The Heterogeneous Responses of Consumption between Poor and Rich to Government Spending Shocks

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Abstract

Government spending shocks have substantially different effects on consumers across the income distribution: consumption increases for the poor whereas it decreases for the rich in response to a rise in government expenditure. I shed light on this issue by incorporating a progressive tax scheme and productive public expenditure into a heterogeneous agent model economy with indivisible labor. When the government increases its spending and accompanies it by a rise in tax progressivity, the poor are employed and increase their consumption since after-tax wage rates increase while the rich decrease their consumption because of a fall in after-tax wage rates

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I Introduction

Understanding how government spending shocks affect an economy is important since fiscal instruments are often used to smooth economic fluctuations, and they may directly affect consumers' welfare. Existing papers in the literature have devoted a great deal of effort to finding the effects of government expenditure on real economic activity.[1] However, most of them have mainly focused on how government spending affects macro variables, such as aggregate output, consumption, and employment. In addition to the aggregate effects of a public spending shock, the distributional effects are also a central issue in public debates, considering increasing concerns about economic inequality. Accounting for this issue is also of importance to the discussion of economic policies since it is closely related to stabilization and redistributive policies.

In fact, government spending shocks have substantially different impact on different consumers. Figure 1 exhibits the responses of average non-durable consumption across income quintiles to government spending shocks using the Consumer and Expenditure Survey (CEX), which spans from the first quarter of 1980 to the third quarter of 2008.[2] I use the Survey of Professional Forecasters (SPF) shocks as the measure of government spending policy shocks following Ramey (2011) and Anderson, Inoue and Rossi (2016).[3] In order to study the effects of a government spending shock, I consider a three-variable Vector Autoregressive (VAR) model including the SPF shock, government spending, and consumption.[4] As shown in Figure 1, there are substantial differences in the responses of consumption across income groups to spending shocks: consumption increases for the poor while it decreases for the rich when government expenditure rises. The peak multipliers for the first three quintiles are positive while they are negative for the top two quintiles.[5] For example, the peak multiplier for the lowest income quintile is 0.14 whereas that of the highest is -0.37. In other words, when government increases its spending by one dollar, poorest consumers increase their consumption by 14 cents, but consumption for the richest decreases by 37 cents on average.[6] These empirical results are consistent with those in Anderson, Inoue and Rossi (2016) and De Giorgi and Gambetti (2012).

However, theoretical backgrounds for these empirical findings are unclear. As discussed by Anderson, Inoue and Rossi (2016), the behaviors of the poor and the rich can be respectively explained by different theories. For example, the responses of individuals in the lower income groups can be

[1] For example, empirical studies such as Blanchard and Perotti (2002), Gali, Lopez-Salido and Valles (2007) and Zubairy (2010) find significantly positive responses of output and consumption to an increase in government spending.

[2] I exclude zero lower bound (ZLB) periods and onward, but I find that estimation results for the full sample (1980:I-2015:III) are still robust. See appendix for details.

[3] The measure of SPF shocks is defined as the difference between actual federal spending growth and the one-quarter ahead SPF forecasted growth.

[4] See appendix for detail on the data and the estimation approach.

[5] The peak multiplier for a group j is computed as $max_h sign\left(\frac{\Delta log C^j_{t+h}}{\Delta log G_t}\right) \left| \frac{\Delta log C^j_{t+h}}{\Delta log G_t} \right| \frac{\overline{C^j}}{\overline{G}}$ where $\frac{\overline{C^j}}{\overline{G}}$ is the average ratio of consumption of the group j to government spending.

[6] These findings are robust when the cumulative multipliers are used as a measure of the effects of government spending shocks. The integral multiplier is defined as the sum of the responses of consumption divided by the sum of changes in government expenditure.

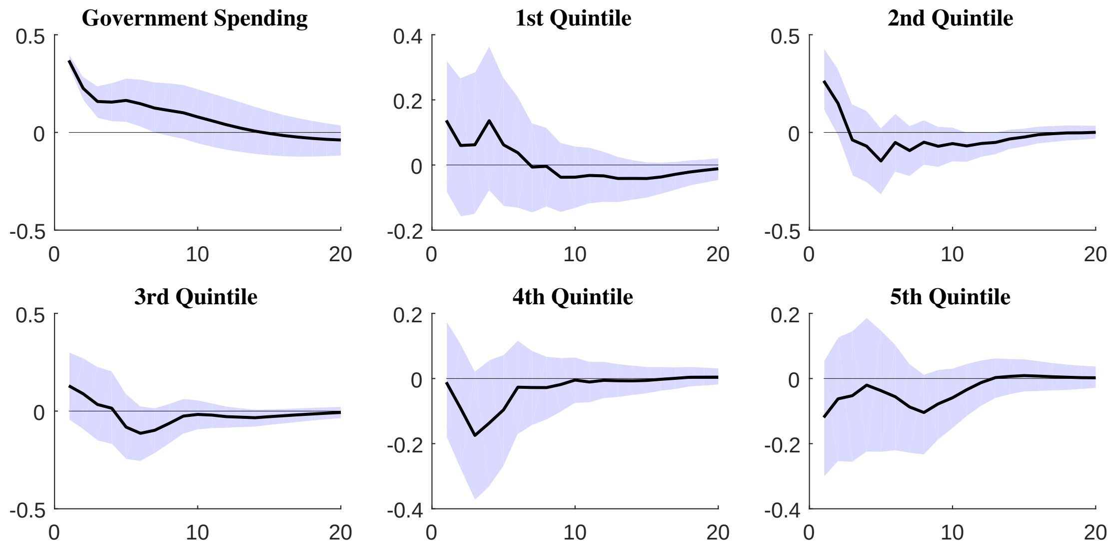

Figure 1. Responses of Consumption across Income Quintiles

Note: Responses of logged real per capita government spending and logged average real per capita consumption across the income quintiles to a SPF shock. The sample periods are 1980:I-2008:III. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile. The shaded regions are the 68 percent confidence bands generated by Monte Carlo simulations.

supported by traditional Keynesian theory such as IS-LM models, while the behavior of the rich can be explained by Neoclassical growth theory including Real Business Cycle (RBC) models.[7] Therefore, this study tries to account for why government expenditure shocks affect consumers differently using a quantitative analysis based on a heterogeneous agent economy.

To this aim, I build a simple dynamic stochastic general equilibrium (DSGE) model where there are a large population of heterogeneous households, a government, and many identical firms. The model economy can be characterized by four main features. First, a household is assumed to not fully insure against idiosyncratic productivity shocks that she faces: the asset market is incomplete as in Huggett (1993) and Aiyagari (1994). Second, it is assumed that a labor supply decision for a household is indivisible following Hansen (1985) and Chang and Kim (2007). Third, and more importantly, the model economy allows for a progressive taxation scheme following Persson (1983), Benabou (2002), Heathcote, Storesletten and Violante (2014) and Ferriere and Navarro (2017). Lastly, firms' production is assumed to be positively affected by government activity: government spending is productive as in Barro (1990) and Baxter and King (1993).

The model economy in which government spending is financed by a change in progressivity successfully replicates the different responses of consumption between the poor and the rich to government spending shocks. In the model economy, when the government increases its spending unexpectedly,

[7]In the Neoclassical growth theory such as the RBC model, consumers lower their consumption after a positive government spending shock mainly due to a negative wealth effect induced by an increase in current or future taxes. On the other hand, according to the textbook IS-LM theory, households increase their consumption in response to a positive spending shock since they behave in a non-Ricardian fashion.

there are two main effects on after-tax wage rates, which are key factors in determining households' consumption and employment.[8] One is an increase in tax progressivity to finance government expenditure, and the other is a rise in labor demand induced by productive government spending. The former has different impacts on after-tax wages across individual income levels while the latter is an economy-wide positive effect on post-tax wages. Specifically, after-tax wage rates rise for consumers in the bottom income quintiles since an increase in wage rates induced by productive government spending dominates a slight rise in tax rates, while post-tax wage rates fall for the top income groups since the positive wage effect cannot fully offset a significant increase in income tax rates. Indivisibility of a labor supply decision helps the poor increase their consumption since households in the lower quintiles are marginal workers, and hence they are employed in response to positive government spending shocks. I also provide supportive empirical evidence for the key channels of the model. First, I empirically document that tax progressivity rises in response to positive public spending shocks. Second, I also find empirical evidence that poor households increase employment while employment rates for the rich tend to decrease in response to positive government spending shocks.

The remainder of this paper is organized as follows. The previous studies related to this work are summarized in Section II. In Section III, I build an incomplete asset market model that employs a progressive tax system, indivisible labor, and productive government spending. Sections IV and V summarize the key findings of the model economy. Section VI concludes.

II Related Literature

This study contributes the literature by providing a theoretical background for the observed distributional effects of government spending shocks. De Giorgi and Gambetti (2012) and Anderson, Inoue and Rossi (2016) study empirical evidence for the heterogeneous effects of an unexpected government spending shock on consumers. Using the CEX data, De Giorgi and Gambetti (2012) employ the common components of the consumption deciles in a VAR with a government spending shock. Their main result is that consumption increases at the bottom of consumption distribution while it falls at the top after a government spending shock. Using a VAR with the SPF shocks, Anderson, Inoue and Rossi (2016) also find that unexpected increases in government spending hurt the working-age and the wealthiest individual the most in terms of consumption. This empirical finding can be rationalized by the model economy in this study. Other related empirical work is Owyang and Zubairy (2013) and Giavazzi and McMahon (2012).[9]

[8] As discussed in Hall (2009), the intratemporal optimality condition is a key to account for the effect of the government expenditure on consumption.

[9] Owyang and Zubairy (2013) investigate the effects of federal government spending shocks on state-level variables and find significant variation in the responses of state-level personal income and employment. Using household-level data, including the Panel Study of Income Dynamics (PSID) and the CEX, Giavazzi and McMahon (2012) also study how individuals respond to a change in government expenditure and find significant heterogeneous responses of hours, consumption, and real wages across households to a spending shock.

Additionally, this study is complementary to a chain of quantitative papers incorporating heterogeneity across individual households to account for the effects of fiscal policies. Key contributions are Heathcote (2005), Ferriere and Navarro (2017), and Gali, Lopez-Salido and Valles (2007). Heathcote (2005) provides one of the first frameworks linking a fiscal policy with heterogeneous agents. He develops a model economy of incomplete capital markets to analyze how changes in the timing of linear taxes for income affect an economy in the short run. The main result of his work is that when capital markets are incomplete, income tax cuts affect consumption largely compared the complete market economy. Heathcote (2005) focuses on the impacts of tax shocks on individual consumption whereas this paper considers the effects of government spending shocks on consumers. The model economy in this study is probably closest to that in Ferriere and Navarro (2017). They adopt an incomplete market model which incorporates indivisible labor and progressive taxes to assess the effects of government spending. From the simulation result of the model, they argue that when government expenditure is financed with a more progressive taxation scheme, a multiplier on aggregate consumption can be positive. While Ferriere and Navarro (2017) mainly focus on the responses of macro variables by asking how government spending can be expansionary, this paper focuses more on the disaggregate effects of government expenditure on consumption across income groups. Relative to the government spending analysis of Ferriere and Navarro (2017), I add productive government spending, which is also an important feature to account for the reasonable responses of key macro and micro variables.[10] Gali, Lopez-Salido and Valles (2007) finds that sticky prices and constrained consumers (also called rule-of-thumb or non-Ricardian consumers) in the context of calibrated New Keynesian models can reproduce an increase in aggregate consumption in response to a rise in public expenditure.[11] While there are only two types of heterogeneity in the model economy in Gali, Lopez-Salido and Valles (2007), the model economy in this paper generates rich heterogeneity across households' wealth, income, and consumption. Compared to work of Gali, Lopez-Salido and Valles (2007), another contribution of this study is that the model economy can successfully account for the responses of both aggregate and disaggregate consumption to government spending shocks without introducing non-Ricardian consumers. Other studies on analyzing relevance of heterogeneity for fiscal policies are Kaplan and Violante (2014), Heathcote, Storesletten and Violante (2014), and Chang, Chang and Kim (2016).

III The Model

I develop a simple dynamic stochastic general equilibrium (DSGE) model which employs a continuum (measure one) of heterogeneous households, a government, and many identical firms. In the

[10] For example, with this assumption, the model economy can generate an increase in the wage rate in response to positive government spending shocks, while the standard RBC model predict a decrease in wages.

[11] In the model of Gali, Lopez-Salido and Valles (2007), constrained households are assumed to behave in a "hand-to-mouth" manner. In other words, they completely consume their labor income earned in the current period, and they cannot intertemporally optimize their consumption. Hence, constrained consumers tend not to smooth their consumption path in the face of fluctuations in taxes.

model economy, there are four main assumptions. First, asset markets are incomplete as in Huggett (1993) and Aiyagari (1994) in that households cannot fully insure against their idiosyncratic productivity shocks. This assumption helps generate substantial heterogeneity across characteristics of individual households including wealth, income, employment status, and consumption. Second, following Hansen (1985), Rogerson (1988) and Chang and Kim (2007), it is assumed that a household indivisibly decides hours of work.[12] Third, more importantly, the model economy allows for a progressive taxation scheme for the government following Persson (1983), Benabou (2002), Heathcote, Storesletten and Violante (2014) and Ferriere and Navarro (2017). Lastly, government expenditure is productive in the production of firms: the firms' production is affected by productive government activity (Barro, 1990; Baxter and King, 1993; Fisher and Turnovsky, 1995; Leeper, Walker and Yang, 2010). The different tax burden helps consumers have different after-tax wage rates across their income, which is a main source of the heterogeneous responses of consumption across the income distribution. In particular, an interaction between productive public spending and a discrete labor decision allows poor households to be employed, and hence their consumption increases in response to a rise in government expenditure. Thus, I contribute to the literature by incorporating productive public expenditure and progressivie taxation into a heterogeneous agent model economy.

A Environment

Households

Each household maximizes her expected lifetime utility over consumption c_t and hours of work h_t , shown as :

$$\max_{\{c_t,h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\ln c_t - \chi \frac{h_t^{1+1/\phi}}{1+1/\phi} \right) \right]$$

subject to

$$c_t + a_{t+1} = w_t x_t h_t + (1+r_t)a_t - T(w_t x_t h_t + r_t a_t),$$

$$c_t > 0 \text{ and } a_{t+1} \geq \bar{b},$$

where $0 < \beta < 1$ denotes the time discount factor, $\chi > 0$ is a parameter for disutility from working, and ϕ represents labor supply elasticity. When a household works for h_t amount of hours, she earns $w_t x_t h_t$ as wage earnings, where w_t is the wage rate for the efficiency unit of labor, and x_t

[12] As is well-known, extensive margins for time devoted to work play an important role in accounting for the variation in total hours worked.

denotes her labor productivity. A household can save or borrow by trading a claim for assets a_t, which yields the real rate of return, r_t. A household faces a borrowing constraint that limits the fixed amount of debt: the assets holding cannot go below $\bar{b}$ at any time. Each household should pay taxes T, which depend on her total income (the sum of labor and capital income), $w_t x_t h_t + r_t a_t$.[13] Importantly, it is assumed that a labor supply decision made by a household is indivisible following Hansen (1985), Rogerson (1988), and Chang and Kim (2007): a household supplies a fixed amount of hours ($h_t = \bar{h}$), or she does not work at all ($h_t = 0$). Accordingly, there are two employment statuses for each household: employment and non-employment. The capital markets are incomplete following Huggett (1993) and Aiyagari (1994): households cannot issue any assets contingent on their future idiosyncratic risks x, which follows a stochastic process with transition probabilities $P_x(x'|x) = Pr(x_{t+1} = x'|x_t = x)$. In addition, it is assumed that the idiosyncratic risks to productivity follow an AR(1) process in logs:

$$\ln x' = \rho_x \ln x + \varepsilon_x, \quad \varepsilon_x \sim N(0, {\sigma_x}^2).$$

Firms

The production technology for the representative firms is represented by the function given by:

$$F(K, L, G) \equiv K^\alpha L^{1-\alpha} G^\gamma,$$

where K, L and α denote aggregate capital, aggregate effective labor, capital income share, respectively. Particularly, following Barro (1990), Baxter and King (1993), Fisher and Turnovsky (1995), and Leeper, Walker and Yang (2010), it is assumed that government spending, G, can affect a firm's production characterized by a parameter γ, which represents the degree of government expenditure externality or output elasticity of public expenditure. That is, an increase in public expenditure raises a firm's productivity directly. It is widely recognized that government spending on roads, public research spending, and medical services raises the potential production of an economy.[14] G can be interpreted as a stock of public capital as in Baxter and King (1993) and Leeper, Walker and Yang (2010), while in this study it is considered as a flow of productive public services or public goods for production following Futagami, Iwaisako and Ohdoi (2008), Kamiguchi and Tamai (2011) and Albertini, Poirier and Roulleau-Pasdeloup (2014). However, the quantitative results of the two perspectives are similar.[15]

The representative firm makes decisions for labor and capital demand to maximize current profits such that:

$$\Pi_t = \max_{K_t, L_t} \left\{ K_t^\alpha L_t^{1-\alpha} G_t^\gamma - w_t L_t - (r_t + \delta) K_t \right\},$$

where δ is the depreciation rate for capital.

[13]The form of a taxation scheme in the model will be discussed in details.
[14]For empirical evidence on the productive government spending, see Bom and Ligthart (2014).
[15]Regarding this issue, see the working paper of Albertini, Poirier and Roulleau-Pasdeloup (2014) for details.

The Government

The government exogenously spends its expenditure in every period. Specifically, a government spending shock is assumed to follow a stochastic process with an AR(1) process:

$$g' = \rho_g g + \varepsilon_g, \quad \varepsilon_g \sim N(0, {\sigma_g}^2),$$

where g denotes log deviation of G from its steady state, i.e., $g \equiv \ln G - \ln G_{ss}$, and G_{ss} is the steady state level of government spending.[16]

The income tax schedule of an individual household is assumed to follow a log-linear tax function, which is characterized by two parameters λ and τ:

$$T(y) \equiv \begin{cases} \max\{(1-\lambda y^{-\tau})y, 0\} & if\ y \geq 0 \\ 0 & if\ y < 0 \end{cases}, \tag{1}$$

where y represents individual income, and τ denotes the progressivity of the tax system, and λ characterizes the average level of taxation.[17] $\max\{(1-\lambda y^{-\tau})y, 0\}$ implies no negative taxes or no public transfers. Suppose that y is positive. Positive (negative) τ means that the tax system is progressive (regressive): marginal tax rates are larger (lower) than average rates. Particularly, when $\tau = 0$, the tax system is affine taxation: marginal tax rates are the same as average rates, and, therefore, $T(y) = (1-\lambda)y$. This type of the taxation function is widely used in various studies such as Heathcote, Storesletten and Violante (2014) and Chang, Chang and Kim (2016).

Recursive Representation

Consider a recursive equilibrium for the model economy. For each household, the individual state variable is the vector $\theta \equiv (a, x)$, and the aggregate state is the vector $\Theta \equiv (\mu, G)$ where μ is a joint distribution of asset holdings and productivity across households. The Bellman equation for a employed worker $V^E(\theta, \Theta)$ is defined as:

$$V^E(\theta, \Theta) = \max_{c,a'} \left\{ \ln c - \chi \frac{\overline{h}^{1+1/\phi}}{1+1/\phi} + \beta \mathbb{E}\left[V(\theta', \Theta')\right] \right\}$$

subject to

$$c + a' = w(\Theta)x\overline{h} + (1 + r(\Theta))a - T(w(\Theta)x\overline{h} + r(\Theta)a), c > 0,\ a' \geq \overline{b},$$

[16] It is assumed that government spending shocks and the individual shocks are independent of each other.

[17] With positive y, $1-\tau$ can be interpreted as a measure for the elasticity of after-tax income to before-tax income (Heathcote, Storesletten and Violante, 2014).

and

$$\mu' = \Psi(\mu, G)$$

where Ψ denotes a forecasting function for μ.

The value function for a non-employed worker, denoted by $V^N(\theta, \Theta)$, is:

$$V^N(\theta, \Theta) = \max_{c,a'} \{\ln c + \beta \mathbb{E}\left[V(\theta', \Theta')\right]\}$$

subject to

$$c + a' = (1 + r(\Theta))a - T(r(\Theta)a), c > 0,\ a' \geq \bar{b}, \text{ and } \mu' = \Psi(\mu, G)$$

The value function $V(\theta, \Theta)$ is defined as:

$$V(\theta, \Theta) = \max_{h \in \{0, \bar{h}\}} \left\{V^E(\theta, \Theta), V^N(\theta, \Theta)\right\}.$$

B Definition of Equilibrium

A recursive competitive equilibrium is a transition operator $\Psi(\Theta)$, a set of factors $\{K(\Theta), L(\Theta)\}$, a set of value functions $\{V^E(\theta, \Theta)$,$V^N(\theta, \Theta)$, $V(\theta, \Theta)\}$, a set of market prices $\{w(\Theta), r(\Theta)\}$, and a set of policy functions $\{c(\theta, \Theta)$,$a'(\theta, \Theta)$,$h(\theta, \Theta)\}$ such that:

1) Individual optimization: Given market prices, $w(\Theta)$ and $r(\Theta)$, optimal decision rules $c(\theta, \Theta)$, $a'(\theta, \Theta)$ and $h(\theta, \Theta)$ solve the Bellman equations.

2) The firm's profit maximization: $K(\Theta)$ and $L(\Theta)$ satisfy $F_L(K, L, G) = w(\Theta)$ and $F_K(K, L, G)$ $= r(\Theta) + \delta$ for all Θ.

3) Markets clearing: For all Θ,

    - Labor market clearing: $L(\Theta) = \int xh(\theta, \Theta)d\mu$,
    - Capital market clearing: $K(\Theta) = \int a d\mu$, and
    - Goods market clearing: $K(\Theta)^\alpha L(\Theta)^{1-\alpha} G^\gamma = C(\Theta) + I(\Theta) + G$ where $C(\Theta) = \int c(\theta, \Theta)d\mu$, and $I(\Theta) = K'(\Theta) - (1 - \delta)K(\Theta)$.

4) Balanced budget of the government: $G = \int T(w(\Theta)xh(\theta, \Theta) + r(\Theta)a)d\mu$ for all Θ.

5) Consistency of individual and aggregate behaviors.

Table 1—Parameters of the Model Economy

Parameter	Value	Description
β	0.98703	Time discount factor
$\overline{h}$	1/3	Extensive margin for hours worked
ϕ	0.3	Labor supply elasticity
χ	352.27	Parameter for disutility from working
ρ_x	0.939	Persistence of productivity shocks
σ_x	0.287	Standard deviation of productivity shocks
$\overline{b}$	-2.0	Borrowing constraint
α	0.33	Capital income share
δ	0.025	Capital depreciation rate
γ	0.15	Output elasticity of public expenditure
ρ_g	0.92	Persistence of government spending shocks
σ_g	0.012	Standard deviation of government spending shocks
G_{ss}/Y_{ss}	0.2	Steady state ratio of G to Y
λ	0.740	Parameter for average tax rate in steady state
τ	0.20	Progressivity of taxes in steady state
ω	0.85	Tax policy parameter

C Calibration

In this section, I discuss calibration for the parameters used in the model economy. A simulation period is a quarter in the model, which is consistent with that of the CEX data used in Section III. Table 1 summarizes the parameter values used in the model economy.

Preference and Borrowing Constraint

The parameter ϕ, which represents the micro elasticity of labor supply, is set to 0.3. This value is based on the findings that conventional micro estimates of the elasticity of labor supply are small $(0-0.5)$.[18] Fixed amount of hours worked, $\overline{h}$, is chosen to be $1/3$. The time discount factor, β, and the disutility parameter of working, χ, are set so that quarterly return to capital is one percent, and the employment rate is 70 percent. The U.S. data such as the PSID and Survey of Consumer Finances (SCF) consistently report that employment rates are around 70 percent.[19] The borrowing constraint, $\overline{b}$, is -2.0, which is approximately double the quarterly average income in the model economy.[20]

Production Technology

The capital income share, α, and the quarterly depreciation rate, δ, are calibrated to be 0.33 and 2.5 percent, respectively. The output elasticity of public capital, γ, differs substantially across studies.

[18] It is noted that the choice of ϕ does not affect the simulated results due to indivisibility of a labor supply decision for households.

[19] Self-employed workers are included for the calculation of employment rates as they are also included in the CEX data.

[20] With this value, the fraction of households who own zero or negative wealth is around 20 percent, which is consistent with that in the U.S. data such as the PSID 1994.

Bom and Ligthart (2014) estimate the average of the output elasticity of public expenditure over 578 different estimates from 68 studies for various countries. I compute the simple average of estimates for the U.S. from Table A1 of Bom and Ligthart (2014) and find that it is 0.148.[21] Thus, I set $\gamma = 0.15$.

Labor Productivity

For individual labor productivity shocks, previous studies in the literature including Floden and Linde (2001), French (2005), Chang and Kim (2006), and Chang, Kim and Schorfheide (2013) consistently report that the shocks are persistent and variance of them is also large. Following Chang, Kim and Schorfheide (2013), I set $\rho_x = 0.939$ and $\sigma_x = 0.287$, which are estimated with the AR(1) wage process from the PSID.[22]

Government

Regarding the government spending shocks, I choose $\rho_g = 0.92$ and $\sigma_g = 0.015$ from the estimates of Zubairy (2014). The steady-state ratio of the government spending to GDP is set to be 0.2 ($G_{ss}/Y_{ss} = 0.2$). The steady-state level of tax progressivity, τ, is calibrated to be 0.2, which is the average of progressivity using two different measures for the sample periods between 1980 and 2007.[23] In the steady state, the parameter λ is chosen so that the government runs a balanced budget.

IV Cross-sectional Distributions

As I investigate the distributional effects of the government spending shocks on consumption across the income quintiles, I first analyze if the model economy generates reasonable heterogeneity across individual households. Particularly, it is important to reasonably replicate consumption distribution or average consumption across the income quintiles as a means to an end for this study.

Table 2 summarizes the detailed information on income and asset holdings from the U.S data (the SCF 1992 and the PSID 1994) and the model.[24] Overall, the wealth is less concentrated in the model economy. The wealth Gini indexes for the SCF 1992 and the PSID 1994 are 0.78 and 0.79, respectively, while it is 0.62 in the model economy. However, the primary objective in this paper is not to account for the highly concentrated wealth distribution.[25]

[21] Bom and Ligthart (2014) find that the simple average estimate for the whole sample is 0.188.

[22] Chang, Kim and Schorfheide (2013) use the maximum-likelihood estimation (MLE) of Heckman (1979) when they estimate the AR(1) process of wage rates in logs to solve the self-selection problem for wage workers.

[23] Based on the same tax schedule function of this study, Heathcote, Storesletten and Violante (2014) find that the estimate of progressivity parameter is around 0.15 - 0.23.

[24] I use the PSID 1994 survey because this survey year has information on both wealth and income, and it falls in the midpoint of the sample period of the CEX in this study. For a robustness check, I use the SCF 1992, which is from Diaz-Gimenez, Quadrini and Rios-Rull (1997).

[25] For studies on highly concentrated wealth distribution in the context of the heterogeneous agent model frameworks, see Quadrini (2000), Castaneda, Diaz-Giminez and Rios-Rull (2003) and Cagetti and De Nardi (2006).

Table 2— Distribution of Wealth and Income

	Quintile					Gini
	1st	2nd	3rd	4th	5th	
Panel A: Wealth Distribution						
Data						
SCF 1992	-0.39	1.74	5.72	13.43	79.49	0.78
PSID 1994	-1.22	0.88	4.98	14.68	80.68	0.79
Model Economy	-3.13	3.49	12.72	26.86	60.06	0.62
Panel B: Income Distribution						
Data						
SCF 1992	2.18	6.63	11.80	19.47	59.91	0.57
PSID 1994	-0.27	5.06	13.94	24.80	56.48	0.57
Model Economy	1.59	6.13	13.15	24.08	55.05	0.53

Note: Distributions of wealth (Panel A) and income (Panel B) for U.S. data and the model economy. Statistics for the SCF 1992 are from Diaz-Gimenez, Quadrini and Rios-Rull (1997).

The model economy successfully reproduces the income distribution, which is a baseline dimension of inequality in this paper to study the distributional effects on the government spending shocks on consumption across the income quintiles. In both data and model economy, households in the first quintile earn less than three percent of total income, and the income share for the fifth quintile is around 60 percent.[26] The Gini coefficient for income in the model is 0.53, which is close to the data (0.57). In order to take a close look at characteristics of the income distribution, I compute various dimensions of inequality, including the consumption shares and average consumption (per capita) across the income quintiles for the data and the model economy in Table 3.[27] As shown in the U.S data, the increasing pattern of labor supply (the employment rates) across the income quintiles is well-reproduced in the model economy.[28] Also, the consumption shares across the income distribution are successfully reproduced: households in the lowest income quintile consume 11.02 percent and 13.91 percent of total consumption in the data and the model, respectively, while households in the top quintile consume 33.31 percent and 28.93 percent of total consumption in the data and the model, respectively. Importantly, average consumption (per capita) across the income quintiles in the model economy fits the U.S. data well.[29] The first and the fifth quintiles of the income distribution in the model economy consume $1,550 (in U.S. dollars for year 2000) and $3,230

[26]The negative income for the income-poorest may come from their business or capital losses (Diaz-Gimnnez, Glover and Rios-Rull, 2011). Using the SCF, Diaz-Gimenez, Quadrini and Rios-Rull (1997) and Diaz-Gimnnez, Glover and Rios-Rull (2011) also find that the income-poorest have negative income.

[27]Statistics for income and employment rates are from the PSID 1994, and information on consumption is computed from the CEX averages.

[28]This is hard to obtain in a standard incomplete market model.

[29]For comparison between the data and the model economy, I adjust the units of consumption in a way that average consumption of the model economy matches mean consumption in the CEX. Average quarterly consumption for data and the model is in U.S. dollars for year 2000.

Table 3— Characteristics of Income Distribution (ranked by income)

	Quintile					All
	1st	2nd	3rd	4th	5th	
Panel A: Data						
Share of income	-0.27	5.06	13.94	24.80	56.48	100
Group average/Sample average	-0.01	0.25	0.70	1.24	2.82	1
Employment rate	17.51	67.90	85.82	93.76	96.25	72.2
Share of consumption	11.02	15.07	18.07	22.53	33.31	100
Average consumption ($\times\$10^3$)	1.23	1.68	2.01	2.51	3.71	2.23
MPC	0.58	0.49	0.47	0.44	0.40	0.48
Panel B: Model Economy						
Share of income	1.59	6.13	13.15	24.08	55.05	100
Group average/Pop. average	0.08	0.31	0.66	1.20	2.75	1
Employment rate	10.79	50.92	88.76	99.82	99.99	70.0
Share of consumption	13.91	17.38	18.20	21.59	28.93	100
Average consumption ($\times\$10^3$)	1.55	1.94	2.03	2.41	3.23	2.23
MPC	0.86	0.63	0.60	0.80	0.56	0.69

Note: Characteristics of income distribution. Statistics for income and employment rates are from the PSID 1994. Statistics for consumption are computed from the CEX 1980:I-2007:I. The average quarterly per capita consumption for the data and the model is in thousands of U.S. dollars for year 2000. The values of MPC in the data are from Jappelli and Pistaferri (2014). The quarterly MPCs in the model are transformed into annual ones using the formula $1-(1-\text{quarterly MPC})^4$.

over a quarter, respectively, which are comparable to the data ($1,230 and $3,710, respectively).

Next, I compare the marginal propensity to consume (MPC) produced in the model to the empirical values in the literature. The average MPC in the model is 0.69, which is much larger than the 0.33 reported in Sahm, Shapiro and Slemrod (2010) or the 0.48 in Jappelli and Pistaferri (2014).[30] The model economy generates the higher MPC since both individual and aggregate shocks are highly persistent, while most of the estimates of MPC in the exiting empirical papers are based on the tax rebate policies in 2001 and 2008 (e.g., Johnson, Parker and Souleles (2006) and Sahm, Shapiro and Slemrod (2010) among others), which are temporary changes in income.[31] The MPCs across income quintiles for the data and the model are reported in the last row of Panel A and B in Table 3, respectively. As reported in Jappelli and Pistaferri (2014), there are a wide range of heterogeneity in the MPC across households, and it declines with income.[32] The model economy also broadly replicates the decreasing pattern of the MPCs across income groups even if the MPC in the fourth quintile jumps.[33] Following Chang and Park (2017), I also focus on the MPCs across income groups

[30]The model-implied MPC is obtained using a simple regression: I regress consumption on after-tax income with constant term based on 1,000 periods of quarterly aggregate time series. I transform the quarterly into an annual MPC using the formula $1-(1-\text{quarterly MPC})^4$.

[31]Similarly, a Huggett-style incomplete market model by Chang and Park (2017) also generates higher the average MPC of 0.85.

[32]Jappelli and Pistaferri (2014) use the 2010 Italian Survey of Household Income and Wealth when estimating the MPCs.

[33]Using a life-cycle model with liquid and illiquid assets, Kaplan and Violante (2014) shows a striking difference of MPCs

relative to the average since a direct comparison between the levels of MPC for the model and the empirical estimates may not be fair. The relative MPCs for the first and fifth income quintile in the model are 1.25 and 0.82, respectively, the corresponding empirical values are 1.22 and 0.83, respectively. Thus, the model generates MPCs that are quite similar to those in the data in a relative sense.

From the results in this section, I argue that the model economy generates reasonable heterogeneity to study the distributional effects of the government expenditure on consumption over income levels.

V Distributional Effects of Government Spending

A Taxation scheme

In this section, I investigate the effects on the government spending shocks, focusing on the responses of consumption across the income quintiles. For the taxation scheme, I assume that government expenditure is partially financed by adjusting progressivity. Specifically, given the tax function previously discussed, a path of τ and λ will be adjusted so that the government keeps a balanced budget when government spending unexpectedly increases. Since there are infinitely many combinations of the two parameters which satisfy the balanced government budget, I assume that the government employs a simple linear rule for the combination of the two parameters such that:

$$(1-\omega)\widetilde{\tau} + \omega\widetilde{\lambda} = 0, \tag{2}$$

where $\widetilde{z}$ denotes deviation of a variable, z, from its steady state. Notice that the parameter ω captures weight on the policy only financed by τ changes. For example, a case that $\omega = 0$ implies that the government employs a linear taxation scheme where the proportional income tax rate is $1-\lambda$, while $\omega = 1$ means that government spending is only financed by changing τ with fixed λ.

The next question is how government spending affects tax progressivity. To see this, I compute a measure for tax progressivity using the log-linear function for the tax system in Equation 1. Suppose that $y > 0$. Following Heathcote, Storesletten and Violante (2014) and Ferriere and Navarro (2017), tax progressivity, τ, can be computed such that:

$$\tau = \frac{T'(y) - T(y)/y}{1 - T(y)/y}. \tag{3}$$

out of the fiscal stimulus payment for those who are hand-to-mouth and those who are not. A recent paper by Chang and Park (2017) reports the comparison of MPC's between the quantitative model and the data.

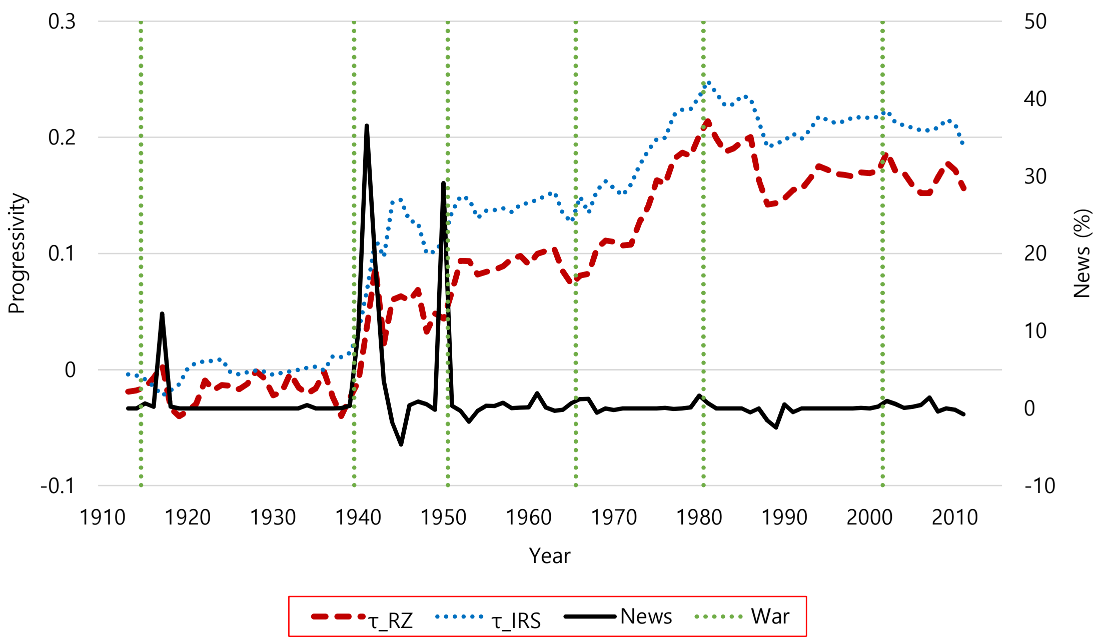

FIGURE 2. HISTORICAL TRENDS OF TAX PROGRESSIVITY

Note: Historical trends of tax progressivity with two different measures. Measures for tax progressivity is computed using Equation 3. Given the average marginal tax rates which are from Barro and Redlick (2011) and Mertens (2013), τ_RZ is measured using information on nominal tax and nominal GDP from Ramey and Zubairy (2014) while τ_IRS is computed using information on taxes and total income from IRS. News variables are defined as the fraction of nominal GDP of the previous year (%). War periods are WWI (1914), WWII (1939), the Korean War (1950), Vietnam War (1965), Soviet Invasion to Afghanistan (1980), and 9/11 (2001).

According to Equation 3, measures for the average tax rate ($T(y)/y$) and the average marginal tax rate ($T'(y)$) across income levels are needed to obtain a measure for progressivity, τ. I use information on the share of nominal tax over nominal GDP from Ramey and Zubairy (2014) as a measure for the average tax rates. As a robustness check, I use the time series for total taxes (total tax liability) and income from Internal Revenue Service (IRS). For the average marginal tax rate ($T'(y)$), the historical data computed by Barro and Redlick (2011) and Mertens (2013) are used.[34] In particular, as far as the measures for government spending shocks are concerned, I use the defense news series built by Ramey and Zubairy (2014). News variables are defined as the fraction of nominal GDP of the previous year. Figure 2 reports the historical trends of measure for U.S tax progressivity, news shocks, and the years the wars started over the period of 1913-2011.[35] An interesting fact emerges from Figure 2: progressivity of taxes tends to rise with positive news shocks. For example, tax progressivity skyrocketed during war time such as WWI (1914), WWII (1939), the Korean War (1950) and, more recently, 9/11 (2001).

In order to quantitatively investigate whether and how much progressivity increases with a rise in

[34]Data for the periods of 1913-1945 are from Barro and Redlick (2011), and time series for 1946-2011 are from Mertens (2013).

[35]War periods are WWI (1914), WWII (1939), Korean War (1950), Vietnam War (1965), Soviet Invasion to Afghanistan (1980), and 9/11 (2001).

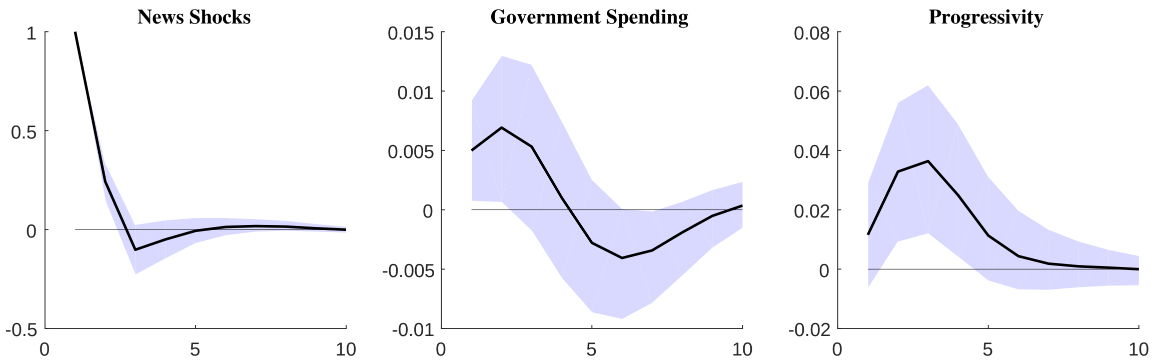

FIGURE 3. RESPONSES OF TAX PROGRESSIVITY TO NEWS SHOCKS

Note: Responses of real per capita government spending and tax progressivitiy (τ_RZ) to news shocks for the sample period 1950-2008. The government spending and tax progressivitiy are logged. The shaded regions are the 68 percent confidence bands generated by Monte Carlo simulations. The horizontal axis reports number of years after the shock.

government spending shocks, I estimate response functions of progressivity to defense news shocks based on the VAR where the defense news shocks are ordered first, and constant terms, quadratic trend terms, and a one-period lag are included. I use an annual sample for the post-WWII periods but excluding the zero lower bound (ZLB) periods and onward to be consistent with the CEX sample (1980:I-2008:III). As shown in Figure 3, tax progressivity rises in response to positive public spending shocks. These results are in support of evidence that a rise in government spending is accompanied by an increase in degree of tax progressivity. Table 4 reports progressivity elasticities of government spending across different samples and estimation approaches. According to Table 4, the progressivity elasticity of government spending is around 4 - 6. Hence, I choose $\omega = 0.85$ so that the elasticity is around five.[36] This finding is in line with work of Vélez (2014) and Ferriere and Navarro (2017). Vélez (2014) shows that progressive income taxation in the twentieth century is a byproduct of war using a long time series of the top marginal personal income tax rate of multiple countries. Ferriere and Navarro (2017) also find that the effect of government spending on macro variables is much larger when it is financed with more progressive taxes. Similarly, Barro and Redlick (2011) and Mertens (2013) report that significant increases in the federal average marginal income-tax rate are related to wartime.

TABLE 4— PROGRESSIVITY ELASTICITY OF GOVERNMENT SPENDING

Peak	Two-year Integral	Four-year Integral
5.26	3.73	5.80

Note: Progressivity elasticity of government spending for the sample period 1950-2008.

[36]Ferriere and Navarro (2017) use a much larger value for the progressivity elasticity of government spending: they assume that the ealsticity is 10 for the “Higher Progressivity” case.

B Results

Responses of Aggregate Variables

The responses of key aggregate variables of the model economy to government spending shocks for 20 quarters of horizon are shown in Figure 4. In response to a positive government spending shock, output increases significantly. The impact or peak output multiplier for government expenditure in the model economy is around one, which is comparable to empirical findings of Blanchard and Perotti (2002), Fatas and Mihov (2001), and Zubairy (2010). Particularly, the model economy generates the fact that consumption and the wage rate respond positively to government spending shocks, while the standard RBC model predict reduction in wages and consumption.[37] The consumption multiplier for government expenditure in the model economy is around 0.03.[38] Investment is crowded out by public spending shocks, which is also found in empirical work such as Blanchard and Perotti (2002), Mountford and Uhlig (2009), and Zubairy (2010). Lastly, hours (employment) and interest rates also rise significantly as in empirical analyses of the literature.

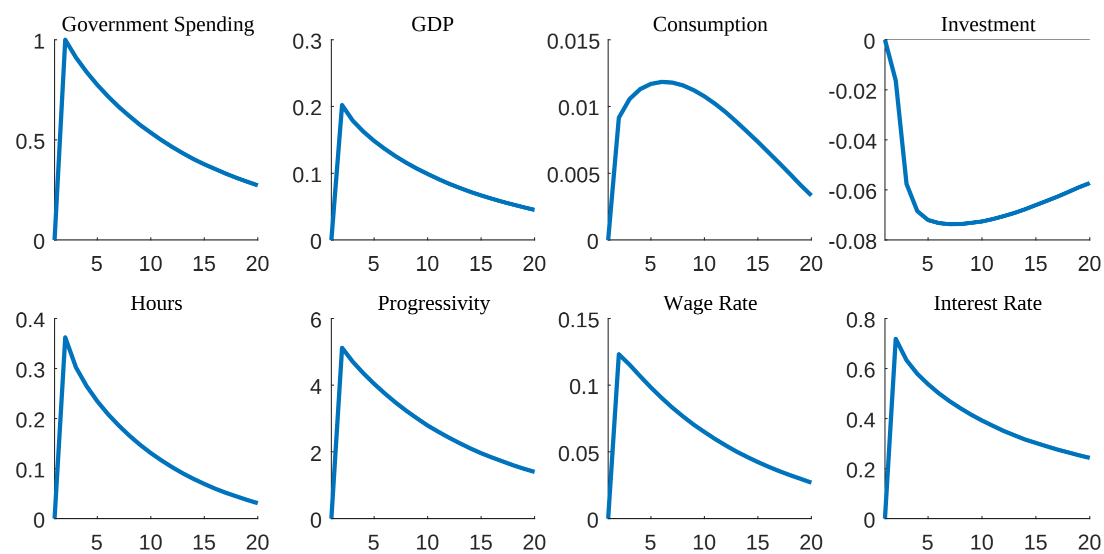

FIGURE 4. IMPULSE-RESPONSES OF AGGREGATE VARIABLES: MODEL ECONOMY

Note: Responses of aggregate variables to a government spending shock. All variables other than interest rates are logged.

Distributional Effect on Consumption

The main focus of this study is on the distributional effects of the government spending shocks on consumption across the income distribution. Figure 5 exhibits the responses of consumption across

[37]A rise in consumption and wage in response to a positive government spending shock is supported by most of the empirical studies in the literature, such as Fatas and Mihov (2001), Blanchard and Perotti (2002), Gali, Lopez-Salido and Valles (2007), Zubairy (2010), and Ramey (2011).

[38]See Blanchard and Perotti (2002), Gali, Lopez-Salido and Valles (2007), Mountford and Uhlig (2009) and Ramey (2011) for the estimates of consumption multipliers of government spending.

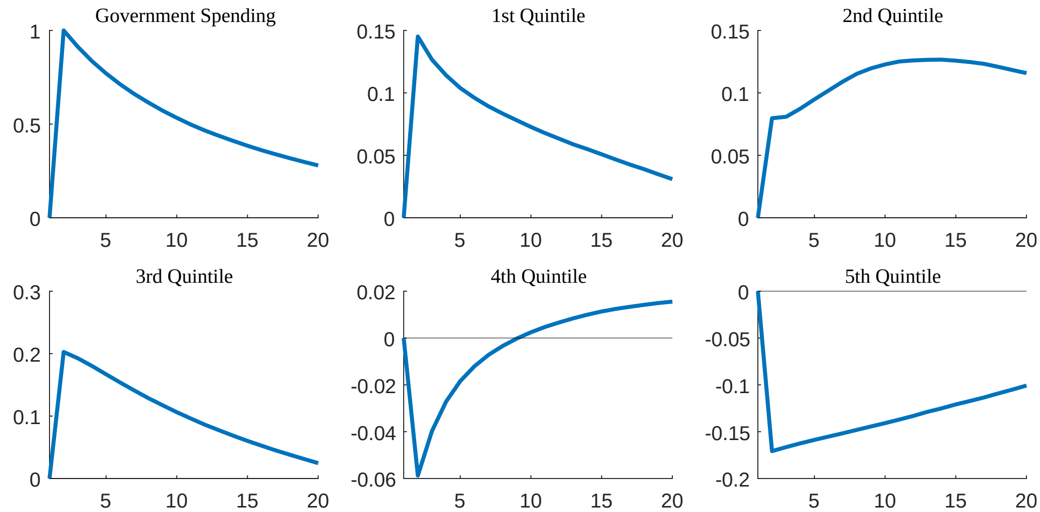

Figure 5. Responses of Consumption across Income Quintiles

Note: Responses of average per capita consumption across the income quintiles to a government spending shock. All variables are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

the income quintiles to a government spending shock. The model economy successfully matches the responses of consumption between the poor and the rich with the empirical findings in Section III. According to Figure 5, consumption of households in the first three income quintiles increases while that of the richer households (the top two quintiles) decreases. Table 5, which reports consumption multipliers for government expenditure across income groups, confirms these findings. The peak multipliers are positive for the poor income groups and negative for the rich. For example, the peak multiplier of the first income quintile is 0.28 while that of the fifth quintile is -0.69. The signs of one-year and two-year integral multipliers are also well replicated.

Table 5— Multipliers across Income Quintiles: Model Economy

Variable	Peak IRF	1 Year Integral	2 Year Integral
1st Quintile	0.28	0.27	0.27
2nd Quintile	0.31	0.24	0.32
3rd Quintile	0.52	0.54	0.54
4th Quintile	-0.18	-0.12	-0.08
5th Quintile	-0.69	-0.76	-0.84

Note: Consumption multipliers across the income quintiles in the model economy. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

The intuitive explanation for the results is as follows. Under the assumption of the divisible labor decision, as discussed in Hall (2009), it is the intratemporal optimality condition – jointly determining optimal hours and consumption – that has a key mechanism accounting for the effect of the government expenditure on consumption. Hence, after-tax wage rates are crucial to determine the responses of consumption to a spending shock. If government spending is financed by changing progressivity, a substantial degree of heterogeneity of post-tax wage rates across the income distribution arises. Therefore, the tax system associated with the spending policy plays a crucial role in the different responses of consumption between the poor and the rich. When the government increases its spending unexpectedly, there are two main effects on after-tax wage rates in the model economy: a rise in tax progressivity to finance the rise in spending and an increase in labor demand due to productive public expenditure. The former differently affects post-tax wages across income levels while the latter is an economy-wide effect on after-tax wage rates. Specifically, with positive income, the after-tax wage rate, w_{at}, is given by

$$w_{at} \equiv \lambda \{wxh + ra\}^{-\tau} w. \tag{4}$$

Suppose that λ is fixed for simplicity. Then, for given prices, r and w, a rise in τ after a spending shock allows changes in w_{at} to be different across income levels: w_{at} tend to increase for the poor but decrease for the rich.[39] Since w rises due to productive government spending, w_{at} increases significantly for consumers in the lower income quintiles, but they fall for those who are in the top quintile since the effect of productive government spending is dominated by the effect of tax progressivity. Panel B in Figure 6, which depicts responses of w_{at} across the income quintiles to a positive government spending shock, supports this mechanism: w_{at} of the first four income groups show the positive responsiveness while it significantly decreases for the top income quintile .

Table 6— Marginal Worker Distribution (ranked by income)

	Quintile					All
	1st	2nd	3rd	4th	5th	
$\xi = 0.03$	11.96	7.45	6.77	3.53	0.53	6.05
$\xi = 0.05$	18.49	12.54	10.67	5.44	0.82	9.59
$\xi = 0.07$	24.34	17.72	14.73	7.56	1.15	13.10

Note: Shares of marginal workers across the income quintiles. Marginal workers are defined as Equation 5. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

When a labor supply decision is indivisible, post-tax wage rates are much more important for the consumption dynamics since labor supply elasticity for the poor becomes even larger with indivisibility of labor supply. Table 6, which shows shares of marginal workers across the income quintiles, provides evidence for it. A marginal worker is defined as a worker who is almost indifferent between working and not-working at the steady state. Formally, given assets holding, a, and productivity, x, a household is a marginal worker when $m(a, x) = 1$, and $m(a, x)$ is given by:

[39]Of course, an increase in the prices results in a reduction in w_{at}, but this effect may not be large with small positive τ.

$$m(a,x) \equiv \begin{cases} 1 & if \; \left| V^E(a,x) - V^N(a,x) \right| < \xi \\ 0 & otherwise \end{cases}, \tag{5}$$

where ξ is a small real number. According to Table 6, marginal workers are relatively many at the bottom of income distribution. For example, when $\xi = 0.05$, around 20 percent of households are marginal workers in the first income quintile, while the share of marginal workers is less than one percent in the top quintile.[40] In other words, labor supply elasticity of lower-income consumers is much larger than that of the rich households. Accordingly, non-employed households (before a spending shock) in the lower income groups, who are likely to be marginal workers as shown in Table 6, become employed after the shock since w_{at} is greater than the reservation wage rates. Figure 6 confirms this story line: households in the first three lowest income quintiles increase hours of work or decide to be employed due to a significant rise in w_{at}.[41] In turn, this allows the poor to increase after-tax income and consumption as found in Figure 6 and Figure 5. However, as shown in Figure 6, hours worked for consumers in the upper quintiles (the fourth and the fifth income groups) drop, and their post-tax income remains almost constant or falls since w_{at} increases a bit or decreases.[42] Finally, the rich reduce their consumption (Figure 5). If λ is allowed to change following the tax policy rule in Equation 2, the main results are still the same.[43] Interestingly, the behaviors of consumers in the fourth income group are different from the others. For the poor (the first three quintiles), the direction of hours is consistent with that of w_{at}, which implies that the substitution effect is larger than the income effect. The top income quintile does not change their hours of work since w_{at} for a majority of the richest are still greater than the reservation wage rates, or the share of marginal workers is very small. However, households in the fourth income group decrease their consumption and hours with a small rise in w_{at}, which suggests that the income effect dominates the substitution effect.

I also provide supportive empirical evidence for the different responses of employment across income groups to government spending shocks, which is the key channel of the model. For this analysis, I use the Current Population Survey (CPS) since the CPS has better information on labor force participation. Since information on income in the CPS is available in March of every year, I cannot use quarterly data for employment rates across income quintiles. Hence, I use annual data which span 1980 to 2014 and use the SPF shocks for the measure of government spending policy shocks.[44]

[40] I choose $\xi = 0.05$ as a benchmark number since the share of workers who change their employment status is 9.6 percent in the steady state.

[41] Of course, employed workers at the bottom quintiles of the income distribution also can increase their consumption due to an increase in after-tax income induced by a rise in w_{at} for them.

[42] Not surprisingly, there might be households in the richest quintile who lose their jobs but this effect may not be large since most of them are not marginal workers as in Table 6.

[43] Compared to fixed λ, w_{at} for the poor (for the rich) may increase (decrease) less since τ increases less.

[44] In this case, the measure of SPF shocks is defined as the difference between the actual federal spending growth from a year ago in March and the four-quarter ahead SPF forecast of government spending in March for the measure of government spending policy shocks.

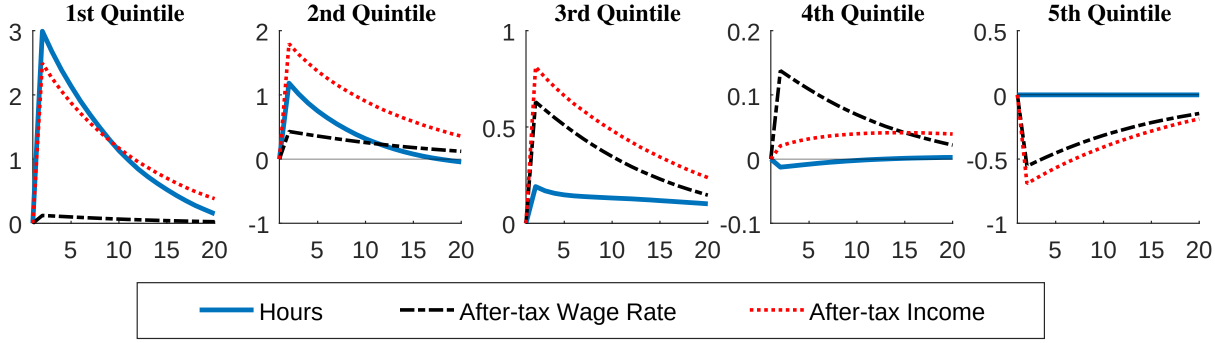

Figure 6. Responses of Hours, After-tax Wage Rates, and After-tax Income across Income Quintiles

Note: Responses of average hours , average after-tax wage rates, average after-tax income across the income quintiles to a government spending shock. All variables are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

To estimate the effects of a government spending shock on employment by income, I employ the VAR where the SPF shock is ordered first, and constant terms, quadratic trend terms, and a one-period lag are included. Figure 7 reports the estimated response of employment rates across income groups. As expected by the model economy, households in the lower income quintiles increase employment while employment rates for richer households tend to decrease in response to positive government spending shocks. This can be in support of evidence that there are heterogeneous effects of government spending on employment between the poor and the rich.

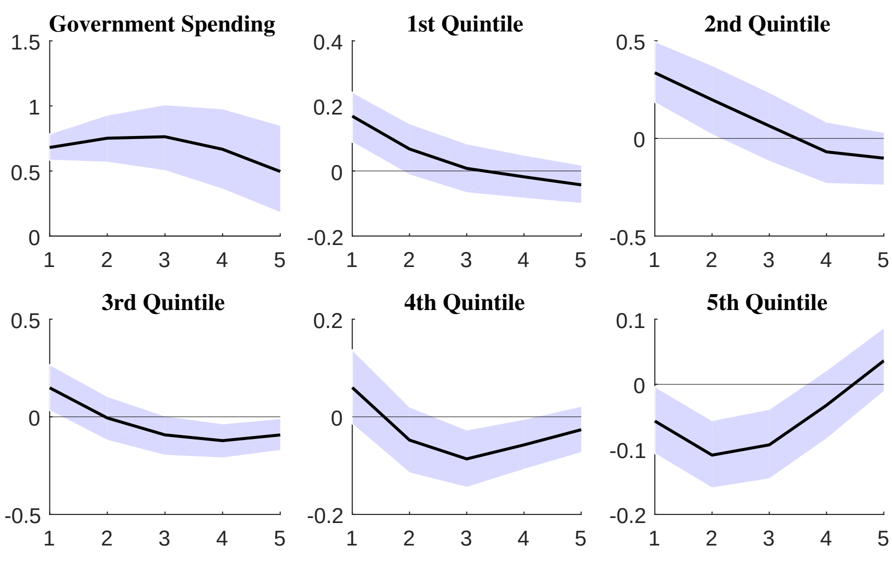

Figure 7. Responses of Employment Rate across Income Quintiles

Note: Responses of employment rates across the income quintiles to a government spending shock based on the CPS 1980-2014. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

Role of Indivisible labor

Indivisibility of a labor choice allows for producing the heterogeneous Frisch elasticity of labor supply across income levels since individuals have different reservation wages with the indivisible labor: labor supply elasticity in the bottom of the income distribution is very large while that of the rich households is almost zero.[45] In contrast, the Frisch elasticity is the same between the poor and the rich under the assumption of a flexible hours decision by definition. A discrete choice for labor supply plays two important roles in the model economy. First, the assumption allows the government to increase progressivity to finance a rise in government spending since labor supply elasticity of higher-income households is very small under the assumption of indivisible labor. Second, households in the lower income groups can significantly increase hours worked with indivisibility of a labor choice, which allows the poor to increase consumption. However, the above two facts are incompatible in a model with divisible labor. On the one hand, if elasticity of labor supply is too high in the divisible labor model, the government should decrease progressivity to increase tax revenue, which is inconsistent with empirical evidence. On the other hand, when labor supply is very inelastic, the poor cannot increase their consumption due to a small rise in hours. The latter case is reported in Figure 5.

Figure 5 compares the responses of key aggregate variables (Panel A) and consumption across the income quintiles (Panel B) to a government spending shock in the indivisible and divisible labor models. For the divisible labor model economy (DL model), I set the same value of Frisch labor elasticity (0.3) as in the indivisible labor model (IL model).[46] As found in Figure 5, the DL model fails to replicate the responses of both macro and micro variables even if progressivity increases as much as in the IL model. Small elasticity of labor supply for poor households results in a decrease in consumption for most of them. Since in the DL model labor supply elasticity for the rich is relatively large compared to that in the IL model, they reduce their hours significantly as a consequence of a decrease in after-tax wage rates, which leads to a drop in aggregate hours. The relatively large labor supply elasticity for higher income households also results in a substantial decrease in income and causes their investment to drop significantly. Consequently, aggregate consumption and investment fall, and a reduction in hours and capital will finally decrease output in the DL model.

Role of Productive Government Spending and Taxation Scheme

The interaction between productive government expenditure and the more progressive taxation scheme in response to a unexpected rise in government spending generates the heterogeneous effects of government spending on consumption by income as well as the reasonable responses of the key aggregate variables. In order to investigate the marginal contributions of each, I consider three additional model economies: an economy with productive government spending only ($\gamma = 0.15$,

[45] The Frisch labor supply elasticity is defined as the percentage change in hours caused by the percentage change in wages, abstracting from the effect on wealth.

[46] For other parameter values in the DL model, the same calibration strategies used in the IL model are applied.

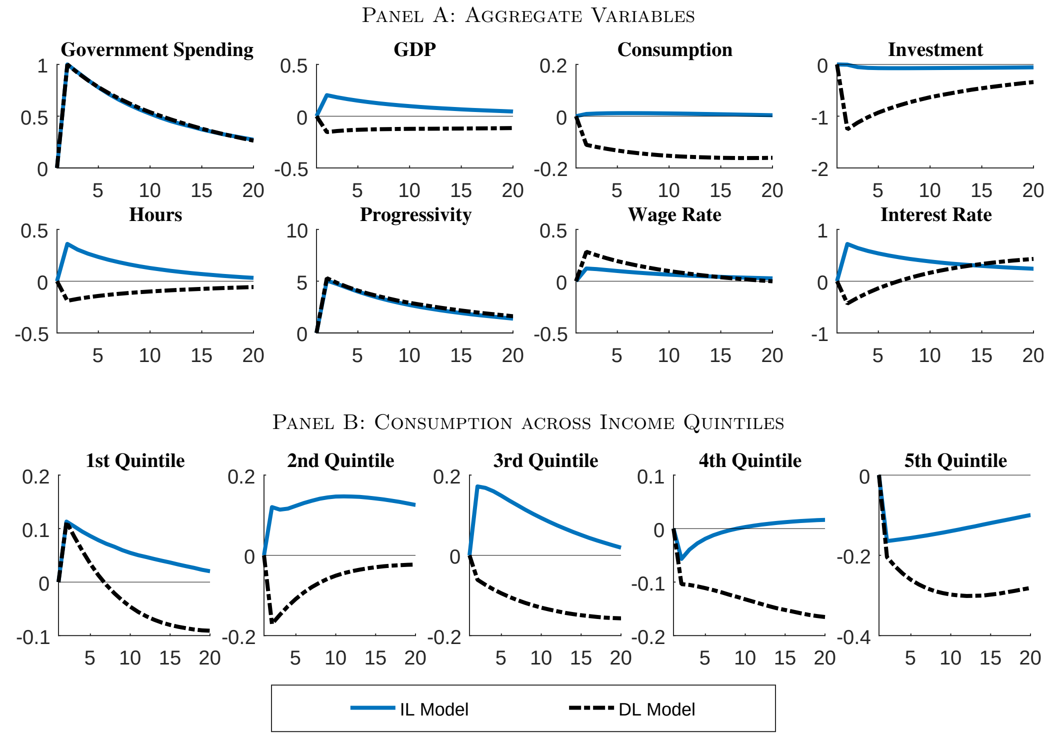

Figure 8. Impulse-responses with Indivisible and Divisible Labor

Note: Responses of aggregate variables (Panel A) and consumption across the income quintiles (Panel B). "IL" and "DL" denote indivisible and divisible labor, respectively. All variables other than interest rates are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

$\tau = 0$), an economy with progressive taxation only ($\gamma = 0$, $\tau = 0.2$), and an economy with neither of them ($\gamma = 0$, $\tau = 0$). Except for γ and τ, calibration strategies for the three models are the same as for the benchmark model economy.

Figure 9 shows the responses of the key macro variables (Panel A) and consumption across income groups (Panel B). These responses are comparable to each other because all the model economies are subject to an identical path of government spending shocks. As the model economy with productive government spending only shows, productive government spending alone does not generate the aggregate effects of government spending shocks comparable to what we observe in the data. When $\tau = 0$, the tax system is linear. This implies that changes in tax rates in response to government spending shocks are the same for all the households. In the model with productive government spending only, a rise in after-tax wage rates due to productive government spending is dominated by the rise in tax rates. Accordingly, due to a fall in post-tax wages, both aggregate hours and consumption decrease after a positive government spending shocks. Productive government spending only also fails to explain the heterogeneous responses of consumption across income groups since there are no different effects on after-tax wage rates across households under the affine taxation: as found in Panel B of Figure 9, households in the all the income quintiles other than the third quintile

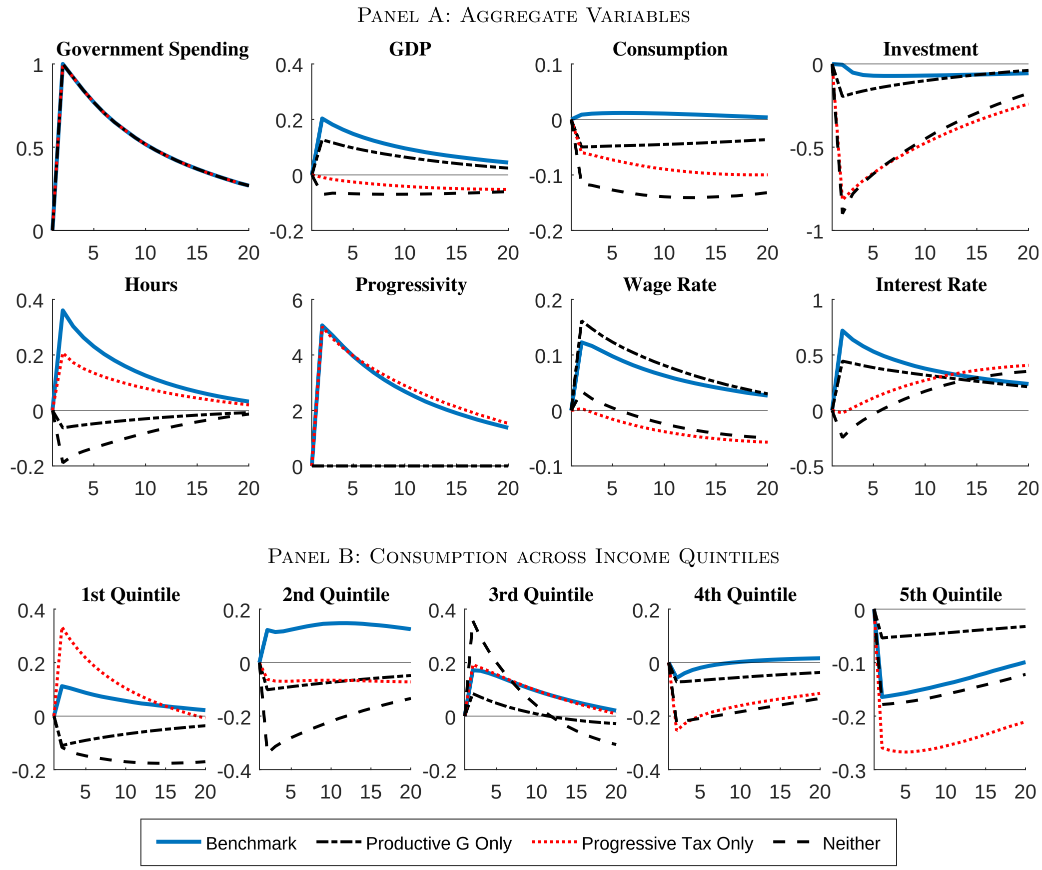

Figure 9. Impulse-responses for the Four Models

Note: Responses of aggregate variables (Panel A) and consumption across the income quintiles (Panel B). All variables other than interest rates are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile. "Productive G Only" denotes an economy with productive government spending only, and "Progressive Tax Only" refers to an economy with progressive tax only, and "Neither" denotes an economy with neither of them.

reduce their consumption.[47]

Next, the model economy with progressive taxation only shows that progressive tax system alone cannot account for the responses of the key macroeconomic variables even though it replicates the distributional effects on consumption between the poor and the rich. On aggregate, output and wages decrease in this model in response to a unexpected rise in public spending, which is not comparable to the empirical findings in the literature. In this model, firms cannot increase labor demand since the model excludes productive government spending. Hence, hours increase less compare to the benchmark model, and wage rates decrease. In the model economy with progressive taxation only, there are more heterogeneous effects on after-tax wages since an economy-wide effect on after-tax wage rates induced by productive government spending is omitted.[48] Thus,

[47] Compositional changes may cause consumption in the third income quintile to increase.

[48] In the model economy with progressive taxation only, ω is chosen to be 0.97 which is larger than the 0.85 in the benchmark model. Hence, the larger ω also helps the model have more heterogeneous effects on post-tax wage rates across households.

rich households tend to reduce investment and consumption considerably while households in the bottom of the income distribution can increase their consumption. Finally, aggregate investment falls significantly mainly due to a big decrease in after-tax income for the rich, and it in turn leads to less capital accumulation and a decrease in output. A significant decline in consumption from the rich results in a fall in consumption on aggregate.

By the same logic, the model economy with neither of productive government spending and progressive tax system fails to account for the responses of both aggregate and disaggregate variables to a spending shock. From this analysis, I can conclude that the interaction between productive government spending and progressive taxation scheme play a crucial role in explaining the distributional effects of government spending on consumption by income as well as the responses of the key aggregate variables.

VI Conclusion

This paper tries to uncover why consumers behave differently in response to a government spending shock. To this end, I construct a heterogeneous agent model economy which incorporates a progressive taxation scheme, productive government expenditure, and indivisible labor. I find that the model economy successfully replicates the different responses of consumption between the bottom and the top of income distribution to government spending shocks. When the government increases its spending accompanied with a rise in tax progressivity, poor households are employed and hence increase their consumption due to an increase in after-tax wage rates while the rich decrease consumption since the effect of productive government spending cannot fully offset a significant increase in tax rates.

Existing theoretical macroeconomic models inspired by Gali, Lopez-Salido and Valles (2007) suggest that credit-constrained consumers are crucial to account for why government spending shocks have substantially different effects on consumers. On the other hand, this study proposes a new perspective by suggesting that it is important to consider different tax burdens across consumers when studying the distributional effects of government spending shocks.

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Appendix

A1. Data Sources

Micro Data

- CEX: I mainly use the CEX data for the periods of 1980:Q1-2008:Q4. The period which was constructed by Heathcote, Perri and Violante (2010).
- PSID: For information on income, wealth and employment rates used for Table 2 and Table 3, I make a use of the PSID 1994 survey because the survey year has information on wealth as well as income and employment rates, and it is in the middle of the sample period of the CEX.

Macro Data

- SPF Shocks: As a measure of a government spending shock for the estimation in Section III, I use the SPF shocks developed by Ramey (2011).
- Defense News Shocks: Defense news series are from Ramey and Zubairy (2014).
- Government Spending: Data for real government spending per capita is also from Ramey and Zubairy (2014).
- Average Tax Rate: There are two sources for the average tax rates. As a bench mark, I make use of the time series for the share of nominal tax over nominal GDP from Ramey and Zubairy (2014). As a robustness check, I also use data for total tax liability and income from Internal Revenue Service (IRS).
- Average Marginal Tax Rate: The historical data computed by Barro and Redlick (2011) and Mertens (2013) are used. Time series for the periods of 1913-1945 are from Barro and Redlick (2011), and data for the periods of 1946-2011 are from Mertens (2013).

A2. Empirical Evidence

In this section, I empirically investigate the distributional effects of government spending shocks on consumption across the income distribution using micro data. Related work is Anderson, Inoue and Rossi (2016) and De Giorgi and Gambetti (2012).

Data and Approach

I use the CEX, which is conducted by the Bureau of Labor Statistics (BLS), to collect information on income, consumption and age across individual households.[49] I mainly use quarterly data which

[49] The CEX is rotating panel data where individuals are interviewed for four consecutive quarters at most.

span from the first quarter of 1980 to the third quarter of 2008 (right before zero lower bound (ZLB) periods).[50] Following Heathcote, Perri and Violante (2010), the measure of non-durable consumption includes food and beverages, tobacco, apparel and services, personal care, gasoline, public transportation, household operation, medical care, entertainment, reading material and education. The definition of the non-durable goods is similar to that of Anderson, Inoue and Rossi (2016) and De Giorgi and Gambetti (2012).[51] Annual income is defined as before-tax income, which is the sum of wages, salaries, business and farm income, financial income, and transfers.[52] The measure of age is defined as the age of a head of each household. Income and non-durable consumption for households are real per capita values: they are divided by family size (the number of family members), deflated by CPI-U series, and seasonally adjusted by X-12-ARIMA. It is important what measure is used for government spending shocks. I use the SPF shocks, constructed by Ramey (2011), as the measure of government spending policy shocks. The measure of SPF shocks is defined as the difference between actual federal spending growth and the one-quarter ahead SPF forecasted growth.[53] Regarding the measure of government spending, real per capita total government spending is used.

In order to study the effects of a government spending shock, I consider a three-variable Vector Autoregressive (VAR) model as in Anderson, Inoue and Rossi (2016), including the SPF shock, government spending, and consumption. Formally,

$$X_t = B(L)X_{t-1} + E_t, \tag{A1}$$

where X_t is a vector including the SPF shock, the logged real government spending, and logged real consumption across different socioeconomic groups; $B(L)$ is a polynomial in the lag operator; E_t is vector of shocks identified via the recursive ordering procedure where the SPF shock is ordered first, and consumption last. Constant terms, quadratic trend terms, and four lags are included in the VAR as in Ramey (2011) and Anderson, Inoue and Rossi (2016).[54] As discussed in Anderson, Inoue and Rossi (2016), by including the shocks measures in a Structural VAR (SVAR) where the shock is ordered first, we can ensure that the shock is uncorrelated with past information contained in the other variables in the VAR. Of course, by dong this, variables other than the shock are allowed to react to the shock itself on impact.

[50] The data for the period before 2007 are from Heathcote, Perri and Violante (2010).

[51] Anderson, Inoue and Rossi (2016) define non-durable consumption as expenditures on food, alcoholic beverages, tobacco, utilities, personal care, household operations, public transportation, gas and motor oil, and miscellaneous expense, and De Giorgi and Gambetti (2012) use food (including alcohol and tobacco), heating fuel, public and private transport (including gasoline), and personal care as the non-durable consumption following Attanasio and Weber (1995).

[52] In the CEX, unfortunately, information on household-level income is only available in the first and fourth survey, which means that income for the second and third surveys is the same as that of the first, while information on consumption is available on a quarterly basis. Since income data are only used to construct income groups as in Anderson, Inoue and Rossi (2016), I believe that the effects of the measurement errors for income may not affect main results seriously.

[53] I use the SPF shocks instead of using the defense spending news shocks developed by Ramey (2011) since the news shocks do not show enough explanatory power for government spending in the sample period I focus on (Anderson, Inoue and Rossi, 2016).

[54] The results are robust to different lag order lengths.

Empirical Results

In this subsection, I present the main empirical results of the effects of government spending shocks on consumption across various dimensions of inequality. I mainly focus on the responses of average non-durable consumption in the five groups (quintiles) of individuals sorted by income levels. Additionally, empirical results based on age and consumption quintiles, as proxies for income groups, will be discussed.

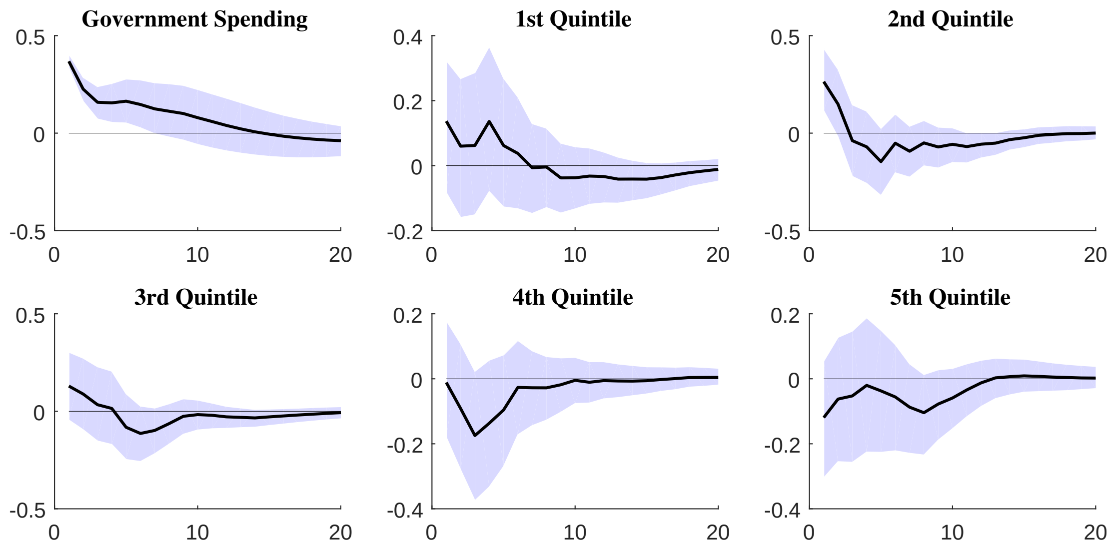

FIGURE A1. RESPONSES OF CONSUMPTION ACROSS INCOME QUINTILES

Note: Responses of logged real per capita government spending and logged average real per capita consumption across the income quintiles to a SPF shock. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile. The shaded regions are the 68 percent confidence bands generated by Monte Carlo simulations.

Figure A1 exhibits the responses of average consumption across the income quintiles to government spending shocks (SPF shocks).[55] As shown in Figure A1, there are substantial differences in the responses of consumption across income groups to spending shocks: consumption increases for the poor while it decreases for the rich when government expenditure rises. Estimated peak and cumulative multipliers across the income quintiles are summarized in Table A1.[56] The peak multipliers for the first three quintiles are positive while they are negative for the top two quintiles. For example, the peak multiplier for the lowest income quintile is 0.14 whereas that of the highest is -0.37. In other words, when government increases its spending by one dollar, poorest consumers increase their consumption by 14 cents, but consumption for the richest decreases by 37 cents on average. These findings are robust when the cumulative multipliers are used as a measure of the effects of government spending shocks.[57] The fourth and fifth columns of Table A1 report the cumulative

[55] I smooth the impulse-response functions using centered moving averages with three periods.

[56] The peak multiplier for a group j is computed as $max_h sign\left(\frac{\Delta log C^j_{t+h}}{\Delta log G_t}\right) \left|\frac{\Delta log C^j_{t+h}}{\Delta log G_t}\right| \frac{\overline{C^j}}{\overline{G}}$ where $\frac{\overline{C^j}}{\overline{G}}$ is the average ratio of consumption of the group j to government spending.

[57] The integral multiplier is defined as the sum of the responses of consumption divided by the sum of changes in government

multipliers for a one-year and two-year horizon, respectively. Both integral multipliers indicate that consumption of the first three lowest income quintiles rises while that of the last two income groups falls after positive spending shocks.[58] These empirical results are consistent with those in Anderson, Inoue and Rossi (2016) and De Giorgi and Gambetti (2012).

Table A1—Estimated Multipliers across Income Quintiles

Variable	Peak	68 Percent C.I.	1 Year Integral	2 Year Integral	Full Sample
1st Quintile	0.15	$[0.03, 0.24]$	0.20	0.18	0.07
2nd Quintile	0.27	$[0.16, 0.35]$	0.14	0.01	0.18
3rd Quintile	0.07	$[-0.06, 0.19]$	0.09	0.04	0.11
4th Quintile	-0.19	$[-0.40, -0.02]$	-0.19	-0.23	-0.18
5th Quintile	-0.39	$[-0.80, -0.10]$	-0.46	-0.62	-0.18

Note: Estimated consumption multipliers across the income quintiles. "Peak" denotes the peak multipliers, "68 Percent C.I" denotes the 68 percent confidence interval for the peak multipliers, and "1 Year Integral" denotes the one-year cumulative multipliers. The sample periods are 1980:I-2008:III other than "Full Sample." "Full Sample" reports the peak multipliers for the period 1980:I-2015:III. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile. Confidence bands are generated by Monte Carlo simulations.

I also consider other individual characteristics such as age and consumption as a robustness check. Age and consumption can be viewed as proxy variables for individual income. Figure A2 summarizes the effects of government spending shocks on consumption across age and consumption quintiles. As far as the responses of consumption across age groups are concerned, as shown in the upper panel of Figure A2, consumption increases for the youngest and the oldest individuals, and it decreases for the middle-aged individuals when government expenditure increases. Considering that income profiles over ages are inverted U-shaped or hump-shaped, these findings are consistent with those of income quintiles. The bottom panel of Figure A2 shows that consumption in the lower consumption quintiles increases while consumption in the top decreases, which confirms that the poor consume more and the rich consume less in response to an increase in government expenditure based on the assumption that consumption is a good proxy for income.

A3. Computational Procedures

Steady-state (Stationary) Economy

I use the algorithm suggested by Rios-Rull (1997) to find the stationary measure, μ_{ss}. The steps are as follows.

Step 1. Have guesses for endogenous parameters such as β, χ, G_{ss}, and λ.

Step 2. Construct grids for individual state variables, such as asset holdings, a, and logged individual labor productivity, $\hat{x} = \ln x$, where the number of grids for a and $\widehat{x}$ are denoted by n_a and

expenditure.

[58] For robustness check, I also consider the responses of median consumption in each income quintile to government spending shocks, and the results are similar to those of the average consumption case.

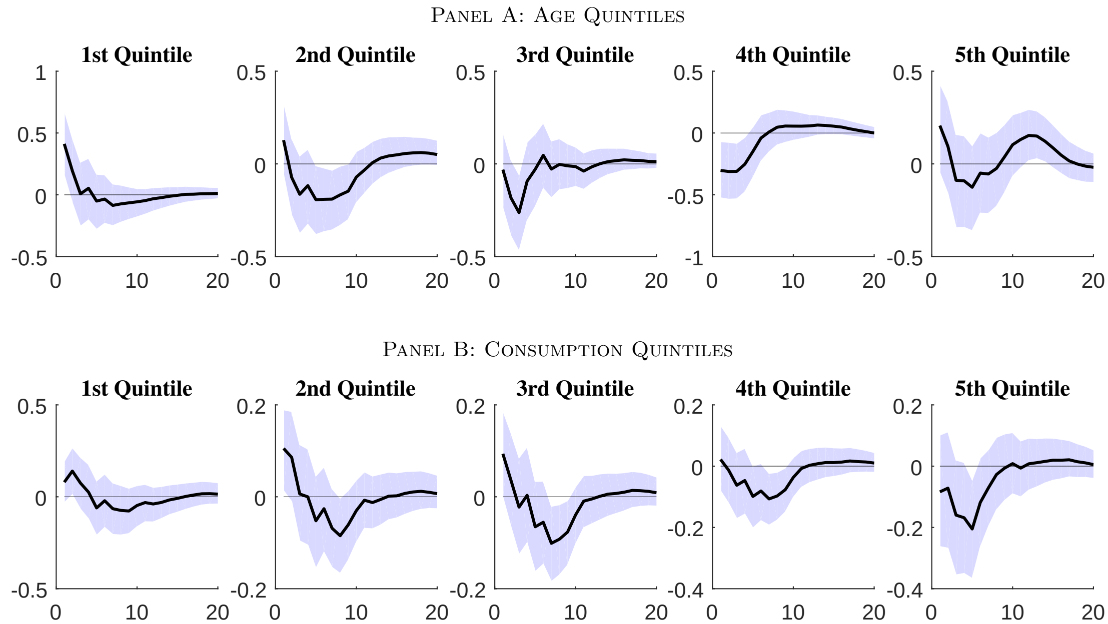

FIGURE A2. RESPONSES OF CONSUMPTION ACROSS AGE AND CONSUMPTION QUINTILES

Note: Response of the logged average real per capita consumption across age quintiles (Panel A) and consumption quintiles (Panel B) to a SPF shock. The sample periods are 1980:I-2008:III. "1st Quintile" denotes the youngest or the lowest consumption quintile, and "5th Quintile" denotes the oldest or the highest consumption quintile. The shaded regions are the 68 percent confidence bands generated by Monte Carlo simulations.

n_x, receptively. I use $n_a = 201$ and $n_x = 19$. The range of a is $[-2, 200]$. More asset grid points are assigned on the lower asset range using a convex function. $\widehat{x}$ is equally spaced in the range of $[-3\sigma_{\hat{x}}, 3\sigma_{\hat{x}}]$, where $\sigma_{\hat{x}} = \sigma_x/\sqrt{1-\rho_x^2}$.

Step 3. Approximate the transition probability matrices for individual labor productivity, $\mathbb{P}_x$, using Tauchen (1986).

Step 4. Solve the individual value functions at each grid point. In this step, I obtain the optimal decision rules for saving $a'(a,x)$ and hours worked $h(a,x)$, the value functions $V^E(a,x)$, $V^N(a,x)$, and $V(a,x)$. The detailed steps are as follows:

a) Compute the wage rate in the steady state, w_{ss}, through the firm's first-order condition, $w_{ss} = (1-\alpha)\left(\frac{\alpha}{r_{ss}+\delta}\right)^{\frac{\alpha}{1-\alpha}} G_{ss}^{\frac{\gamma}{1-\alpha}}$, where the steady-state real interest rate, r_{ss}, is chosen to be 0.01.

b) Make an initial guess for the value function, $V_0(a,x)$ for all grid points.

c) Solve the consumption-saving problem for each employment status:

$$V_1^E(a,x) = \max_{a' \geq \bar{b}} \left\{ \ln\left(w_{ss}x\bar{h} + (1+r_{ss})a - T(w_{ss}x\bar{h} + r_{ss}a) - a'\right)\right.$$
$$\left. -\chi\frac{\bar{h}^{1+1/\phi}}{1+1/\phi} + \beta\sum_{x'=1}^{n_x}\mathbb{P}_x(x'|x)V_0(a',x')\right\},$$

and

$$V_1^N(a,x) = \max_{a' \geq \bar{b}} \left\{ \{\ln\left((1+r_{ss})a - T(r_{ss}a) - a'\right) + \beta \sum_{x'=1}^{n_x} \mathbb{P}_x(x'|x) V_0(a',x')\} \right\}.$$

d) Compute $V_1(a,x)$ as $V_1(a,x) = \max\left\{V_1^E(a,x), V_1^N(a,x)\right\}$.

e) If V_0 and V_1 are close enough for each grid point, and go to the next step. Otherwise, update the value functions ($V_0 = V_1$), and go back to (c).

Step 5. Obtain the time-invariant measure, μ_{ss} with finer grid points for assets. Using cubic spline interpolation, compute the optimal decision rules for asset holdings with the new grid points. μ_{ss} can be computed using the new optimal decision rules and $\mathbb{P}_x$.

Step 6. Compute aggregate variables using μ_{ss}. If the computed rental price for capital, the employment rate, government spending-ouput ratio, the average income tax rate become sufficiently close to the targeted ones, then the steady-state economy is found. Otherwise, reset the endogenous parameters, and go back to Step 4.

Dynamic Economy

In order to solve a dynamic economy, the distribution across households, μ, which affects prices, should be kept track of. Instead, following Krusell and Smith (1998), I use the first moment of the distribution and the forecasting function for it to solve a dynamic economy.

Step 1. Construct grids for aggregate state variables such as aggregate capital, K, and government spending, G, where the number of grids for K and G are denoted by n_K and n_G, receptively. I use $n_K = 9$ and $n_G = 9$. The range of K is $[0.9K_{ss}, 1.1K_{ss}]$, where K_{ss} is the steady-state mean capital. g, defined as $g = \ln G - \ln G_{ss}$, is equally spaced in the range of $[-3s_g, 3s_g]$, where $s_g = \sigma_g/\sqrt{1-\rho_g^2}$. The grids for individual state variables are the same as those in the steady-state (stationary) economy.

Step 2. Parameterize coefficients for forecasting functions for the next-period capital, the wage rate, and tax progressivity:

(A2) $$\ln K' = a_0 + a_1 \ln K + a_2 \ln G,$$

(A3) $$\ln w = b_0 + b_1 \ln K + b_2 \ln G,$$

(A4) $$\tau = d_0 + d_1 \ln K + d_2 \ln G.$$

Given the wage rate w, the real interest rate, r, is computed from the firm's profit maximization: $r = G^{\frac{\gamma}{\alpha}} \alpha \left(\frac{w}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}} - \delta$.

Step 3. Using the forecasting functions of A2, A3, and A4, solve the individual value functions at each grid point. In this step, I obtain the optimal decision rules for asset holdings, $a'(a, x, K, G)$, hours worked, $h(a, x, K, G)$, and the value function, $V(a, x, K, G)$. The detailed steps are similar to those in Step 4 of the steady-state economy.

Step 4. Given the forecasting functions of A2, A3, and A4, and the value functions, solve the optimization problem individuals for data for 3,500 periods with finer grid points for assets holding. The detailed steps are as follows.

a) Set initial values for K, G, and $\mu(a, x)$.

b) Obtain the value function, $\widetilde{V}(a, x)$, for finer asset grids, which is evaluated at the aggregate state variables using the value function obtained in Step 3 and forecasting the functions of A2, A3, and A4.[59]

c) Set $\widehat{\tau}$ as a guess for progressivity. Then, $\hat{\lambda}$ is obtained from Equation 2.

d) Given $\widehat{\tau}$ and $\hat{\lambda}$, obtain the decision rule for employment, $h(a, x)$, using the forecasting function of A3 and $\widetilde{V}(a, x)$.[60] Then, compute tax payments, $T(wxh(a, x) + ra)$, from Equation 1.

e) Check a balanced budget for the government: $G = \int T(wxh(a, x) + ra) d\mu$. If the government runs a balanced budget, then go to the next step. Otherwise, reset $\widehat{\tau}$, and go to Step (c). The progressivity that government runs a balanced budget is denoted by τ^*.

f) Set $\widehat{w}$ as a guess for the wage rate. Then, $\widehat{r} = G^{\frac{\gamma}{\alpha}} \alpha \left(\frac{\hat{w}}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}} - \delta$ from the firm's profit maximization.

g) Under $\widehat{w}$, obtain the decision rule for labor supply, $h(a, x)$, using the forecasting function of A4 and $\widetilde{V}(a, x)$.

h) Check labor market clearing: $L = G^{\gamma} \left\{(1-\alpha)/\hat{w}\right\}^{1/\alpha} K = \int h(a, x) x d\mu$. If the labor market clears, then go to the next step. Otherwise, reset $\widehat{w}$, and go back to Step (f). The wage rate that clears the labor market is denoted by w^*.

i) Using $\widetilde{V}(a, x)$, τ^*, and w^*, obtain the decision rules for consumption, $c(a, x)$, employment, $h(a, x)$, and asset holdings, $a'(a, x)$.

j) Compute aggregate variables: $C = \int c(a, x) d\mu$, $L = \int h(a, x) x d\mu$, $K' = \int a'(a, x) d\mu$, $H = \int h(a, x) d\mu$, $Y = K^{\alpha} L^{1-\alpha} G^{\gamma}$, and $I = Y - C - G$.

k) Obtain the next-period distribution, $\mu'(a, x)$, using $\mathbb{P}_x$ and $a'(a, x)$.

[59] I use cubic spline interpolation for off grid points.

[60] Given the forecasting function the wage rate, the rental price for capital r can be computed by: $r = G^{\frac{\gamma}{\alpha}} \alpha \left(\frac{w}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}} - \delta$.

Step 5. Obtain the new coefficients for the forecasting functions using the simulated data with an OLS regression.[61] If the new coefficients are close enough to the previous ones, the simulation is done. Otherwise, update the coefficients and go back to Step 3. I check the goodness of fit for the forecasting functions using R^2. The high accuracy is obtained such that:

$$\ln K' = 0.013379 + 0.991539 \ln K - 0.002313 \ln G, \; R^2 = 0.9994,$$

$$\ln w = -0.177162 + 0.342779 \ln K + 0.127333 \ln G, \; R^2 = 0.9973,$$

$$\tau = 1.464993 - 0.255302 \ln K + 1.008161 \ln G, \; R^2 = 0.9991.$$

A4. Impulse Response Functions

In a heterogeneous agent economy, obtaining impulse-response functions is computationally demanding since the distribution across characteristics of households (μ) needs to be kept track of in each simulation period. To solve this issue, I approximate the cross-sectional distribution using the mean asset as in Krusell and Smith (1998). I generate a 3,500-periods time series using value functions and policy functions, which are obtained from the individual optimization problems. With the simulated data of 1000 periods, I run VAR with one-period-lagged variables and a constant term in which the government spending shock is ordered first and other variables of interest are ordered next. I also use different approaches to compute IRFs, but the three approaches generate qualitatively similar features.[62]

I discuss and compare three different ways to compute the impulse-response functions (IRFs) from the model economy. Approach I and Approach II are based on estimation using the simulated data, while Approach III employs a method directly simulating IRFs using the estimated forecasting the functions of A2, A3, and A4 and the decision rules.

- Approach I: With the simulated data of 1000 periods, I run VAR with one-period-lagged variables and a constant term in which the government spending shock is ordered first and other variables of interest are ordered next.
- Approach II: By construction, government spending shocks are exogenous in the model economy. Hence, using the 1000 periods of simulated data, I estimate a series of regressions for each horizon for each variable. Specifically, I regress $\ln y$ on a constant and $\ln x$, where y is a variable of interest and x is a vector $[G_t \, G_{t-1} \ldots G_{t-19}]$ and obtain the estimates. With an exogenous series of government spending and the estimates, I draw the IRFs.

[61] I drop the first 500 periods to eliminate the impact of the arbitrary choice of initial aggregate state variables.
[62] See appendix for details.

- Approach III: Using the estimated forecasting functions for the future capital, the wage rate, and tax progressivity and the obtained decision rules, I compute the responses of variables of interest. The steps are summarized as follows.

  1) Using the forecasting functions, solve the individual value functions at each grid point.
  2) Assume the series of government spending: I assume that the spending is at steady state value for 500 periods, unexpectedly increases by one percent in period of 501, and decreases following the AR(1) process with no error term.
  3) Given the forecasting functions, the value functions, and the series of government spending, solve the optimization problem individuals under finer grid points for assets.
  4) Compute aggregate and disaggregate variables.

Figure A3 and Figure A4 show the IRFs for key aggregate variables and consumption across the income quintiles using the three approaches. The three approaches generate qualitatively similar results. In particular, the estimation methods (Approach I and Approach II) produce almost identical results by construction.

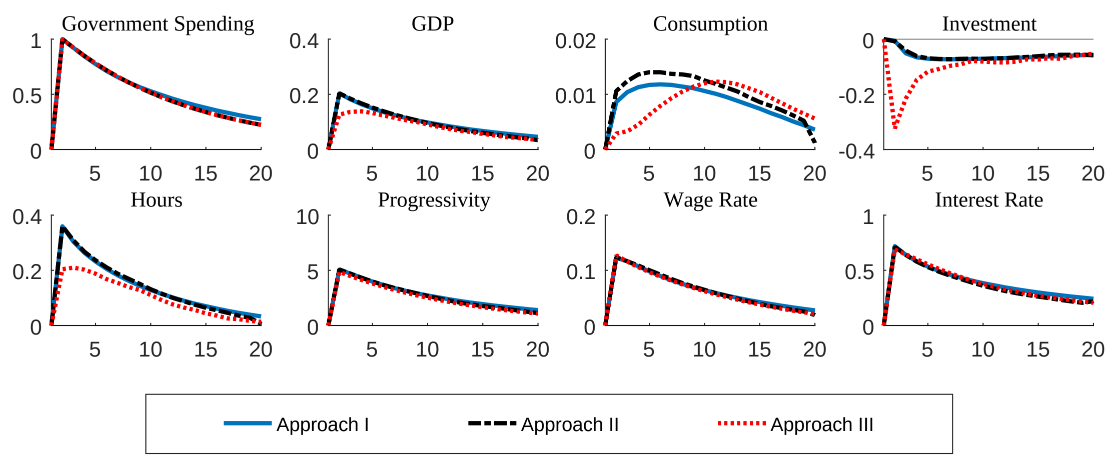

Figure A3. Impulse-responses of Aggregate Variables

Note: Responses of aggregate variables to a government spending shock using the three approaches. All variables other than the interest rate are logged.

A5. Sensitivity Analyses

In this subsection, I check if the results are robust to different values of key parameters: tax progressivity, τ, output elasticities of public spending, γ, and the tax policy parameter, ω. Since whether the model with smaller values of the parameters can account for the main findings is a key issue in these analyses, I only consider the parameter values which are less than the baseline values.[63]

[63]For example, one may argue that the benchmark parameter value of γ is too large.

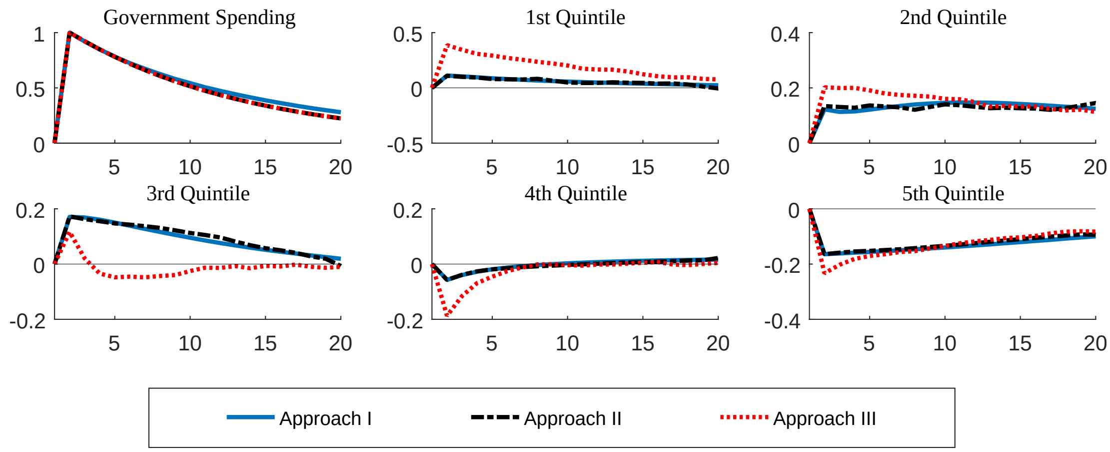

Figure A4. Responses of Consumption across Income Quintiles

Note: Responses of average consumption across the income quintiles to a government spending shock using the three approaches. All variables are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.

The first panel of Figure A5 shows the responses of consumption across the income quintiles to government spending shock with different indexes of tax progressivity, τ. The heterogeneous effects of the government expenditure on consumption across income distribution are consistently found with any positive indexes of tax progressivity.[64] The effects of government spending on consumption are still positive for households in the lower income quintiles and negative for ones in the upper quintiles. Next, the consumption responses across the income quintiles to government spending shocks with different values of output elasticities of public spending are shown in the second panel of Figure A5. With any values of γ, the heterogeneous effects of the government spending on consumption across the income distribution are reasonably generated: the effects of government spending on consumption are positive for the poor (except the second quintile) and negative for the top two quintiles.[65] Lastly, the third panel of Figure A5 reports the consumption dynamics across the income distribution after a spending shock with different measures of tax policy parameter, ω. Overall, the different effects of the government expenditure on consumption across the income quintiles are also well-replicated with different values of ω.[66]

[64] In this analysis, I do not recalibrate ω (the tax policy parameter). Thus, the effect of the different tax progressivity are not monotone.

[65] The reason why the second quintile shows the negative sign is as follows. In the model economy, households in the second group own a relatively large amount of wealth compared to other poor income groups. With large γ, the effects of productive government spending are large, so they can increase their consumption and investment at the same time since after-tax interest rates also rise after a shock. However, when γ is small, they want to save more and consume less since the intertemporal substitution effect is much larger than the income effect.

[66] Similarly, when ω is small, the second quintile reduces consumption since the intertemporal substitution effect is larger than the income effect.

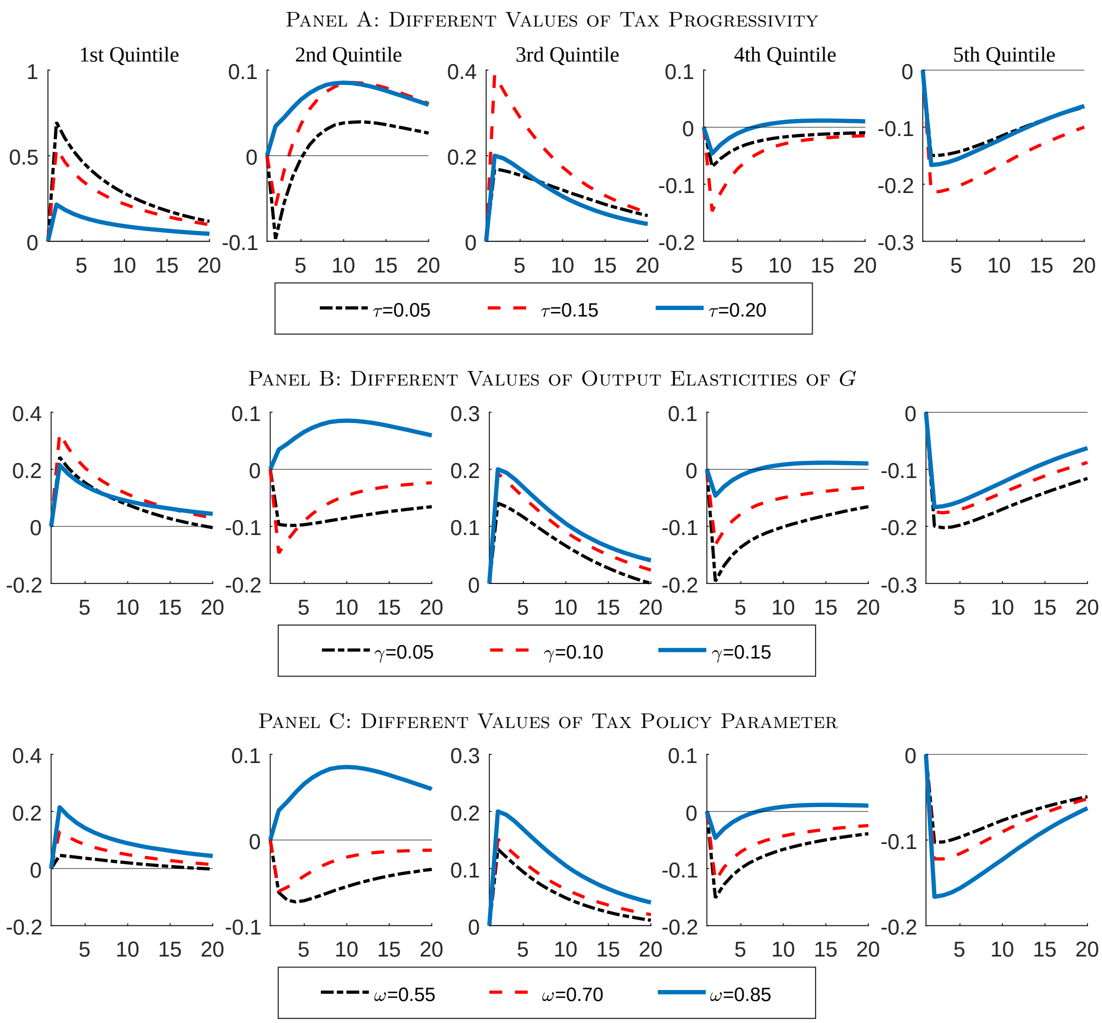

Figure A5. Responses of Consumption across Income Quintiles with Different Parameter Values

Note: Responses of average consumption across the income quintiles to a government spending shock with different parameter values. All variables are logged. "1st Quintile" denotes the lowest income quintile, and "5th Quintile" denotes the top income quintile.