})^{\gamma_w} n_{t+i}^{\tau}\right] \tag{43}$$

Let $(\frac{p_{t+i-1}}{p_{t-1}})^{\gamma_w} = \phi_1$ and $\frac{1+\lambda_w}{\lambda_w} = \phi_2$, So equation(42) becomes

$$n_{t+i}^{\tau} = \left[\frac{\tilde{w_t^{\tau}} \phi_1}{w_{t+i}}\right]^{-\phi_2} n_{t+i}$$

Plug equation(42) into equation(46)

$$\max_{\tilde{w_t^{\tau}}} L = \sum_{i=0}^{\infty} \beta^i \xi_w^i \left[\frac{1}{1-\sigma_n}\left[v(c_{t+i}^{\tau}, y_{g,t+i}^{\tau}) - \psi_n \frac{\left(n_{t+i}^{\tau}\right)^{1+\theta}}{1+\theta}\right]^{1-\sigma_n} + \lambda_{t+i} \frac{\tilde{w_t^{\tau}}}{p_{t+i}} \phi_1 \left(\frac{\tilde{w_t^{\tau}} \phi_1}{w_{t+i}}\right)^{-\phi_2} n_{t+i} + \cdots\right] \tag{44}$$

where $v(c_{t+i}^{\tau}, y_{g,t+i}^{\tau}) = \left(\left(c_{t+i}^{\tau}\right)^{1-\sigma_g} + \psi_g (y_{g,t+i}^{\tau})^{1-\sigma_g}\right)^{\frac{1}{1-\sigma_g}}$.

This optimization problem gives us the following first order conditions.

$$\begin{aligned}(\tilde{w_t^{\tau}})^{1+\phi_2\theta} &\sum_{i=0}^{\infty} \beta^i \xi_w^i \frac{\lambda_{t+i}}{p_{t+i}} w_{t+i}^{\phi_2} \phi_1^{1-\phi_2} n_{t+i} \\ &= \frac{\phi_2}{\phi_2 - 1} \psi_n \sum_{i=0}^{\infty} \beta^i \xi_w^i \left[v(c_{t+i}^{\tau}, y_{g,t+i}^{\tau}) - \psi_n \frac{\left(n_{t+i}^{\tau}\right)^{1+\theta}}{1+\theta}\right]^{-\sigma_n} \phi_1^{-\phi_2(1+\theta)} w_{t+i}^{\phi_2(1+\theta)} n_{t+i}^{1+\theta}\end{aligned} \tag{45}$$

Equation (45) implies that when wages are perfectly flexible ($\xi_w = 0$), the real wage will be a mark-up (equal to $1 + \lambda_{w,t}$) of the ratio of the marginal disutility of labor over the marginal utility of one unit more consumption.

Given the equation (45), the law of motion of the aggregate wage index is given by:

$$w_t^{-1/\lambda_w} = \xi_w \left[w_{t-1} \left(\frac{p_{t-1}}{p_{t-2}} \right)^{\gamma_w} \right]^{-1/\lambda_w} + (1-\xi_w)\tilde{w}_t^{-1/\lambda_w} \tag{46}$$

I consider the two sums of the equation(45) separately and make them equal to a new variable at time t. This allows equation(45) to be written as a recursive formula. The first sum is simplified as follows:

$$SUM3_t = \sum_{i=0}^{\infty} \beta^i \xi_w^i \frac{\lambda_{t+i}}{p_{t+i}} w_{t+i}^{\phi_2} (\frac{P_{t+i-1}}{p_{t-1}})^{\gamma_w(1-\phi_2)} n_{t+i}$$

Then

$$\begin{aligned}
SUM3_{t+1} &= \sum_{i=0}^{\infty} \beta^i \xi_w^i \frac{\lambda_{t+1+i}}{p_{t+1+i}} w_{t+1+i}^{\phi_2} (\frac{p_{t+i}}{p_t})^{\gamma_w(1-\phi_2)} n_{t+1+i} \\
&= \frac{1}{\beta\xi_w} \sum_{j=1}^{\infty} \beta^j \xi_w^j \frac{\lambda_{t+j}}{p_{t+j}} w_{t+j}^{\phi_2} (\frac{p_{t+j-1}}{p_t})^{\gamma_w(1-\phi_2)} n_{t+j} \\
&= \frac{1}{\beta\xi_w} (\frac{p_{t-1}}{p_t})^{\gamma_w(1-\phi_2)} \sum_{j=1}^{\infty} \beta^j \xi_w^j \frac{\lambda_{t+j}}{p_{t+j}} w_{t+j}^{\phi_2} (\frac{p_{t+j-1}}{p_{t-1}})^{\gamma_w(1-\phi_2)} n_{t+j} \\
&= \frac{1}{\beta\xi_w} (\frac{p_{t-1}}{p_t})^{\gamma_w(1-\phi_2)} \left[SUM3_t - \frac{\lambda_t}{p_t} w_t^{\phi_2} n_t \right]
\end{aligned}$$

Such that:

$$SUM3_t = \beta\xi_w (\frac{p_t}{p_{t-1}})^{\gamma_w(1-\phi_2)} SUM3_{t+1} + \frac{\lambda_t}{p_t} w_t^{\phi_2} n_t \tag{47}$$

The second sum cannot be written as recursive formula. Instead, I use the first k terms to represent the infinite sum.[1]

$$SUM4_t = \sum_{i=0}^{k} \beta^i \xi_w^i \left[v(c_{t+i}^\tau, y_{g,t+i}^\tau) - \psi_n \frac{\left(n_{t+i}^\tau\right)^{1+\theta}}{1+\theta} \right]^{-\sigma_n} \phi_1^{-\phi_2(1+\theta)} w_{t+i}^{\phi_2(1+\theta)} n_{t+i}^{1+\theta} \tag{48}$$

Given equations (47)and (48), equation (45) becomes:

$$(\tilde{w}_t)^{1+\phi_2\theta} \frac{1}{1+\lambda_w} \frac{1}{\psi_n} SUM3_t = SUM4_t \tag{49}$$

4.2.1 The Dynamics of Calvo Wage

I replace the labor supply equation of the model with flexible prices given by equations (46), (47), (48) and (49):

$$w_t^{-1/\lambda_w} = \xi_w \left[w_{t-1} \left(\frac{p_{t-1}}{p_{t-2}} \right)^{\gamma_w} \right]^{-1/\lambda_w} + (1-\xi_w)\tilde{w}_t^{-1/\lambda_w}$$

[1]In the simulation, I use k=20. The residuals become sufficient small.

$$SUM3_t = \beta\xi_w(\frac{p_t}{p_{t-1}})^{\gamma_w(1-\phi_2)}SUM3_{t+1} + \frac{\lambda_t}{p_t}w_t^{\phi_2}n_t$$

$$SUM4_t = \beta\xi_w(\frac{p_t}{p_{t-1}})^{\gamma_w(1-\phi_2)}SUM4_{t+1} + w_t^{\phi_2(1+\sigma_n)}n_t^{1+\sigma_n}$$

$$(\tilde{w}_t)^{1+\phi_2\sigma_n}\frac{\phi_2 - 1}{\phi_2}SUM3_t = SUM4_t$$

where β, γ_w, λ_w and ξ_w are parameters.

4.3 Market Clearing Conditions

Similar to the model economy with flexible price setting, the model economy with staggered price and wage setting has to satisfy the clearing conditions in both labor, goods, capital and cash markets.

$$y_{p,t} = c_t + i_{p,t} + im_t + i_{g,t}$$
$$n_t = n_{p,t} + n_{g,t}$$

5 Shocks to Government Production

Different types of fiscal shocks may have differential impacts on government production. In this section, I explore the reaction of government production to four hypothetical fiscal shocks. I consider shocks to the following aspects of government production: the government production budget, government employment, government intermediate goods and different categories of government outputs.

5.1 Shocks to the Budget of Government Production

In this scenario, I assume the budget for government production follows an AR(1) process, as shown in equation (50). Government spending is financed by a lump-sum tax levied on households. Furthermore, the government continuously optimizes its production subject to its budget constraint.

$$ln(GB_t) = (1-\rho_g)\cdot ln(\overline{GB}) + \rho_g \cdot ln(GB_{t-1}) + \epsilon_{gb} \tag{50}$$

where GB is the budget of government production. In equilibrium, $GB_t = T_t$. ρ_g is the intertemporal coefficient. ϵ_{gb} is the fiscal shock to $ln(GB)$.

Given the evolution process of the government budget and the CES functional form of government production, purchases of government inputs im_t, $k_{g,t}$ and $n_{g,t}$ can be described as follows:

$$im_t = GB_t \cdot d_1/p_t$$
$$k_{g,t} = GB_t \cdot d_2/(r_{kg,t}p_t)$$
$$n_{g,t} = GB_t \cdot (1-d_1-d_2)/(w_t p_t)$$

5.2 Shocks to Government Employment

In this scenario, I maintain the assumption that the government production follows an AR(1) process, as in equation (50). However, the deviation of the budget from steady state can only affect the compensation to government employees. Therefore, the purchases of government inputs im_t, $k_{g,t}$ and $n_{g,t}$ can be shown as following:

$$
\begin{aligned}
im_t &= \overline{im} \\
k_{g,t} &= \overline{k_g} \\
n_{g,t} &= (GB_t - \overline{im} \cdot p_t - \overline{k_g} \cdot r_{kg,t} p_t)/(w_t p_t)
\end{aligned}
$$

where $\overline{im}$ and $\overline{k_g}$ are the steady state values of government intermediate goods and government capital.

5.3 Shocks to Government Intermediate Goods Consumption

In this scenario, government spending evolves according to equation (50). But the deviation of government spending from steady state only affect the purchases of government intermediate goods. Therefore, the allocations of government inputs im_t, $k_{g,t}$ and $n_{g,t}$ can be shown as following:

$$
\begin{aligned}
im_t &= (GB_t - \overline{n_g} \cdot w_t p_t - \overline{k_g} \cdot r_{kg,t} p_t)/p_t \\
k_{g,t} &= \overline{k_g} \\
n_{g,t} &= \overline{n_g}
\end{aligned}
$$

5.4 Shocks to Specific Categories of Government Outputs

In this scenario, I assume that the government can produce a range of outputs with different degrees of complementarity with private consumption. I assume that the government can adjust its production in response to a positive shock to government spending. Therefore, a government spending shock can also be modeled as a shock to the average value of the elasticity of substitution between government outputs and private consumption.

The features of this scenario can be described as follows:

$$
\begin{aligned}
ln(GB_t) &= (1 - \rho_g) \cdot ln(\overline{GB}) + \rho_g \cdot ln(GB_{t-1}) + \epsilon_{gb} \\
im_t &= GB_t \cdot d_1/p_t \\
k_{g,t} &= GB_t \cdot d_2/(r_{kg,t} p_t) \\
n_{g,t} &= GB_t \cdot (1 - d_1 - d_2)/(w_t p_t) \\
sim_t &= \rho_g \cdot sim_{t-1} + \epsilon_{gb}
\end{aligned}
$$

The average level of the inverse of the elasticity of substitution between government outputs and private consumption is defined as:

$$\sigma_g \cdot (1 + mul \cdot sim_t) \tag{51}$$

where mul is the weight of the budget shock to the average level of σ_g. In this case, I assume labor and private consumption are separable and re-calibrate the new model economy.

6 Simulation of The Economy with Different Fiscal Shocks

This section shows the simulation results of the model economy with the fiscal shocks described in previous section. For each scenario, I will display the results with flexible prices and sticky prices separately. In order to perform the simulation, I first calibrate the AR(1) process of government spending in the U.S. economy. The counterpart of government spending is the value of the government budget in my model economy.

I assume the government expenditure follows an AR(1) process, as shown in equation (50). I use the data set of U.S. general government spending from 1960:I–2006:IV in NIPA to estimate this process. Following Hodrick and Prescott [1997], I use $\lambda = 1600$ to detrend the series of the data.

The estimations results of equation (50) are shown in Table 3.

Table 3: Government Expenditure Process Estimation

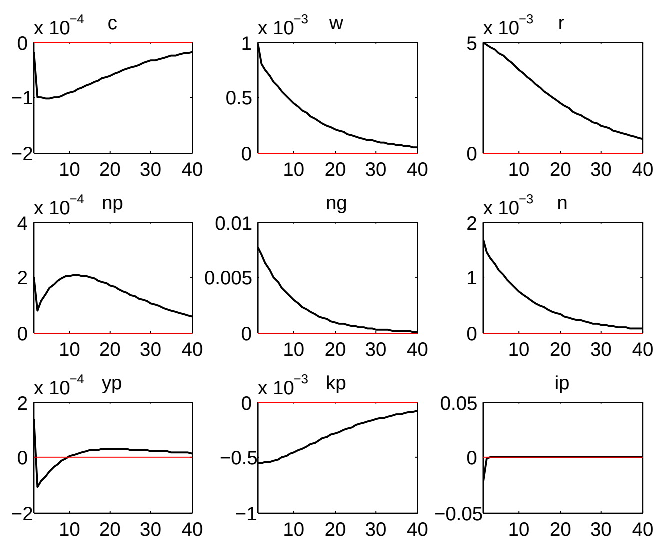
parameter	Description	Mstimation
ρ_g	Coefficient of AR(1) process	0.79
σ_g	Standard Deviation of ϵ_g	0.00821

*Notes:*The data set is from 1960:I-2006:IV, NIPA.

6.1 Shocks to the Budget of Government Production

The settings of private production and household labor supply in this paper are the same as in Canzoneri et al. [2006]. Households are competitive monopolistic producers for the intermediate goods that are used to produce private final outputs.

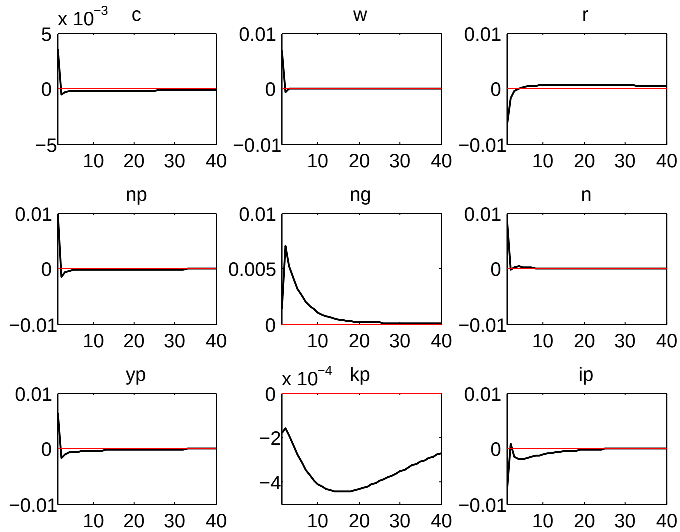
Figure 1: Shocks to Government Spending with Flexible Prices



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$

I implement the simulation in a flexible price environment. The private firms and households are competitive monopolistic players. They have certain levels of monopolistic power over their production and labor supplies. In this simulation, government production follows a cost-efficient pattern. Figure 1 shows the impulse responses of a standard deviation shock on the government budget.

Figure 2: Shocks to Government Spending with Sticky Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$

Since the government in this scenario allocates its inputs cost-efficiently, a positive shock to government spending increases government employment and other inputs accordingly. As the labor demand increases, the real wage goes up. Households choose to supply more labor to the market. Households decrease capital supply to the market in order to compensate for the decrease in consumption. The increase of the rental rate makes private firms increase labor demand even though the real wage is slightly higher than the steady state level.

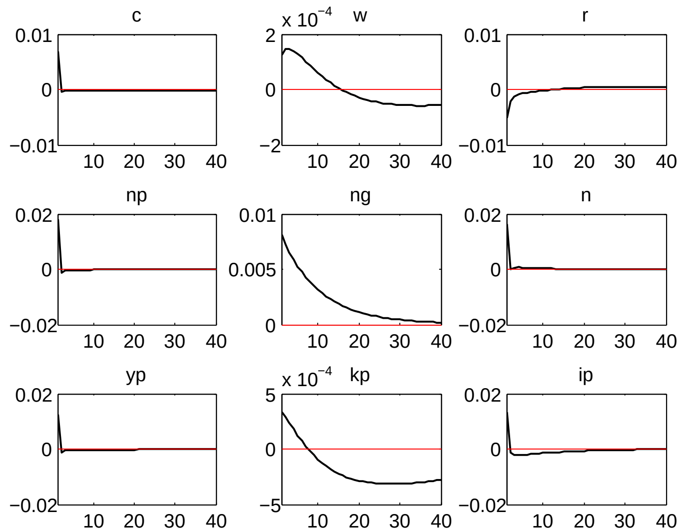
Figure 2 shows the responses of a positive shock to government spending in a staggered price environment. Following Pierre et al. [2003], I set $\xi_p = 0.85$ and $\gamma_p = 0.408$. Since a portion of private firms can not adjust their output price immediately, they produce more output to fulfill the positive demand shocks. As shown in Figure 2, we have a positive response of consumption, labor supply and output to a positive demand shock, at least in the short-run.

Figure 3 shows the simulation results in an environment of both sticky price and sticky wages. The results intensify the responses in Figure 2 except for the responses of real wage. In figure 3, with a similar positive shock to the government budget, the wage does not deviate much from steady state. The reason is that households cannot adjust their wage freely. Furthermore, they must supply more labor if there is a positive demand shock.

6.2 Shocks to Government Employment.

Now, I assume that the government can adjust the purchase of certain government inputs but keep the purchase of other inputs fixed at the long-run optimal level. Figure 4 displays the results of a simulation where the fiscal budget shock only affects the compensation to government employees in a flexible price environment. With a positive shock to government spending, government hires more labor and

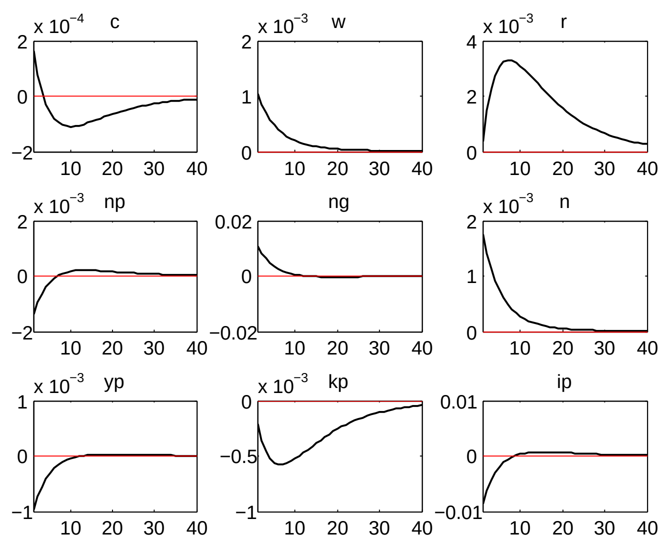
Figure 3: Shocks to Government Spending with Sticky Price and Wage



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$, $\xi_w = 0.65$, $\gamma_w = 0.656$

crowds out hiring in the private sector. Therefore, total private output decreases and private labor decreases.

Figure 4: Shocks to Government Employment with Flexible Price

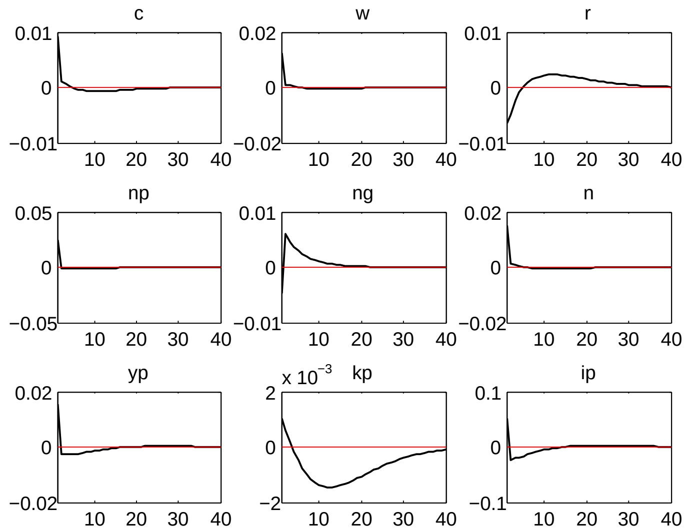


Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$

Figure 5 displays the simulation in a sticky price setting. The main difference from Figure 4 is that a positive shock to government employment can increase private consumption because of the positive complementarity between labor and private consumption. Since prices are sticky in this model, private firms hire more labor and private output increases.

Figure 6 displays the simulation of a spending shock on government employment in a sticky price and wage setting. Since wage can not adjust immediately, same positive shock to the compensation of government employee will generate stronger response of government hiring. However, the responses of private consumption, pri-

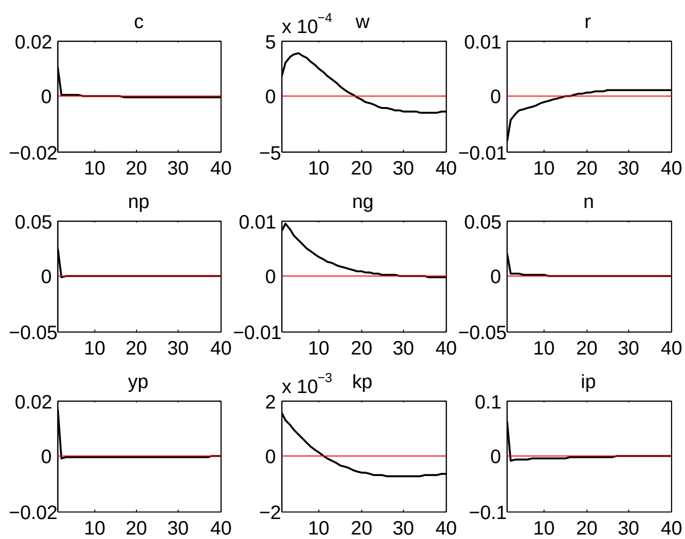
Figure 5: Shocks to Government Employment with Sticky Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$

vate employment and private output are quite similar to the responses in Figure 5. Therefore, the staggered wage setting does not intensify the response of private economy related to the scenario with staggered price.

Figure 6: Shocks to Government Employment with Sticky Price and Wage

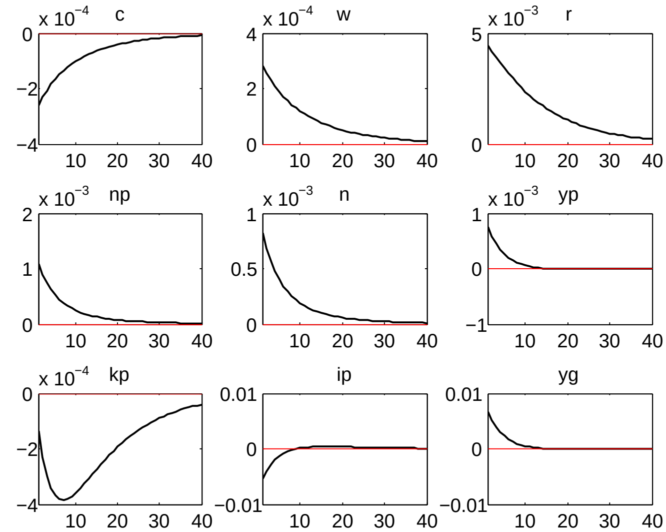


Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$, $\xi_w = 0.65$, $\gamma_w = 0.656$

6.3 Shocks to Government Intermediate Goods

This subsection shows the results of the simulation where the shocks of government spending only work on the channel of intermediate goods purchasing. Figure 8 displays the simulation results of a positive shock to the purchases of government intermediate goods. The responses of the main variables are quite similar to the predictions of a standard neoclassical model. However, the real wage increases as the government increase the purchases of intermediate goods. One of the possible reasons is that these competitive monopolistic producers shift their labor demand curve when facing extra demand shocks.

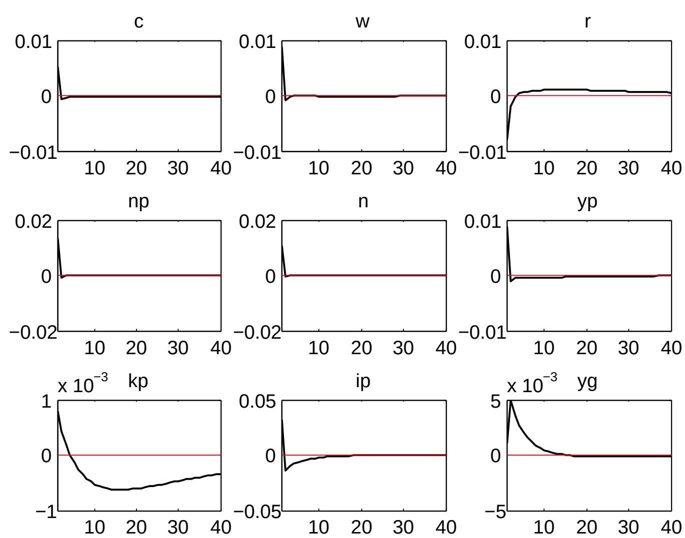
Figure 7: Shocks to Government Intermediate Goods with Flexible Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$

Figure 8 shows the results when we introduce a sticky price environment in the model economy. The increase of private consumption is due to the assumption that private consumption and labor supply are complements. Private outputs increase because of the positive demand shock of government intermediate goods.

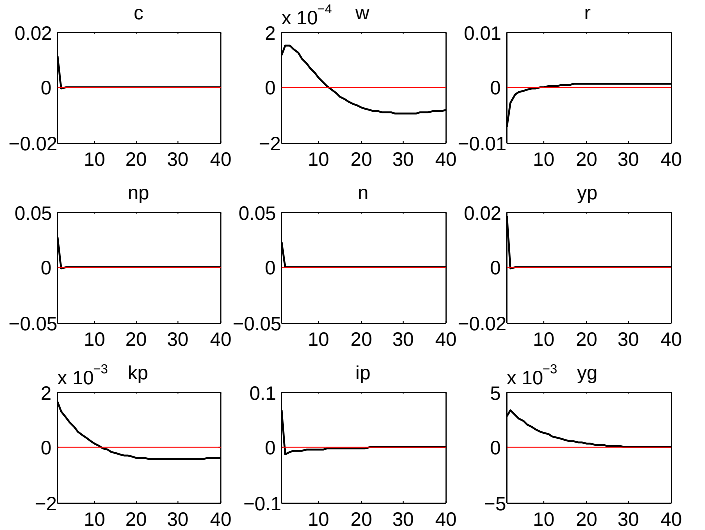
Figure 8: Shocks to Government Intermediate Goods with Sticky Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$

Figure 9 shows the results when I introduce sticky price and sticky wage into the model economy. The results are similar to Figure 8. However the responses of main macro-variables are generally intensified because of the stickiness of wage. It is not a surprise that the deviation of wage becomes smaller than in Figure 8.

Figure 9: Shocks to Government Intermediate Goods with Sticky Price and Wage



Notes: $\sigma_g = 0.75$, $\sigma_n = 1.5$, $\xi_p = 0.85$, $\gamma_p = 0.408$, $\xi_w = 0.65$, $\gamma_w = 0.656$

6.4 Shocks to Specific Categories of Government Outputs

This subsection focus on the assumption that the government can adjust its production of outputs, altering the level of complementarity with private consumption. From this perspective, government has two ways to stimulate private consumption. First, government can adjust the composition of its production, raising the level of complementarity with private consumption. Second, government increase the quantity of goods produced, which are complements to private consumption. I combine these two strategies and simply assume that the government budget shock works on σ_g[2], the average level of the inverse elasticity of substitution between government outputs and private consumption. The level of the shocks on σ_g is governed by mul. In the simulation, I assume $mul = 0.1$. This assumption implies that a standard deviation shock of government spending can only shift σ_g by less than 0.1%.

Figure 10 shows the simulation when the government can adjust its outputs according to the complementarity level with private consumption. Private consumption increases because of the positive change of σ_g. Households will save less, so the capital stock will decrease, along with labor demand in private firms. Private sector output will decrease.

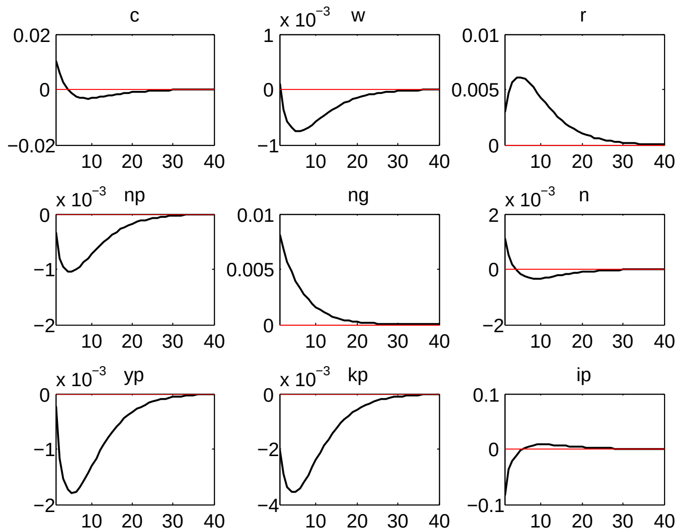
Figure 11 shows the simulation results in a Calvo staggered price environment. Since private firms can not fully adjust their prices, they instead choose to hire more labor. Therefore, both wages and private output increase.

Figure 12 shows the simulation results in a staggered wage setting. Except for real wage, other macro-variables all show stronger responses from the shock to government spending comparing with Figure 11.

The simulation results of these four fiscal spending strategies imply that government can, in fact, intervene in the private economy through the different channels of government production. The effects and mechanisms of these strategies are not

[2]In order to alleviate the relevant shocks on the elasticity of substitution between labor and private consumption, for simplicity, I assume utility of labor and consumption are separable. I set $\sigma_n = 0$ and re-calibrate the parameters of model economy.

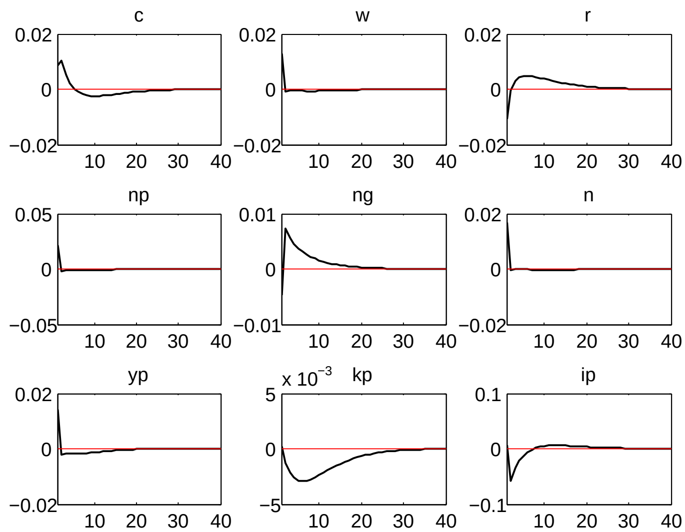
Figure 10: Shocks to Specific Government output with Flexible Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 0$, $mul = 0.1$

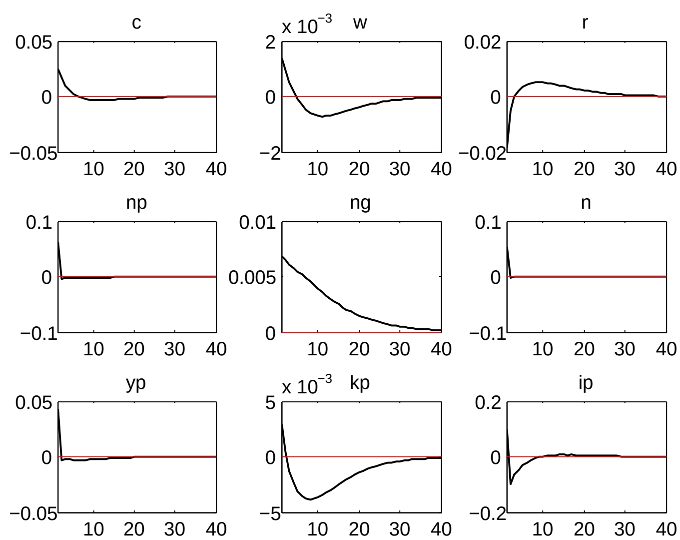
exactly the same. Combined with Calvo price and wage settings, we can span the range of theoretical results on the responses of private consumption, private output, real wage and private labor to a government spending shock.

Figure 11: Shocks to Government Output with Sticky Price



Notes: $\sigma_g = 0.75$, $\sigma_n = 0$, $\xi_p = 0.85$, $\gamma_p = 0.408$, $mul = 0.1$

Figure 12: Shocks to Specific Government Outputs with Sticky Price and Wage



Notes: $\sigma_g = 0.75$, $\sigma_n = 0$, $\xi_p = 0.85$, $\gamma_p = 0.408$, $\xi_w = 0.65$, $\gamma_w = 0.656$

7 Conclusion

The purchase of government inputs and the production of government outputs plays a crucial role in the operation of the U.S. economy. Distinguishing different categories of government inputs and outputs, according to their natural properties or complimentarity levels with private consumption, provides additional channels for the government to intervene in private economy. This paper studies these channels in a neoclassical model with a benevolent government producer in a Calvo staggered price setting.

I build a standard two-sector business cycle model with price rigidity and calibrate the model economy with U.S. quarterly data from 1960-2006 in NIPA. Then I simulate the model economy. The simulation results indicate that the shocks to government employment and intermediate goods can generate different effects on the private economy.

In sum, in the Calvo staggered price and wage environment, if a government can adjust its fiscal policies according to different channels of government production, as well as the level of complementarity/substitutatbility between private consumption and government production, it is able to span the whole set of theoretical results on the responses of private consumption, private output real wage and private employment to positive government spending shocks.

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