The Distributional Effects of Government Spending Shocks*

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Abstract

This paper studies the distributional effects of government spending shocks, and examines how postwar U.S. government spending policy has affected inequality. I distinguish between government goods purchases and government employee compensation, and take into account the heterogeneity among households. I show that shocks to government goods purchases have substantially different distributional effects than to government employment. The heterogeneity in households' responses comes from two sources: (i) changes in factor prices resulting from the shocks, (ii) different income structures of households due to the difference in wealth. Shocks to the two components of government spending have opposite effects on interest rates and wage rates. Therefore, through the price channel, these two shocks result in significantly different distributional effects. Quantitative investigation is conducted using a calibrated heterogeneous-agents model with incomplete markets. My analysis reveals that the postwar U.S. government spending policy has amplified consumption and wealth inequalities.

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1 Introduction

Understanding how the economy responds to government spending shocks is important, since government spending is often used as a policy tool to smooth economic

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fluctuations. For example, the U.S. government announced the American Recovery and Reinvestment Act in February 2009 with the goal of combating the recent recession. However, there is a debate regarding the real effect of fiscal stimulus. Empirical studies such as Blanchard and Perotti (2002) and Nakamura and Steinsson (2011) argue that the government spending multiplier is greater than one. Eggertsson (2010), Christiano et al. (2011) and Woodford (2011) suggest that the government need to conduct counter-cyclical government spending policies to smooth the output fluctuations, especially when the nominal interest rate is constrained by the zero lower bound. In contrast, Edelberg et al. (1999), Barro and Redlick (2011), Ramey (2011), Drautzburg and Uhlig (2011) and Conley and Dupor (2013) show that the government spending has negative or non-significant effects on private consumption or employment. Most of the existing studies have focused on the aggregate effects. On the other hand, empirical studies such as Anderson et al. (2012) and De Giorgi and Gambetti (2012) find that government spending shocks have substantially different effects on heterogeneous consumers. Moreover, Heathcote (2005) and Kaplan and Violante (2011) demonstrate that heterogeneity can be particularly relevant for fiscal policies. Bachmann et al. (2013) show that the welfare gain of eliminating fiscal uncertainty is unevenly distributed among households.

Despite the excellent empirical and theoretical work, scholars examining the distributional effects of government spending have not yet fully explored the importance of distinguishing between different components of government spending. Yet, without such an understanding, we are left with an inadequate analysis that can potentially create conditions for ill-informed policy decisions. This paper contributes to the literature on studying the distributional effects of government spending shocks, taking into explicit account the role of government expenditure on employment. Moreover, instead of limiting the analysis to the aggregate effects, this study examines whether postwar U.S. government spending policy has reduced or amplified consumption and wealth inequalities. The majority of the literature overlooks the employee compensation component, treating government spending as consisting entirely of goods purchases. However, as emphasized in Finn (1998) and Cavallo (2005), distinguishing between the wage and salary component versus expenditures on goods is important, because shocks for these two components can lead to very different aggregate effects. More importantly, as shown later, shocks to government goods purchases and employment have significantly different effects on factor prices, i.e. on interest rates and wage rates. The changes in factor prices may amplify the overall effect on one wealth group of households while dampen the overall effect on the other. For example, an increase in government employment increases the real wage while decreases the real interest rate. A higher wage may benefit the households who rely on labor income, while a lower interest rate may hurt the households who have a large capital income share.

In the empirical section, I examine the effects of government spending shocks on factor prices. The identification method applied is an agnostic approach of imposing sign restrictions on impulse response functions. This analysis yields two important findings. First, the two government spending shocks have opposite effects on real wages. A positive government goods purchases shock tends to reduce real wages while a positive government employment shock tends to increase real wages on impact and in the medium term. Second, the government goods purchases shock has positive effects on the real interest rate in the medium and long term while it has negative effect initially. On the other hand, the government employment shock tends to reduce the real interest rate.

In theoretical analysis, the changes in factor prices represent a channel through which a government spending shock can affect households unequally. Specifically, a shock to government goods purchases increases the demand of private sector output and therefore the labor demand in private sector. On the supply side, the negative wealth effect causes households to increase labor supply. As a result, private sector labor increases in equilibrium which leads to a reduction in wage rates and an increase in interest rates. The overall effect of this shock on households then depends on their sources of income. Since capital income is the main income source for high income households, the negative wealth effect is partially offset by the increase of the interest rate. On the other hand, the main source of income for lower income households is labor income, so the negative wealth effect is amplified by the decrease of the wage rate. Therefore, the responses of consumption, labor supply and investment for high income households are smaller than those of lower income households under a shock to government goods purchases.

On the contrary, a positive shock to government employment decreases the equilibrium labor in the private sector. The reasons are the following. First, at the aggregate level, there is a weaker wealth effect of the government employment shock, because all of the additional taxes are repaid to the households as wage payments.[1] As a result, there is no significant increase in total labor supply. Second, the shock directly creates additional labor demand in the government sector. Therefore, labor in the private sector has to decrease in equilibrium. In other words, a shock to government employment will reallocate labor from the private sector to the government

[1]There is still an aggregate wealth effect as this shock increases the usage of private resource–labor.

sector. As a result, the equilibrium wage rate goes up while the interest rate goes down. The overall effect is amplified on households whose main income source is capital income, while it is partially offset on households who rely on labor income. Accordingly, by distinguishing between the ways government spends, I am able to provide a more precise approach to evaluate government spending policies.

I quantitatively examine the distributional effects of government spending shocks using a calibrated version of the stochastic growth model with incomplete markets. In the model, there are a large number of households who face idiosyncratic labor productivity shocks as well as aggregate productivity and government spending shocks. Following Castaneda et al. (2003), I calibrate the model such that its steady state values match the corresponding statistics in the data, including the wealth distribution. Then two policy experiments with temporary government spending shocks are conducted and compared. In both experiments, the government increases its expenditure by 10% relative to the steady state level for four quarters, then returns to its steady state level permanently. In the first experiment, the government spending increase is entirely on goods purchases, while in the second, the government hires more employees. I calculate the on impact elasticities of consumption, labor supply and capital choice to the government spending shocks for each quintile of households divided by wealth. The difference in the elasticities between the richest and poorest quintiles is smaller in the second experiment. The reason is, the changes of factor prices have opposite directions. The price changes amplify the overall negative income effect on lower income households in the first experiment while reduce it in the second.

To examine whether the U.S. postwar government spending policy has reduced or amplified consumption and wealth inequalities. I first estimate the postwar U.S. government spending policy using the method in Finn (1998). Second, I solve the model with aggregate fluctuations using the approach described in Krusell and Smith (1998). Finally, I simulate the model economy with and without the estimated policy and compare the long-run average of consumption, labor supply and wealth of households in each wealth quintile. Quantitative results reveal that the postwar U.S. government spending policy has amplified consumption and wealth inequalities.

The rest of this paper is organized as follows. Section 2 provides empirical evidence. Section 3 discusses the main mechanism of how government spending shocks affect different households with the help of a simple static heterogeneous agents model. Section 4 describes the full model and calibration. The main results and policy experiments appear in Section 5. Section 6 concludes.

2 Effects of government spending shocks on prices

The majority of the literature that studies the effects of government spending shocks overlook the employee compensation component, treating government spending as consisting entirely of goods purchases. However, in this section, I show that shocks to government goods purchases and employment have significantly different effects on interest rates and wage rates.

To identify government spending shocks, I use the method of imposing sign restrictions on impulse response functions, which was first developed in Uhlig (2005) and then extended by Mountford and Uhlig (2009). Specifically, I identify a government goods purchases shock as well as a government employment shock by imposing sign restrictions on the government spending variables themselves and imposing orthogonality to a business cycle shock as well as a monetary policy shock. The business cycle and monetary policy shocks are also identified with sign restrictions. The VAR's vector of observable variables include government goods purchases, government employment[2], real GDP, real wages, ex post real interest rate, adjusted reserves, GDP deflator, the producer price index for crude materials, real private consumption and real private non-residential investment. The ex post real interest rate is constructed using the federal funds rate and CPI inflation. The VAR consists of these ten variables at a quarterly frequency from 1954Q3 to 2012Q4. It has six lags and uses the logarithm for all variables. The identifying sign restrictions on the impulse responses appear in Table 1. A business cycle shock is defined as a shock which jointly moves GDP, private consumption, private non-residential investment in the same direction for four quarters following the shock. A monetary policy shock moves ex post real interest rates up and reserves as well as prices down for four quarters after the shock. This is consistent with Mountford and Uhlig (2009) which imposes that the nominal interest rate rises and prices fall. The monetary policy shock is also required to be orthogonal to the business cycle shock. The primary purpose of identifying the business cycle and monetary policy shocks is to filter out the effects of these shocks on the government spending variables. Government spending shocks are identified only by restricting the impulse responses of the spending variables and the requirement that they are orthogonal to the business cycle and monetary policy shocks. I separately identify a government goods purchases shock and a government employment shock. Specifically, a government goods purchases shock is defined as a shock where government goods purchases rise for a year. A government employment shock is

[2] The data source of government employment is from Francis-Ramey updates in Ramey's website. More about data is in Appendix C

defined as a shock where government employment rises for a year.[3] [4]

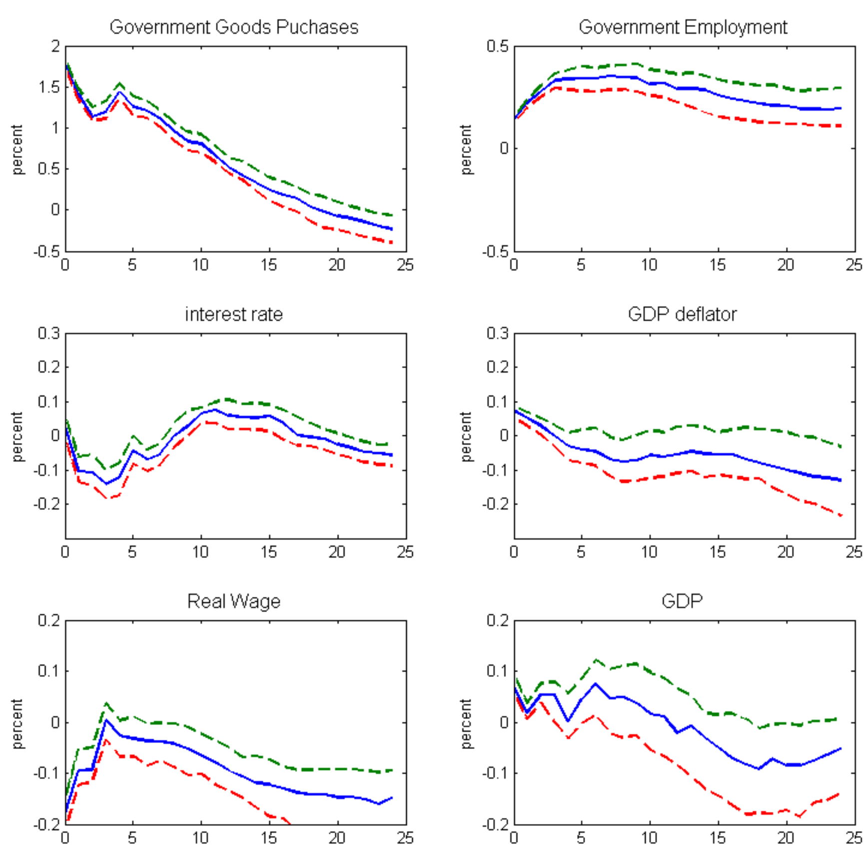
Table 1: Identifying sign restrictions

	G. goods pur.	G. Emp	GDP, cons, nonres.inv.	interest rate	Adj. res.	Prices
Busi. cycle			+			
Monetary				+	–	–
G. goods pur.	+					
Gov. Emp.		+				

The sign restrictions on the impulse responses for each shock. A "+" means that the impulse response of the variable is restricted to be positive for four quarters. A "-" means a negative response for four quarters. Blank entries indicates no restrictions are imposed.

2.1 A government goods purchases shock

Figure 1: Impulse responses to the government goods purchases shock



The medium, 32nd and 68th percentiles are plotted.

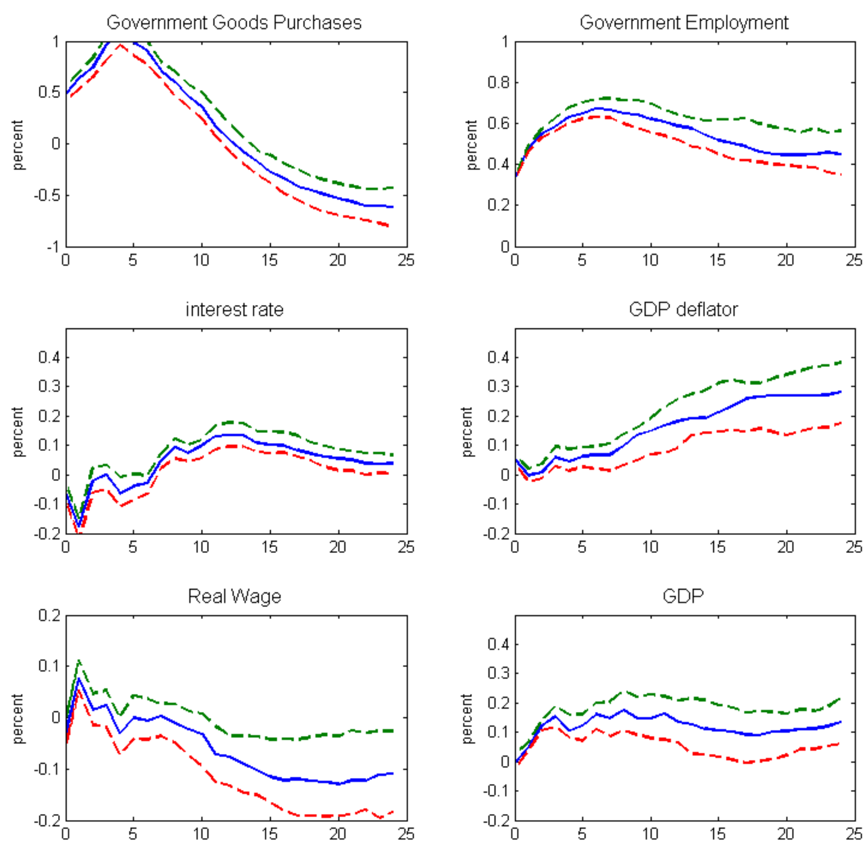
[3]The purpose of these tight restrictions is to rule out very transitory shocks to fiscal variables.
[4]Following Mountford and Uhlig (2009), 100 draws are taken.

The impulse responses to a government goods purchases shock are shown in Figure 1. Figure 1 illustrates three important findings. First, real wages respond negatively to this shock. Second, the ex post real interest rate responds positively on impact and in the long term. On the other hand, GDP deflator jumps on impact and decreases constantly implying a decrease in inflation. Third, government employment responds positively to the government goods purchases shock, which indicates that the two components of government spending may not be perfectly independent.

2.2 A government employment shock

The impulse responses to a government employment shock are shown in Figure 2.

Figure 2: Impulse responses to the government employment shock



The medium, 32nd and 68th percentiles are plotted.

Figure 2 also illustrates three important findings. First, real wages respond positively in initial periods. Second, the ex post real interest rate responds negatively on impact and in the medium term, while GDP deflator response is positive and getting larger.

Third, government goods purchases respond positively on impact and in the medium run but negatively at longer horizons, which emphasizes that the two government spending components may not be perfectly independent.

2.3 Summarizing the empirical findings

There are two important empirical findings which need to be emphasized.

1. The two government spending shocks have opposite effects on real wages. The government goods purchases shock tends to reduce real wages while the government employment shock tends to increase real wages in initial periods.

2. The two government spending shocks have different effects on the real interest rate. The government goods purchases shock has positive influence on the real interest rate on impact and long term. On the other hand, the government employment shock tends to reduce the real interest rate in initial periods.

These two findings illustrate that different components in government spending have different general equilibrium effects. Starting from the next section, I study the distributional effects of shocks to the two components in government spending.

3 A simple static model

In this section, I describe the main mechanism by which government spending shocks affect heterogeneous households with the help of a simple static model. Many researchers show that in a representative agent neoclassical growth model, private consumption drops and labor supply increases in response to an increase of government spending. I show that private consumption and labor supply responses to an unexpected change in government spending depend on the type of the shock (goods purchases or employment) and households wealth.

The economy is populated by a continuum of households with potentially different capital stock endowments. A household values private consumption, c, and leisure, $1-l$. It is endowed with capital stock, k, which has a proportional production cost of rate δ. Households supply labor to a labor intermediate which distributes the labor composite to both private sector and the government. The private production sector is competitive and uses a Cobb-Douglas constant-returns-to-scale technology. The government buys goods from the private sector and hires labor to work in the government to provide public services. The government offers the competitive wage rate to its employees, which is the same as the wage rate in the private sector. Government spending is financed by lump-sum taxes and the government budget is balanced.

A household with endowment k solves:

$$max_{c,l} u(c, l)$$

s.t.

$$c \leqslant wl + rk - T$$

where $w = (1-\alpha)zK^{\alpha}L_p^{-\alpha}$, $r = \alpha zK^{\alpha-1}L_p^{1-\alpha}$, and $T = G + wL_g$. L_p is the total labor in the private sector, L_g is the government employment, and G is the government goods purchases. The government goods purchases and government employment are exogenous.

The first order condition is:

$$u_l(c, l) + u_c(c, l)w = 0 \tag{1}$$

The utility function satisfies: $u_c > 0$, $u_{cc} < 0$, $u_l < 0$, $u_{ll} < 0$, and $u_{lc} = u_{cl} < 0$ for non-separable utility or $u_{lc} = u_{cl} = 0$ for separable utility.

Proposition I. The aggregate private sector labor $L_p(z, G, L_g)$ is strictly increasing in G and strictly decreasing in L_g. One implication is that the wage rate (interest rate) falls (increases) when G increases and the wage rate (interest rate) increases (falls) when L_g increases.[5]

The intuition is that when the government increases its goods purchases, it consumes more resource of the economy. Then, there is a negative wealth effect to households in the economy. The wealth effect leads households to reduce consumption while increase labor supply. On the other hand, the additional demand for goods by the government leads to an increase of labor demand in the private sector. As a result, the equilibrium labor increases in the private production sector. Consequently, from the constant return to scale production function, the wage rate goes down and capital interest rate goes up. On the contrary, a government employment shock leads the government to hire more employee and increase its overall wage payment. To balance the budget, the government has to collect more lump-sum taxes. However, in the view of households, the aggregate wealth effect is weaker, because the additional

[5] The proof is in Appendix A.

lump-sum taxes are paid to households as wage payments. Then there is no strong incentive to increase labor supply. On the other hand, the shock directly increase labor demand in the government sector. As a result, some of the labor in the private sector has to be reallocated to the government sector. Consequently, because of the constant return to scale production technology, the wage rate increases and the interest rate falls.[6]

This proposition shows that, besides the direct wealth effect, there is another channel through which a government spending shock can affect the economy. That is, it changes the prices. Next, I will show how the two government spending shocks affect households with different levels of wealth.

3.1 A shock to government goods purchases

Household income is:

$$i = wl + rk - G - wL_g$$

The response of income to a shock for government goods purchases is then:

$$\frac{\partial i}{\partial G} = w\frac{\partial l}{\partial G} + \frac{\partial w}{\partial G}l + \frac{\partial r}{\partial G}k - 1 - \frac{\partial w}{\partial G}L_g$$

There are two components: the income effect, $\frac{\partial w}{\partial G}l + \frac{\partial r}{\partial G}k - 1 - \frac{\partial w}{\partial G}L_g$, and the income change due to changes in labor supply, $w\frac{\partial l}{\partial G}$.

There are three components in the overall income effect. $\frac{\partial w}{\partial G}l < 0$ is the change in labor income. $\frac{\partial r}{\partial G}k > 0$ is the change of capital income. $-1 - \frac{\partial w}{\partial G}L_g$ is the change in taxes. The income effect is an increasing function in k, i.e. $\frac{\partial \text{income effect}}{\partial k} = \frac{\partial w}{\partial G}\frac{\partial l}{\partial k} + \frac{\partial r}{\partial G} > 0$, because $\frac{\partial r}{\partial G} > 0$, $\frac{\partial w}{\partial G} < 0$, and $\frac{\partial l}{\partial k} < 0$. Since labor supply is a decreasing function of k, i.e. $\frac{\partial l}{\partial k} = -(u_{lc} + u_{cc}w)r[u_{lc}w + u_{cc}w^2 + u_{ll} + u_{cl}w]^{-1} < 0$, we have $l > L > L_g$ when k is low. Therefore, the income effect is negative when k is small and could be positive if k is large enough.

Intuitively, households have two sources of income: capital income and labor income. The increase of capital income, due to the increase in the interest rate, partially offsets the negative wealth effect. On the other hand, the decrease in the wage rate amplifies the negative wealth effect. The overall effect then depends on the wealth level of households. Since households have different endowments of capital, the overall wealth effects are different and depend on the capital endowment of households. If a household is poor, i.e. the capital stock endowment k is low, it has

[6] This finding is consistent with the results in Finn (1998) and Cavallo (2005).

a large labor income share but a small capital income share. In this case, the increase in capital income is not large enough to offset the decrease in labor income and the increase in taxes. The household reduces its consumption and increases its labor supply due to the negative wealth effect. As the capital stock increases, the capital income share is larger and the overall effect is smaller. The household responses of consumption and labor supply become smaller and could change signs if k is large enough.

3.2 A shock to government employment

The response of income to a shock for government employment is then:

$$\frac{\partial i}{\partial L_g} = w\frac{\partial l}{\partial L_g} + \frac{\partial w}{\partial L_g}l + \frac{\partial r}{\partial L_g}k - \frac{\partial w}{\partial L_g}L_g - w$$

There are also two components: the overall income effect, $\frac{\partial w}{\partial L_g}l + \frac{\partial r}{\partial L_g}k - \frac{\partial w}{\partial L_g}L_g - w$, and the income change due to change in labor supply, $w\frac{\partial l}{\partial L_g}$.

Similarly, there are three components in the income effect. $\frac{\partial w}{\partial L_g}l > 0$ is the change of labor income. $\frac{\partial r}{\partial L_g}k < 0$ is the change of capital income. $-\frac{\partial w}{\partial L_g}L_g - w$ is the change in taxes. The income effect is negative when k is large enough, and is a decreasing function of k, i.e. $\frac{\partial \text{income effect}}{\partial k} = \frac{\partial w}{\partial L_g}\frac{\partial l}{\partial k} + \frac{\partial r}{\partial L_g} < 0$, because $\frac{\partial r}{\partial L_g} < 0$, $\frac{\partial w}{\partial L_g} > 0$, and $\frac{\partial l}{\partial k} < 0$.

In this case, the changes in factor prices increase labor income while decrease capital income. The absolute value of the negative income effect becomes larger as the capital stock becomes larger. That is because, with a higher level of capital stock, there is a larger income reduction due to the drop in the interest rate. The implication is that an increase in government employment tends to dampen the income and consumption inequalities; however, it achieves this by reducing the income and consumption of all households.

From the analysis of the simple static model above, I have shown that there are heterogeneous effects of government spending shocks. The shocks affect households through two channels: the negative wealth effect and the changes of prices. The overall effects on different households depend on their wealth and the type of the shock.

4 A quantitative model with heterogeneous agents

In this section, I construct a heterogeneous agent model and calibrate it such that it matches the U.S. wealth distribution as well as several other targets in the data. I then use this model to study the quantitative distributional effects of shocks to the two components in government spending. The model is based on Castaneda et al. (2003). The key ingredients of the model economy are the following: (i) it has a unit mass of households with identical preferences; (ii) the households face an uninsurable idiosyncratic labor productivity shock; (iii) every household goes through the life cycle stages of working-age and retirement; (iv) there is a positive probability of dying for the retired households, and when the retired households die they are replaced by a working-age descendant; (v) the households care about their descendants' utility as much as their own utility; (vi) there is a borrowing constraint; (vii) there are stochastic aggregate productivity, government goods purchases, and government employment shocks.

4.1 The model economy

4.1.1 Labor productivity shocks

The model economy contains a unit mass of continuum of households. A household can either be of working-age or retired. A working-age household has an exogenous probability of retiring in the next period and faces an uninsured idiosyncratic stochastic process that determines their labor productivities. A retired household faces an exogenous probability of dying in the next period and has a labor productivity of zero. A retired household is replaced by a working-age descendant who inherits the household wealth when he dies. Following Castaneda et al. (2003), a one-dimensional shock, ϵ, is used to denote the household's random age and random labor productivity jointly. I assume that this is an independent and identically distributed process which follows a finite state Markov chain. The conditional transition probabilities are given by $\Gamma_{ss} = Pr\{\epsilon_t = \epsilon' | \epsilon_t = \epsilon\}$, where $\epsilon, \epsilon' \in S = \{\xi \cup R\}$. $\xi = \{\epsilon_l, \epsilon_h\}$ and $R = \{0, 0\}$ are two 2-dimensional sets contain the labor productivity of working-age households and retired people, respectively. I have two retirement states, because I use the last working-age labor productivity to keep track of the earnings ability of retired households in order to capture the inter-generational transmission of earning ability. The transition matrix can be partitioned into:

$$\Gamma_{ss} = [\begin{array}{cc} \Gamma_{\epsilon\epsilon} & \Gamma_{\epsilon R} \\ \Gamma_{R\epsilon} & \Gamma_{RR} \end{array}]$$

where, $\Gamma_{\epsilon\epsilon}$ describes the changes in the labor productivity of working-age households that are still of working-age in the next period; $\Gamma_{\epsilon R}$ denotes the transition probabilities from the working-age states into the retirement states; $\Gamma_{R\epsilon}$ describes the transitions from the retirement states into the working-age states when a retired household dies and is replaced by its descendant; Γ_{RR} denotes the changes in the retirement states of retired households that are still retired in the next period. Next, I describe my assumptions with respect to these four submatrixes. $\Gamma_{\epsilon R} = p_r I$, where p_r is the probability of retiring, and I is the identity matrix. This means that every working-age household faces the same probability of retiring. I further assume that every retired household faces the same probability of dying, and $\Gamma_{RR} = (1 - p_d)I$, where p_d is the probability of dying. Following Castaneda et al. (2003), ϵ_l is normalized to be one. $\Gamma_{\epsilon\epsilon}$, $\Gamma_{R\epsilon}$, and ϵ_h are selected to match the wealth distribution in the data and I impose the restrictions such that the descendant of a retired household whose last working-age labor productivity is high has a higher probability to draw the high productivity shock in the initial period. Given the above assumptions and the fact that each row of the transition matrix has a sum of one, I have $\Gamma_{\epsilon\epsilon} = [\begin{array}{cc} p_{11} & 1 - p_{11} - p_r \\ 1 - p_{22} - p_r & p_{22} \end{array}]$ and $\Gamma_{R\epsilon} = [\begin{array}{cc} p_{31} & p_d - p_{31} \\ p_d - p_{42} & p_{42} \end{array}]$. Thus, I have $p_{11}, p_{22}, p_{31}, p_{42}$ and p_r, p_d need to be selected.

4.1.2 Preferences

Households value consumption and leisure, and they are altruistic towards their descendants. The households preferences can be described as:

$$E \sum_{t=0}^{\infty} \beta^t [\frac{c_t^{1-\sigma}}{1-\sigma} + \chi \frac{(1-l_t)^{1-\theta}}{1-\theta}]$$

where, $\beta \in (0, 1)$ is the discount factor; c_t is consumption, $l_t \in [0, 1]$ is labor supply. σ and θ are the curvatures of consumption and leisure, respectively. χ is the relative share of consumption and leisure.

4.1.3 Households problem

Households can accumulate wealth in the form of real capital, k_t, to buffer their streams of consumption against the idiosyncratic labor productivity shocks as well as aggregate shocks. I further assume that the capital holdings belong to a compact set, and the lower bound of this set is a form of liquidity constraint.[7] As shown in Huggett (1993), there exists an upper bound for the asset holdings as long as the after-tax rate of return to saving is smaller than the rate of time preference. The private production sector is assumed to be perfectly competitive, which implies that factor prices are given by their corresponding marginal productivities.

The individual states are, therefore, (k, s). The aggregate states contain aggregate productivity, z, government goods purchases, G, government employment, L_g, and the distribution of households μ. Households choose consumption, labor supply and capital to maximize their utility in an infinite horizon.

The recursive formulation of a household's problem is:

$$v(k, s; \mu, z, G, L_g) = max_{\{c,k',l\}}\{u(c, l) + \beta E[v(k', s'; \mu', z', G', L'_g|z, s)]\}$$

s.t.

$$c + k' = (1 - \tau_k)r(\bar{k}, \bar{l}, \Omega)k + (1 - \tau_l)w(\bar{k}, \bar{l}, \Omega)l\epsilon + k - TI_{s\in\xi} + TrI_{s\in R}$$

and

$$\mu' = H(\mu, \Omega, \Omega')$$

$$k' = f(k, s; \mu, z, G, L_g) \geq \underline{k}$$

where μ is the joint distribution on (k, s) , $\Omega = \{z, G, L_g\}$, $\bar{k}$ is aggregate capital, $\bar{l}$ is the aggregate labor in the private sector, H is the law of motion of the households distribution, f is the decision rule for capital, and

$$r(\bar{k}, \bar{l}, \Omega) = \alpha z(\frac{\bar{k}}{\bar{l}})^{\alpha-1} - \delta,\ w(\bar{k}, \bar{l}, \Omega) = (1 - \alpha)z(\frac{\bar{k}}{\bar{l}})^{\alpha}$$

The index function $I_{s\in\xi}$ and $I_{s\in R}$ mean that only the working-age households are paying lump-sum tax and retired households are getting transfer.

[7] I use zero as the lower bound.

4.1.4 Government

The government in this model purchases private sector goods and hires workers to provide public services. The government offers competitive wages which are the same as the wages in the private sector. The government consumption of goods and the public services do not yield utility to the households. The government also pays transfers to the retired households and it collect labor and capital income taxes to finance its spending. There is no public debt, so the government collects lump-sum tax from the working-age households to balance its budget.

The government budget constraint is

$$G + (1 - \tau_l)w(\bar{k}, \bar{l}, \Omega)L_g + Tr = \tau_k(\alpha Y - \delta \bar{k}) + \tau_l(1 - \alpha)Y + T$$

where, G is government goods purchases; L_g is government employment; Tr is the total amount of transfer; τ_k and τ_l are capital and labor income tax rates, respectively[8]; T is lump-sum tax; Y is the total private output.

4.1.5 The aggregate stochastic processes

Following Finn (1998), I assume the following stochastic processes of the three aggregate exogenous variable, z, G, L_g.

$$log(S_t) = (I - A)log(\bar{S}) + Alog(S_{t-1}) + V_t$$

where $S = (z, G, L_g)'$, V is a 3×1 vector of innovations, I is a 3×3 identify matrix, A is a 3×3 matrix of coefficients, and $\bar{S}$ is the steady state of S. The innovation V is generated from a stationary white noise, normal distribution function. One assumption on the structure is imposed: z_t is unaffected by the movements in $G_{t-1}$and L_{gt-1}. That is, the model identifies the pure technological developments that arise independently of recent fiscal policies.

4.1.6 Aggregation and markets clearing

The aggregate capital satisfies

$$\bar{k} = \int k d\mu$$

[8]I assume the tax rates are fixed.

Households do not choose to work for the private sector or the government, instead they supply labor to a labor intermediate which then distributes total hours into the private sector and the government sector. Labor market clearing requires:

$$L_g + \bar{l} = \int l\epsilon d\mu$$

Private sector goods are used as households consumption, investment, and government goods consumption:

$$Y = \int cd\mu + \int (k' - (1-\delta)k)d\mu + G$$

4.1.7 Equilibrium

A recursive competitive equilibrium is then a law of motion H, a pair of individual functions v and f, pricing functions r and w, the lump-sum tax $T(z, G, L_g)$, such that (i) (v, f) solves the household's problem, (ii) (r, w) are competitive, (iii) H is generated by f, (iv) $T(z, G, L_g)$ solves the government budget constraint, and (v) markets clear.

4.2 Calibration

I calibrate the economy such that its steady state statistics match the corresponding statistics in the data. The list of the parameters and their targets are summarized in Table 2. The values for $\sigma, \theta, \alpha, \delta, p_r, p_d$ are the same as those used in Castaneda et al. (2003). I calculate the average labor and capital income tax rates using the method in Jones (2002). Given that the steady state interest rate is 0.01 and labor input in the private sector is 0.30, I calculate the steady state private output. G_{ss} and L^g_{ss} are selected such that the steady state total government expenditure is 20% of GDP, and the ratio between steady state government goods expenditure and employee compensation is 0.6.[9] Steady state transfers are selected to match the target $Tr = 0.049Y$. T is selected to balance the steady state government budget constraint. Parameters β, χ, ϵ_h, p_{11}, p_{22}, p_{31}, $p_{42}$are jointly endogenously determined by solving the steady state of the model and matching several targets including steady state real interest rate, the normalized level of labor in private sector, and the consumption distribution in the data.

[9]0.6 is the average of U.S. data from 1947-2012.

Table 2: Calibration

Parameter	Value	Targets or Literature
σ	1.5	Castaneda et al. (2003)
θ	1.016	Castaneda et al. (2003)
α	0.36	Castaneda et al. (2003)
δ	0.025	Castaneda et al. (2003)
p_r	0.022	Castaneda et al. (2003)
p_d	0.066	Castaneda et al. (2003)
τ_l	0.23	Jones (2002)
τ_k	0.35	Jones (2002)
G_{ss}	0.0795	$\frac{G+wL^g_{ss}}{Y+wL^g_{ss}} = 0.2$
L^g_{ss}	0.0502	$\frac{G}{wL^g_{ss}} = 0.6$
Tr	0.2415	$\frac{Tr}{Y} = 0.049$
T	0.0371	gov budget balance
β	0.989	$r = 0.01$
χ	1.388	$\bar{l} = 0.30$
ϵ_h	50	the
p_{11}	0.97797	wealth
p_{22}	0.55	distribution
p_{31}	$0.994p_d$	in
p_{42}	$0.4p_d$	data

Table 3 displays the steady state wealth distribution of the model and data. The wealth distribution data is from Chang and Kim (2007). The model matches reasonably well the wealth distribution although it tends to overestimate the lower quintiles and underestimates the 4th quintile.

Table 3: Wealth distribution (%)

Quintiles	1st	2nd	3rd	4th	5th
data	1.03	7.07	13.01	21.10	57.76
model	3.54	9.54	13.01	15.41	58.49

Data source: Chang and Kim (2007)

Table 4 displays the consumption distribution of the long-run average in the model and data. The first row shows the consumption distribution in the U.S. data from Castaneda et al. (2003). The second row shows that the consumption distribution from the model using all households including working age and retired households. The third row shows the consumption distribution from the model using only working age households. This group contains about 75% of the total population under my calibration. A glance at the numbers reported in the second row shows that the consumption is less unequally distributed in the model economy than in the data. However, the consumption distribution of the working-age households matches the data reasonably well. More importantly, since I have not used the consumption distribution as part of my calibration targets, any similarity between the model and data in this aspect should be considered a success in accounting for the U.S. wealth inequality.

Table 4: Consumption distribution (%)

Quintiles	1st	2nd	3rd	4th	5th
data	7.19	12.96	17.80	23.77	38.28
model	13.64	19.22	20.63	21.42	25.09
model: working-age	5.80	12.42	19.31	26.31	36.16

Data source: Castaneda et al. (2003)

4.3 The stochastic processes

The parameters of the exogenous stochastic processes are estimated from the U.S. data. This estimation involved several steps. First, an empirical U.S. z series was derived using Solow residuals. Second, all three series on z, G, L_g exhibit trending behavior, so they were detrended to obtain their stationary components. Third, the system of equations is estimated using seemingly-unrelated regression (SUR), which provides efficient parameter estimates in the presence of contemporaneous correlations between the innovations. As in Finn (1998), the model imposes one assumption: z_t is unaffected by g_{t-1} and l_{gt-1}. That is, the model identifies the pure technological innovations arise independently of recent government spending.

Table 5: Restricted SUR estimation results

Dep. Var.	Regressors	Coefficients	Std. Err.	Significance
z_t	z_{t-1}	0.94	0.02	0.00
g_t	z_{t-1}	0.02	0.04	0.69
	g_{t-1}	0.90	0.02	0.00
	l_{gt-1}	0.13	0.04	0.00
l_{gt}	z_{t-1}	0.14	0.03	0.00
	g_{t-1}	0.01	0.02	0.69
	l_{gt-1}	0.90	0.03	0.00
		v_t^z	v_t^g	$v_t^{l_g}$
	v_t^z	0.01		
	v_t^g	0.0309	0.0172	
	$v_t^{l_g}$	-0.0102	0.4719	0.0141

Sample period of estimation: 1948:1-2004:2. Constants are not reported. v^j is the innovation to variable j, for $j = z, g, l_g$. Correlations are below the diagonal while standard deviations are along the diagonal.

Table 5 displays the estimation results. The results show that each variable is highly and positively autocorrelated. z_{t-1} has a positive and significant effect on government hours while its effect on government goods purchases is statistically insignificant. Government hours variable has significant influence on goods purchases but not vice versa. However, the disturbance of the two government spending variables are highly correlated. The joint processes are discretized by Tauchen (1986) Method in the numerical analysis.

5 The distributional effects of government spending shocks

This section provides the main results of this paper. First, I conduct two policy experiments with unanticipated temporary government spending shocks. In the first experiment, the government temporarily increases its goods purchases by 10% of total government expenditure for one year. In the second one, the government temporarily increases its employment for one year. To make this experiment comparable to the first one, the size of the shock is scaled such that the additional wage payment equals to 10% of total government expenditure. I plot the perfect foresight transition paths of the average consumption, labor supply and wealth for each group of households divided by wealth level. Then I calculate the elasticities of households decision variables to the government spending shock.

Second, I evaluate whether the postwar U.S. government spending policy has reduced or amplified consumption and wealth inequalities. To do this, I simulate the model economy with and without the estimated government spending policies and compare the long-run average of consumption, labor supply and wealth of households in each wealth quintile.[10] In this exercise, I follow Krusell and Smith (1998) to solve the model with aggregate shocks.

5.1 Shocks to government goods purchases

Starting from the steady state, from $t = 0$ to $t = 3$, the government increases its goods purchases from the private sector by 10% of total government expenditure. The government reduces its goods purchases to its steady state level after four quarters. There is no public debt in the model economy, so the government finances the

[10] In each simulation, the model economy is simulated 4000 periods. The first 500 periods are discarded when calculating the long-run averages.

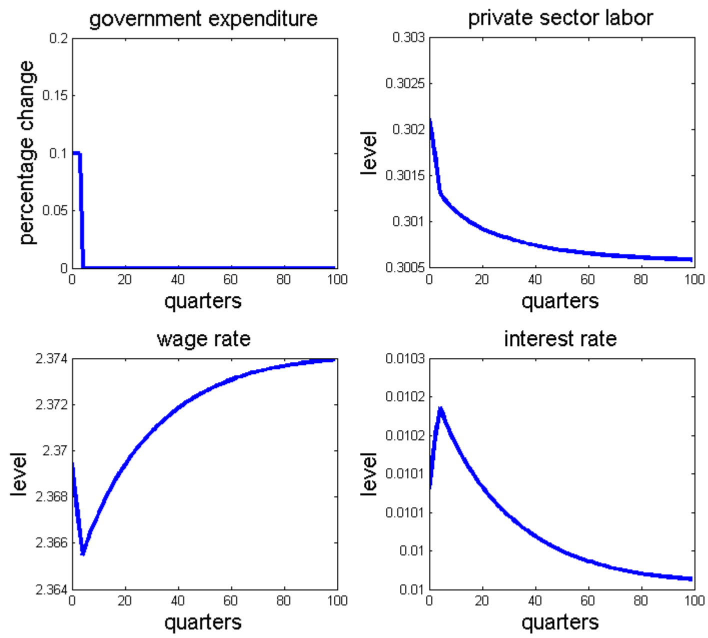
additional expenditures by increasing lump-sum taxes. Households are divided into quintiles according to their wealth levels k in order to evaluate the heterogeneous responses.

There are two channels through which the government spending shocks affect households: the wealth effect channel and the general equilibrium channel. On the one hand, there is a negative wealth effect since the government increases the usage of private resources. Households tend to reduce consumption and increase labor due to this negative wealth effect. Moreover, a shock to government goods purchases provides additional demand for private sector output, which pushes up the labor demand in private sector. As a result, as shown in the upper-right panel of Figure 3, private sector labor increases in equilibrium. On the other hand, the general equilibrium channel works through two factor prices: the wage rate and the interest rate. As shown in the lower panels of Figure 3, the positive change in private sector labor leads to an increase in interest rate but a fall in wage rate. The increase in the interest rate tends to increase the capital income which partially offsets the negative wealth effect. However, the fall in wage rate leads to a decrease in labor income which will amplify the negative wealth effect. Combining these two channels, the overall effect on households depends on the relative importance of capital income and labor income to the households.

Figures 4 through 6 show the average consumption, labor supply and capital choice responses by quintile. The sizes of the responses decrease significantly as households become wealthier. The households in the first quintile has the least wealth, so their main income source is labor income. As the wage rate goes down, their labor income falls. Together with the negative wealth effect caused directly by the shock, the overall effect on the households in the first quintile is large. In addition, since poor people are more likely to be financially constrained, they have less flexibility to smooth consumption. As the households become wealthier, their capital income increases. Consequently, the overall effect is dampened due to the increase in interest rate and the responses of consumption and capital is smaller.

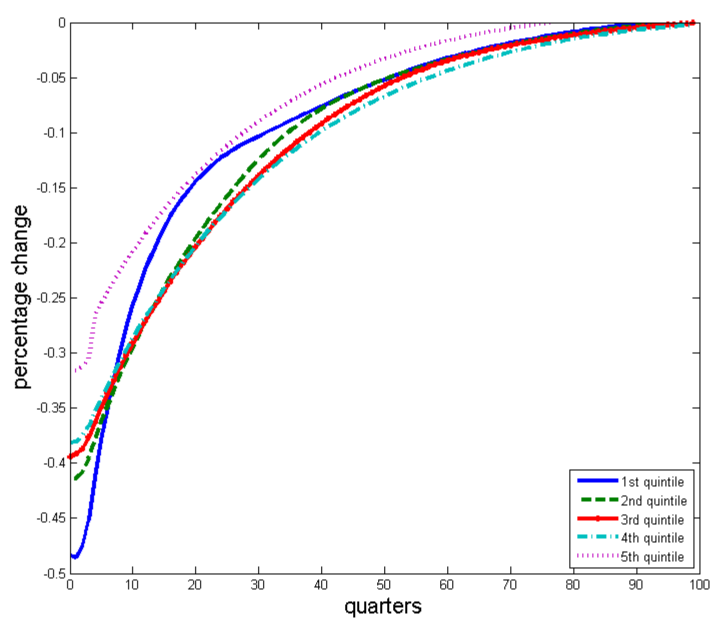
Table 6 shows the peak response elasticities of consumption, labor supply and capital to the government goods purchases shock in the experiment. The last column shows the difference of the elasticities between the 5th quintile and 1st quintile. It provides a measure of the heterogeneity in responses which can be used to compare the effects of government goods purchases shocks and government employment shocks. In this experiment, the poorest households have to reduce 0.018 percent more consumption and 0.230 percent more wealth for each one percent increase in government spending than the richest households, while they have to increase labor by 0.020 percent more than the richest quintile.

Figure 3: Private sector labor, wage and interest rate responses



The upper-right panel shows that this shock pushes up private sector labor in equilibrium. Therefore, wage rate goes down while interest rate increases as shown in the bottom panels.

Figure 4: Consumption responses to a government goods purchases shock



The consumption response is smaller as the households become wealthier. That is because a shock to government goods purchases drives down the wage rate and increases the interest rate, which benefits rich households while amplifies the income effects for lower income households.

Figure 5: Labor responses to a government goods purchases shock

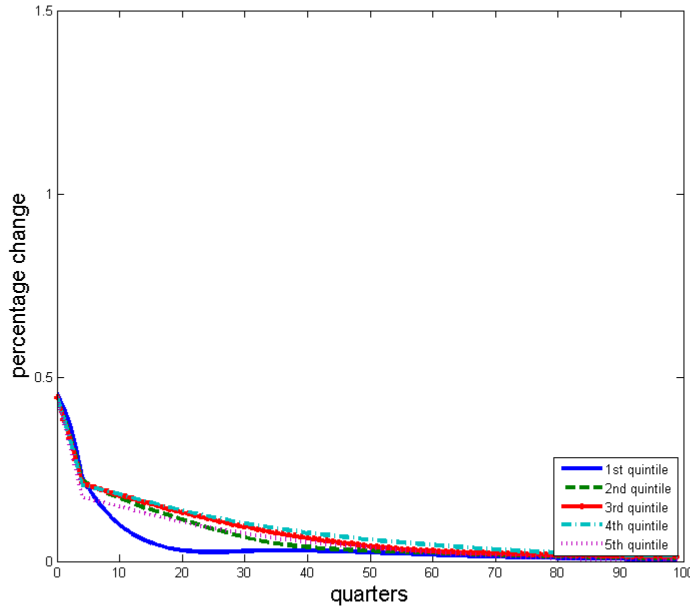


Figure 5: The labor supply response is smaller as the households become wealthier. The reason is similar to the consumption responses.

Figure 6: Capital responses to a government goods purchases shock

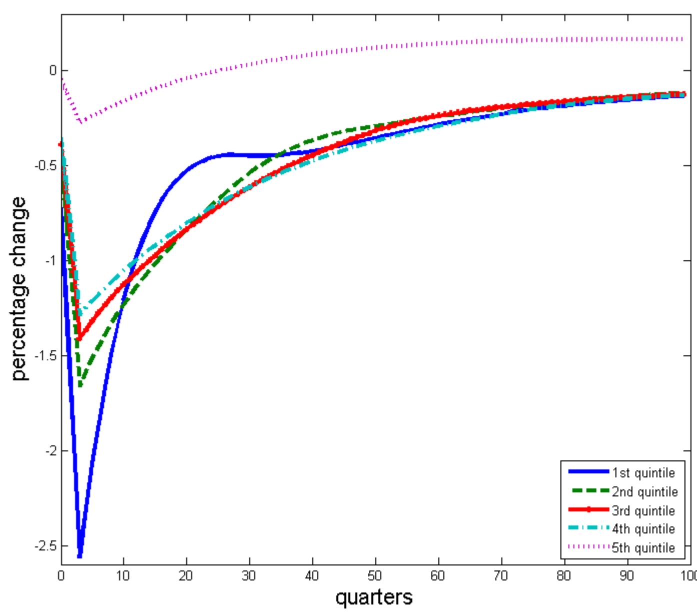


Figure 6: The capital choice response is smaller as the households become wealthier. The reason is similar to the consumption responses.

Table 6: peak response elasticity

	quintile					
	1st	2nd	3rd	4th	5th	gap
consumption	-0.049	-0.041	-0.039	-0.038	-0.031	-0.018
labor supply	0.046	0.044	0.044	0.045	0.044	0.020
wealth (capital)	-0.257	-0.166	-0.141	-0.129	-0.027	-0.230

5.2 Shocks to government employment

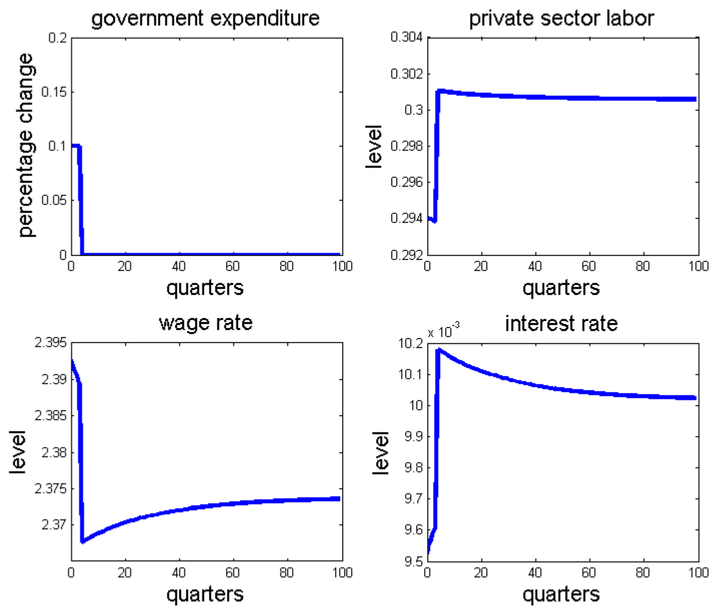
Starting again from the steady state, at $t = 0$, the government increases its employment for four quarters, then goes back to its steady state value. To make this experiment comparable to last one, the size of the shock is scaled such that the additional wage payment equals 10% of steady-state government expenditure. The additional government expenditures are financed by lump-sum taxes.

There are also two channels through which a government employment shock affects the economy. The wealth effect is weaker, because all of the additional taxes are repaid to the households as wage payments. Therefore, there is no significant increase in total labor supply. On the other hand, the shock directly creates additional labor demand in the government sector. As a result, as shown in the upper-right panel in Figure 7, private sector labor has to decrease in equilibrium. The decrease in private sector labor increases the wage rate and reduces the interest rate. That is, the general equilibrium effect increases labor income while it decreases capital income. The overall effect of a government employment shock also depends on the relative importance of capital income and labor income to the households.

Figures 8 through 10 show the average consumption, labor and capital responses by quintile. The sizes of the consumption and capital responses also decrease as the households become wealthier for the first four quintile. However, the difference of consumption responses are smaller compared to the responses to a government consumption shock.[11]Moreover, labor response is even larger as households become wealthier. This is because, the fall in the interest rate amplifies the negative wealth effect while the increase in the wage rate partially offsets the wealth effect, which reduces the gap of the overall effect on households with different wealth. In addition, the sizes of the labor responses are larger than in the case of a government goods purchases shock. The reason is, in addition to the wealth effect, the increase in wage rate itself encourages households to supply more labor.

[11]The sizes of consumption and capital responses for poor households are still larger than those for rich households. The reason is, the additional government expenditure is financed by lump-sum taxes which counts a larger share of income as households become less wealthier.

Figure 7: Private sector labor, wage and interest rate responses



The upper-right panel shows that this shock drives down private sector labor in equilibrium. Therefore, the wage rate goes up while the interest rate decreases as shown in the bottom panels.

Figure 8: Impulse Responses to A Government Employment Shock

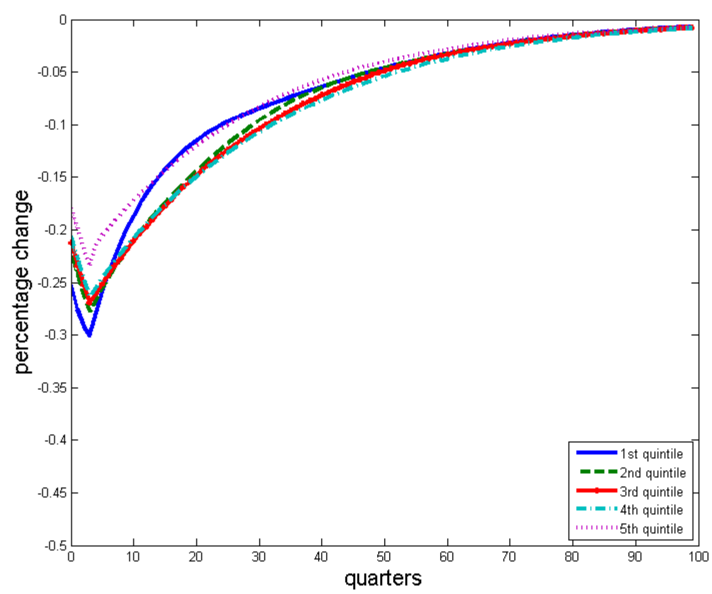


Figure 8: The consumption response is smaller as the households become wealthier. However, the difference of consumption responses are smaller compared to the responses to a government consumption shock. This is because, the fall in the interest rate amplifies the negative wealth effect while the increase in the wage rate partially offsets the wealth effect, which reduces the gap of the overall effect on households with different wealth.

Figure 9: Impulse Responses of Labor to a Government Employment Shock

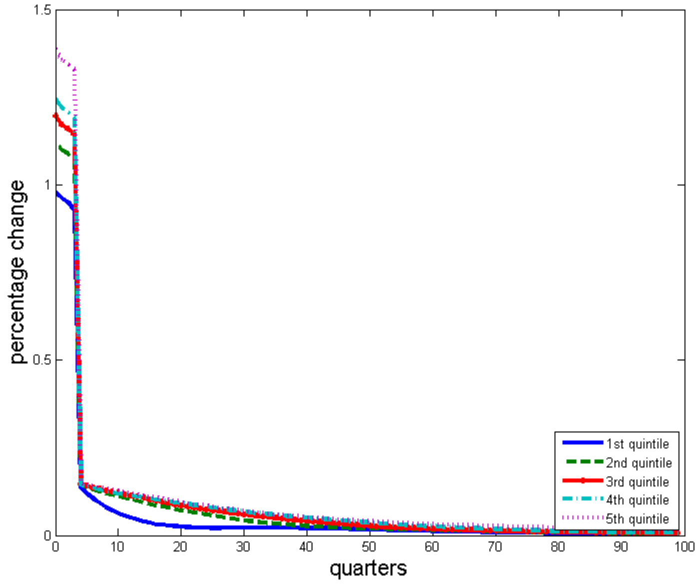
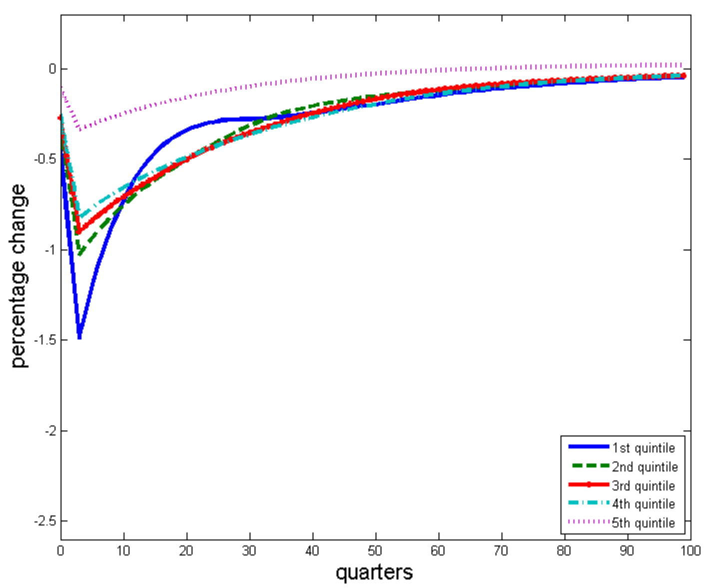


Figure 9: The labor supply response is larger as households become wealthier. The reason is similar to the consumption responses. The sizes of the labor responses are larger than the case with a government goods purchases shock. The reason is, besides wealth effect, the increase in the wage rate itself encourages households to supply more labor.

Figure 10: Impulse responses of capital to a government employment shock



The capital choice response is smaller as households become wealthier. However, the differences are smaller compared to the responses to a government consumption shock. The reason is similar to the consumption responses.

Table 7 shows the peak response elasticities of consumption, labor and capital to a government employment shock. Comparing Tables 6 and 7, we find that the differences in the consumption and capital responses between the richest households and poorest households are smaller under a shock to government employment. This illustrates the importance of the general equilibrium channel. It can amplify or narrow the disparity in the overall effect on households with different level of wealth, depending on how the shock affects factor prices.

Table 7: peak response elasticity

	quintile					
	1st	2nd	3rd	4th	5th	gap
consumption	-0.030	-0.028	-0.027	-0.026	-0.024	-0.006
labor supply	0.098	0.112	0.120	0.125	0.139	-0.041
wealth (capital)	-0.149	-0.103	-0.090	-0.082	-0.034	-0.115

5.3 U.S. government spending policy and inequality

Fiscal policies are often used as tools to smooth economic fluctuations. For example, the U.S. government announced the American Recovery and Reinvestment Act to combat the Great Recession. Several studies suggest that the government should conduct counter-cyclical government spending policies to smooth output fluctuations, especially when the nominal interest rate is constrained by the zero lower bound; see, for example Eggertsson (2010), Christiano et al. (2011) and Woodford (2011). Other studies, such as Edelberg et al. (1999), Barro and Redlick (2011), Ramey (2011), Drautzburg and Uhlig (2011) and Conley and Dupor (2013) show that government spending has negative or insignificant effects on private consumption or employment.

Instead of limiting the analysis to the aggregate effects of spending policies, this subsection answers questions about another aspect of fiscal policy: have government spending policies helped stabilize the U.S. economy? Do the policies dampen or amplify consumption and wealth inequalities? To address these questions, I solve the model with aggregate shocks and compare two simulations of the model economy. In one simulation, the aggregate state variables follow the joint processes described in Section 4.1.5 and estimated in Table 5. In the other simulation, I eliminate the stochastic components of government spending variables while keep the stochastic process of technology shocks. That is, in the second economy, the government keeps constant government goods purchases and employment while the aggregate technology level may fluctuate. I then compare the long-run averages of consumption, labor supply, and capital decisions from the two simulations.

I solve the model with aggregate shocks using the approximate aggregation method described in Krusell and Smith (1998). Briefly, this method works as follows: households act as if only a limited set of moments of μ matter for the determination of factor prices. Therefore, computing the equilibrium with aggregate fluctuations involves finding the value functions, policy functions, and law of motion for the aggregate capital and wage rate within the class of log-linear functions in K and aggregate shocks.[12]

The results are illustrated in Table 8 and 9. Table 8 shows the changes of long-run average consumption, and wealth of different quintiles of households from an economy with the postwar US policies to an economy with constant government spending.[13] As shown in Table 8, the lower four quintiles of households would have more average wealth and consumption in an economy without the estimated U.S. government spending policies. The wealthiest households, on the contrary, would reduce their average wealth and maintain the same level of consumption in such an economy. These findings illustrate that the estimated U.S. government spending can potentially amplify wealth and consumption inequalities. Table 9 confirms this. As shown in Table 9, in an economy without the U.S. policies, the long-run averages of wealth and consumption Gene coefficients are smaller. That is, lower income households are consuming more and holding more wealth while rich households get less share of consumption and wealth.

Table 8: The change of long-run average of consumption and wealth decisions without the estimated U.S. policy compared to the ones with the estimated policy

		quintiles				
		1st	2nd	3rd	4th	5th
wealth	change (%)	0.103	0.105	0.049	0.067	-0.018
consumption	change (%)	0.021	0.013	0.027	0.012	0.000

Table 9: The change in consumption and wealth inequalities without the estimated U.S. policy compared to the ones with the estimated policy

	Gene coefficient changes(%)
wealth	-0.06
consumption	-0.05

Government spending is often used as a policy tool to stabilize the economy. Table 10 compares the private output volatility of the two simulations. As shown in Table 10, I find that government spending policy provides no stability on the private output. In the model, I assume that households do not value public goods or public services,

[12] I use the first moment of assets only in predicting the law of motion for μ and approximation is very accurate as shown in the appendix.

[13] I simulate the economy for 4000 periods and the first 500 periods are discarded.

so the potential welfare implication of the public goods is ignored. However, this is beyond the scope of the current study. Moreover, as long as the public goods do not affect the marginal utility, the results in this study will not change.

Table 10: Output volatility

data	model: U.S. policy	model: fixed expenditure
3.90	3.97	3.95

Data source: Jones (2002)

6 Conclusion

This paper assesses the distributional effects of government spending shocks and examines whether the postwar U.S. government spending policy has dampened or amplified consumption and wealth inequalities. According to the empirical and quantitative studies, shocks to government goods purchases and government employment have dramatically different effects on prices and therefore on different households. Government spending shocks affect households by creating wealth effects and changing factor prices. Households responses depend on the type of government spending shocks and their sources of income. Quantitative analysis reveals that postwar U.S. government spending policy has amplified consumption and wealth inequality, while it has provided no stability on the private output.

Taking into explicit account different components in government spending, rather than treating government spending as consisting entirely of goods purchases, provides a more precise approach to evaluate fiscal policy. This approach extends the literature by bringing into attention the structure of government expenditure, which has been largely overlooked in existing studies and provides a new perspective to the debates over the effects of government spending. Given the better understanding on the impacts of different policy instruments, the immediate future research will be searching for the optimal policies to facilitate stable economic growth and reduce inequality.

Appendix

A. Proof of Proposition I

Use the labor-leisure condition (1), approximate $u_c(c, l)$ and $u_l(c, l)$ around (C, L), the aggregate consumption and labor supply, using Taylor expansion. We have:

$$u_l(C,L)+u_{lc}(C,L)(c-C)+u_{ll}(C,L)(l-L)+w[u_c(C,L)+u_{cc}(C,L)(c-C)+u_{cl}(C,L)(l-L)]=0$$

Integral over households. Since $\int_0^1 c_j dj = C$ and $\int_0^1 l_j dj = L = L_p + L_g$, we have:

$$u_l(C,L)+wu_c(C,L)=0$$

Take derivative with respect to G, we have:

$$\frac{\partial L_p}{\partial G}=[u_{lc}w+u_{ll}-\alpha\frac{w}{L_p}u_c+w(u_{cc}w+u_{cl})]^{-1}(u_{lc}+wu_{cc})>0$$

That is, the aggregate private sector labor $L_p(z,G,L_g)$ is strictly increasing in G.

Take derivative with respect to L_g, we have

$$\frac{\partial L_p}{\partial L_g}=[u_{lc}w+u_{ll}-\alpha\frac{w}{L_p}u_c+w(u_{cc}w+u_{cl})]^{-1}(-u_{ll}-wu_{cl})<0$$

That is, the aggregate private sector labor $L_p(z,G,L_g)$ is strictly decreasing in L_g.

In addition, I show how the factor prices change with G and L_g.

$$\frac{\partial w}{\partial G}=-\alpha(1-\alpha)K^\alpha L_p^{-\alpha-1}\frac{\partial L_p}{\partial G}<0$$

$$\frac{\partial r}{\partial G}=\alpha(1-\alpha)K^{\alpha-1}L_p^{-\alpha}\frac{\partial L_p}{\partial G}>0$$

$$\frac{\partial w}{\partial L_g}=-\alpha(1-\alpha)K^\alpha L_p^{-\alpha-1}\frac{\partial L_p}{\partial L_g}>0$$

$$\frac{\partial r}{\partial L_g}=\alpha(1-\alpha)K^{\alpha-1}L_p^{-\alpha}\frac{\partial L_p}{\partial L_g}<0$$

So, wage rate decreases (increases) in G (L_g) while interest rate increases (decreases) in G (L_g) .

B. The coefficients and R^2 in the forecasting rules

Table 11: Coefficients and $R^2$for the forecasting rules

z	G	L_g	$log(\bar{k}') =$	R^2	$log(w) =$	R^2
l	l	l	$0.0807 + 0.9658log(\bar{k})$	0.99995	$-0.2677 + 0.4542log(\bar{k})$	0.99740
m	l	l	$0.0895 + 0.9636log(\bar{k})$	0.99997	$-0.2483 + 0.4562log(\bar{k})$	0.99863
h	l	l	$0.0997 + 0.9608log(\bar{k})$	0.99994	$-0.2264 + 0.4571log(\bar{k})$	0.99638
l	m	l	$0.0826 + 0.9649log(\bar{k})$	0.99996	$-0.2793 + 0.4588log(\bar{k})$	0.99793
m	m	l	$0.0882 + 0.9639log(\bar{k})$	0.99995	$-0.2494 + 0.4565log(\bar{k})$	0.99689
h	m	l	$0.0967 + 0.9619log(\bar{k})$	0.99997	$-0.2209 + 0.4547log(\bar{k})$	0.99816
l	h	l	$0.0843 + 0.9640log(\bar{k})$	0.99991	$-0.2841 + 0.4606log(\bar{k})$	0.99471
m	h	l	$0.0885 + 0.9637log(\bar{k})$	0.99994	$-0.2523 + 0.4575log(\bar{k})$	0.99574
h	h	l	$0.0970 + 0.9616log(\bar{k})$	0.99996	$-0.2251 + 0.4563log(\bar{k})$	0.99770
l	l	m	$0.0831 + 0.9648log(\bar{k})$	0.99996	$-0.2732 + 0.4566log(\bar{k})$	0.99756
m	l	m	$0.0886 + 0.9639log(\bar{k})$	0.99997	$-0.2445 + 0.4547log(\bar{k})$	0.99792
h	l	m	$0.0944 + 0.9629log(\bar{k})$	0.99995	$-0.2100 + 0.4506log(\bar{k})$	0.99628
l	m	m	$0.0815 + 0.9653log(\bar{k})$	0.99996	$-0.2736 + 0.4565log(\bar{k})$	0.99729
m	m	m	$0.0895 + 0.9634log(\bar{k})$	0.99996	$-0.2512 + 0.4573log(\bar{k})$	0.99732
h	m	m	$0.0971 + 0.9617log(\bar{k})$	0.99996	$-0.2218 + 0.4552log(\bar{k})$	0.99781
l	h	m	$0.0930 + 0.9646log(\bar{k})$	0.99997	$-0.2833 + 0.4604log(\bar{k})$	0.99788
m	h	m	$0.0907 + 0.9628log(\bar{k})$	0.99996	$-0.2598 + 0.4606log(\bar{k})$	0.99682
h	h	m	$0.0969 + 0.9617log(\bar{k})$	0.99993	$-0.2223 + 0.4552log(\bar{k})$	0.99669
l	l	h	$0.0812 + 0.9656log(\bar{k})$	0.99994	$-0.2703 + 0.4554log(\bar{k})$	0.99636
m	l	h	$0.0910 + 0.9629log(\bar{k})$	0.99993	$-0.2500 + 0.4571log(\bar{k})$	0.99489
h	l	h	$0.0946 + 0.9628log(\bar{k})$	0.99994	$-0.2141 + 0.4523log(\bar{k})$	0.99551
l	m	h	$0.0821 + 0.9651log(\bar{k})$	0.99995	$-0.2764 + 0.4578log(\bar{k})$	0.99718
m	m	h	$0.0893 + 0.9635log(\bar{k})$	0.99994	$-0.2523 + 0.4578log(\bar{k})$	0.99561
h	m	h	$0.0956 + 0.9623log(\bar{k})$	0.99996	$-0.2175 + 0.4535log(\bar{k})$	0.99737
l	h	h	$0.0806 + 0.9655log(\bar{k})$	0.99998	$-0.2786 + 0.4585log(\bar{k})$	0.99888
m	h	h	$0.0901 + 0.9630log(\bar{k})$	0.99996	$-0.2574 + 0.4598log(\bar{k})$	0.99768
h	h	h	$0.0949 + 0.9624log(\bar{k})$	0.99995	$-0.2237 + 0.4560log(\bar{k})$	0.99698

l,m,h represent the low, medium and high states of the discretized stochastic processes, respectively.

C. Data

Following Mountford and Uhlig (2009), all the components of national income are in real per capita terms and are transformed from their nominal values by dividing them by the gdp deflator (NIPA table 7.1 Row 4) and the population measure (NIPA table 2.1 Row 35).

GDP: NIPA table 1.1 Row 1.

Private Consumption: NIPA table 1.1 Row 1.

Government Goods Purchases: This is total government expenditure taken from NIPA table 1.1.5, minus NIPA table 1.3.5 which is the gross value added by the general government including compensation of general government employees plus the general government consumption of fixed capital.

Government Employment: This is from Francis-Ramey Updates on Ramey's website.

Real Wages: This is 'Nonfarm Business Sector: Real Compensation Per Hour' Series COMPRNFB from the U.S. Department of Labor: Bureau of Labor Statistics.

Private Non-Residential Investment: This is 'Nominal Gross Private Domestic Investment', NIPA table 1.1 Row 6, minus private residential investment, NIPA table 1.1 Row 11.

Interest Rate: The ex post real interest rate is constructed using the federal funds rate and CPI inflation. Both of them are from the Federal Reserve Bank of St. Louis' database.

Adjust Reserves: This series is taken from the Adjusted Monetary Base at the Federal Reserve Bank of St. Louis' database.

PPIC: The Producer Price Index of Crude Materials is given by the ppicrm series at the Federal Reserve Bank of St. Louis' database. PPIC and Adjust Reserves are arithmeticaly avergaed of the monthly figures to get quarterly data.

GDP Deflator: NIPA table 7.1 Row 4.

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