The Heterogeneous Effects of Government Spending: It's All About Taxes*

Axelle Ferriere† and Gaston Navarro‡

April 2017

Abstract

How expansionary is government spending? We revisit this classic question by taking into account the distribution across households of taxes used to finance these spending. Using US data from 1913 to 2006, we provide evidence that government spending multipliers are positive only when financed with more progressive taxes. We show that this finding can be rationalized in a heterogeneous households model, where a rise in government spending can be expansionary only if financed with more progressive taxes. Key to our results is the model endogenous heterogeneity in households' marginal propensities to consume and labor supply elasticities. Finally, we analyze tax revenue data on households' income to provide evidence of our mechanism at the micro level.

Keywords: Fiscal Stimulus, Government Spending, Transfers, Heterogeneous Agents.

JEL Classification: D30, E62, H23, H31, N42

---

*Preliminary and Incomplete. We are very grateful to David Backus, who helped us along every stage of this paper and taught us how to enjoy that long-term process . We also thank Jonas Arias, Anmol Bhandari, Julio Blanco, Tim Cogley, Francesco Giavazzi, Boyan Jovanovic, Ricardo Lagos, Thomas Sargent, Gianluca Violante, and participants at NYU Student Macro Lunch, the North-American Summer Meeting of the Econometric Society 2014, the Midwest Macroeconomics Meetings 2015, and the SED meeting 2016 for their helpful comments. We are particularly thankful to Daniel Feenberg for his help with TAXSIM data. We also thank Aaron Markiewitz for research assistantship. Ferriere would like to acknowledge the support of the ADEMU project, "A Dynamic Economic and Monetary Union". ADEMU is funded by the European Union's Horizon 2020 Program under grant agreement N 649396 (ADEMU). The views expressed are those of the authors and not necessarily those of the Federal Reserve Board or the Federal Reserve System. Click here for updates.

†European University Institute: axelle.ferriere@eui.eu

‡Federal Reserve Board: gaston.m.navarro@frb.gov

1 Introduction

What are the effects of a temporary increase in government spending on output and private consumption? Although a recurrent question in policy debates, there exists a wide range of empirical and theoretical findings in the literature. While some empirical work finds that an increase in government spending induces large expansions on output and private consumption, others argue for mild responses only.[1] At odds with these results, most commonly used models in macroeconomics predict a limited expansionary response in output after an increase in government spending, and a strong decline in private consumption. The response in output even turns contractionary when distortionary taxes are used.[2]

In this paper, we aim to reconcile these findings by emphasizing the importance of the distribution of taxes. In particular, we estimate the effects of government spending taking into account tax progressivity. At the macro-level, we find that government spending multipliers are positive only when financed with more progressive taxes, and negative otherwise.[3] At the micro-level, we find that government spending has heterogeneous effects across households: it is expansionary for low-income households only when accompanied with an increase in tax progressivity; on the other hand, responses are statistically equal to zero for top-income earners. Importantly, key for the identification of these results, is that tax progressivity fluctuates enough, specially around periods of large changes in government spending. We construct a measure of US tax progressivity for the period 1913-2012, and show that this is effectively the case.

A second contribution of the paper is to develop a model consistent with the above findings, suitable to discuss how tax progressivity shapes the effects of government spending. In particular, we use a model with heterogeneous households and idiosyncratic risk (Aiyagari, 1994) to assess the effects of government spending. In line with the evidence, we find that the progressivity of taxes is a key determinant of the effects of government spending. A temporary increase in government spending can be expansionary, both for output and private consumption, if financed with more

[1] See Ramey (2011a) and Ramey (2016) for recent surveys.

[2] See Baxter and King (1993) or Uhlig (2010) more recently.

[3] Government spending multipliers are defined as the amount of dollars that output increase by after a $1 increase in government spending. See Section 2 for formal definitions.

progressive taxes. It is contractionary otherwise, in line with Baxter and King (1993).

Our results crucially depend on how different households respond to changes in taxes. The model endogenously generates a higher marginal propensity to consume for poor households, as well as a labor supply elasticity that declines with wealth.[4] Thus, an increase in government spending financed with taxes on poor households, generates a strong decline in consumption and labor supply, and consequently an economic contraction. On the other hand, if more progressive taxes are used, the contraction is less severe and spending multipliers are larger. These heterogeneous households' responses is in line with the evidence discussed above. To the best of our knowledge, this intuitive and empirically realistic finding is new in the literature.

Since Baxter and King (1993), it is known that the effects of government spending depend on the taxes used to finance it. In this paper, we focus on a particular dimension of taxes, namely, their distribution across households. The discussion above points out the importance of changes in progressivity, both theoretically and empirically. Although we are primarily interested in understanding how progressivity shapes the effects of government spending, we isolate in Section [X] the effects of a temporary change in tax progressivity, assuming constant government spending. We find that changes in progressivity are a powerful tool for inducing output and consumption expansion. This suggests directions for future research, as we discuss at the end of the paper.

1.1 Breaking the Crowding-Out of Public on Private Consumption

Typically, empirical work measures the effects of government spending by means of a multiplier: the amount of dollars that consumption or output increase by after a $1 increase in government spending. Table 1 summarizes multipliers found in previous work. Output multipliers range from 0.3 to unity, while consumption multipliers are closer to zero - typically not larger than 0.1.[5] These inconclusive findings are already puzzling: as we argue next, 'standard' models in macroeconomics predict a crowding-out of private consumption after an increase in public consumption.[6]

[4]Because we assume an indivisible labor supply choice, the definition of labor supply elasticity is not obvious. The statement refers to the average labor responses, by wealth deciles, to a one-percent increase in wage. Different measures are provided in Section [X].

[5]Except for Blanchard and Perotti (2002) who find large positive consumption multipliers.

[6]By 'standard' we have in mind the two workhorse models in macroeconomics: the neoclassical growth model and the benchmark New Keynesian model.

Table 1: Output and Consumption Multipliers: Summary of the Empirical Literature

Multipliers (on impact)	Output	Consumption
Blanchard and Perotti (2002)	0.90 (0.30)	0.5 (0.21)
Gali, Lopez-Salido, and Valles (2007)	0.41 (0.16)	0.1 (0.10)
Barro and Redlick (2011)	0.45 (0.07)	0.005 (0.09)
Mountford and Uhlig (2009)	0.65 (0.39)	0.001 (0.0003)
Ramey (2011b)	0.30 (0.10)	0.02 (0.001)

Notes: *All numbers are obtained from the original papers. Numbers in parenthesis stand for standard deviations.*

Consider a real business cycle model with a representative household, competitive labor markets, and preferences over consumption c and hours worked h given by:

$$U(c,h) = \frac{c^{1-\sigma}}{1-\sigma} - \frac{h^{1+\varphi}}{1+\varphi}$$

As described in Hall (2009), the key equation for understanding the impact of government spending on private consumption is the *intra-temporal* Euler equation. If lump-sum taxes are used by the government, this equation reads as follows

$$\downarrow \log mph_t = \downarrow \sigma \log c_t + \uparrow \varphi \log h_t, \tag{1}$$

where mph is the marginal product of labor. This equation defines a very tight link between hours worked and consumption: if, as typically found in the data, households work more after an increase in government spending, the marginal product of labor falls and private consumption has to drop for equation (1) to hold. In addition, if government expenditures are financed with labor income taxes τ, these taxes must increase to finance the increase in public consumption.[7] Thus, as shown

[7] We are implicitly assuming a balanced budget.

in equation (2), consumption drops even further, as initially remarked by Baxter and King (1993):

$$\downarrow \log(1-\tau_t) + \downarrow \log mph_t = \downarrow\downarrow \sigma \log c_t + \uparrow \varphi \log h_t, \tag{2}$$

This crowding-out effect of government spending on private consumption is typically seen as puzzling since it is not in line with many empirical findings.

We break equation (2) in two dimensions. First, we assume an indivisible labor supply, as in Hansen (1985), Rogerson (1988), or Chang and Kim (2007) more recently. Then, equation (2) holds with inequality at the individual level, breaking the tight link between government spending, consumption and labor. As pointed out by Chang and Kim (2007), the indivisibility of labor choice generates a countercyclical labor wedge. We show that this effect will help us deliver larger output multipliers, but will not be enough to obtain positive consumption multipliers. The second, and more important, way in which we break equation (2) is by assuming labor income taxes that depend on households' heterogeneous characteristics. As a consequence, at the moment of an increase in government spending, some households may face larger taxes while others may see a reduction in their taxes. The distribution of the tax burden towards wealthier households generates a positive multiplier. This is the key new force that we analyze in this paper.

The rest of the paper is organized as follows. Section 2 contains the empirical analysis, both at the macro and micro level. In Section 3 we layout the model, and Section 4 computes the effect of government spending for different tax progressivity schemes. Section 6 isolates the effect of temporary increases in tax progressivity, and Section 7 concludes.

2 Evidence

In this section, we provide evidence that the government spending multipliers crucially depend on tax progressivity. First, we argue that spending induces a significantly larger expansion on output when accompanied with an increase in tax progressivity. Second, we show that government spending shocks have heterogeneous effects on households: they are expansionary for low-income households only when accompanied with an increase in tax progressivity, but are statistically equal

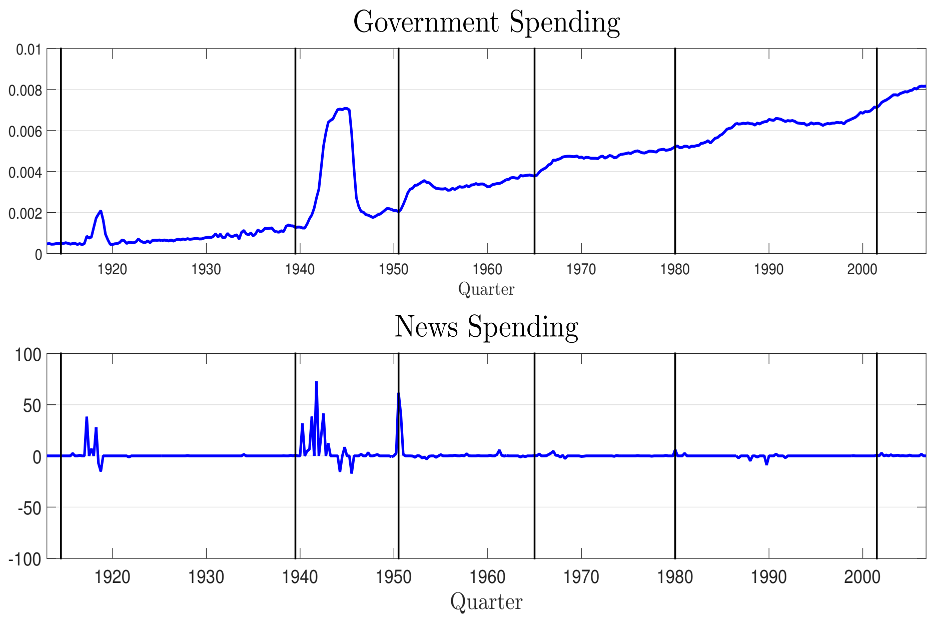


Figure 1: Defense Spending and Ramey Defense News

Notes: Vertical lines correspond to major military events: 1914:q3 (WWI), 1939:q3 (WWII), 1950:q3 (Korean War), 1965:q1 (Vietnam War), 1980:q1 (Soviet Invasion to Afghanistan), 2001:q3 (9/11).

to zero for top-income earners in that case. These findings are the core motivation for the model we develop in Section 3.

As Figure 1 shows, most significant changes in government spending occurred during war periods, prominently before the 1960s. Thus, it is important to have a measure of tax progressivity that starts early in the 20^{th} century. We do this in Section 2.1, where we develop and compute a novel measure of tax progressivity for the US covering the period 1913-2012. We then use this measure to estimate how government spending multipliers depend on tax progressivity. Aggregate multipliers estimations are provided in Section 2.2, while estimate of the distribution of multipliers are provided in Section 2.3.

2.1 A Tax Progressivity Measure: 1913-2012

Our new measure for tax progressivity γ of the federal income and social security tax in the US between 1913 and 2012 is plotted in Figure 2. This measure relies on a fundamental assumption:

that the individual income tax system is well approximated by a loglinear function, which is characterized by two parameters, (λ, γ), where λ captures the level of the tax system and γ its curvature. In particular, we assume that, for a given income y, the after-tax income is equal to $\tilde{y} \equiv \lambda y^{1-\gamma}$. Equivalently, the tax rate $\tau(\cdot)$ for an income level y is given by $\tau(y) = 1 - \lambda y^{-\gamma}$. Using the IRS Public Files for the period 1962-2008, Feenberg, Ferriere, and Navarro (2014) argue that such a tax system fits very accurately the US tax system; similar results are reported by Heathcote, Storesletten, and Violante (2014) and Guner, Kaygusuz, and Ventura (2012).[8] We provide robustness check of this assumption below.

Under this assumption, γ, the parameter that captures the curvature of the tax system, is equal to the ratio of the marginal minus the average tax rate, over unity minus the average tax rate:[9]

$$\gamma \equiv (AMTR - ATR)/(1 - ATR)$$

where $AMTR$ is the annual average marginal tax rate from 1913 to 2012 and ATR is the annual average tax rate from 1913 to 2012.[10] As a robustness check, we verify that our measure γ is highly correlated with the elasticity of the US federal personal income tax, as computed by Dan Feenberg using TAXSIM data over available years (1960-2012).[11] The correlation is of .85 in levels and .43 in growth rates. Finally, we transform this annual measure of progressivity into a quarterly one by repeating four times the annual measure. The rest of the data set is presented in Appendix A.2.

2.2 Macro Evidence from Local Projection Method

We use Jorda (2005) local projection method to estimate impulse responses and multipliers. This methodology has increasingly being used for applied work, including the recent works by Auerbach and Gorodnichenko (2012) and Ramey and Zubairy (2014) who apply this method to estimate

[8] See Section 3.2 for a more detailed explanation of this tax function.

[9] See Appendix A.1 for more details on this measure.

[10] The average marginal tax rate AMTR comes from Barro and Redlick (2011) and Mertens (2015). The average tax rate is based on our own computations using IRS Statistics of Income data and Piketty and Saez (2003). See Appendix A.2 for details.

[11] See Daniel's measure here: http://users.nber.org/∼taxsim/elas/.

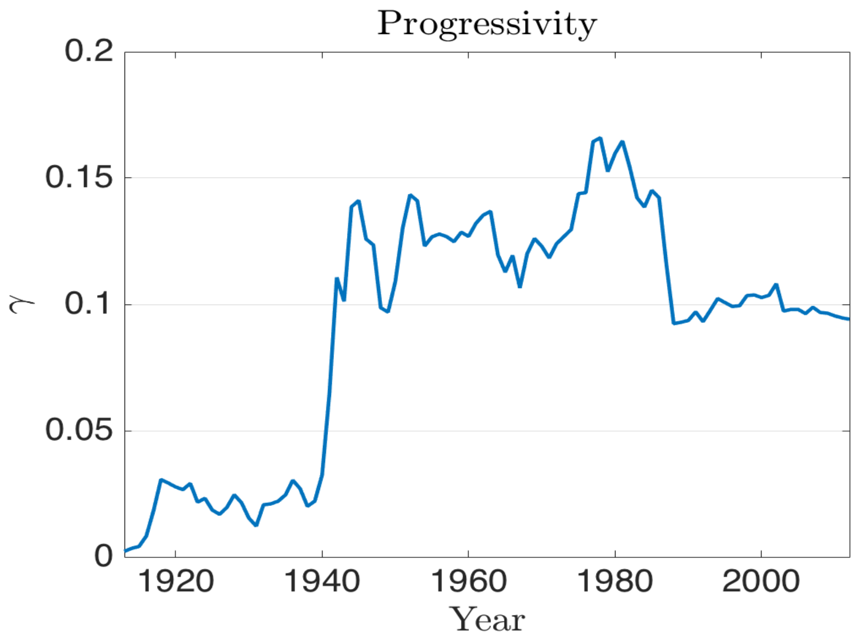


Figure 2: US Federal Tax Progressivity.

Notes: Souce: Authors' calculations.

state-dependent fiscal policy multipliers. A linear version of Jorda (2005) method is as follows

$$x_{t+h} = \alpha_h + A_h(L)Z_t + \beta_h shock_t + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H \tag{3}$$

where x_{t+h} is a vector of variables of interest, Z_t is a set of controls, $A_h(L)$ is a polynomial in the lag operator, and $shock_t$ is the identified shock of interest. In our case, $shock_t$ can take two alternatives: the government spending innovation as identified by Blanchard and Perotti (2002) (*BP* shock henceforth), or the defense news variable constructed by Ramey (2011b), and updated by Ramey and Zubairy (2014) (*RZ* shocks henceforth). For different horizons h, equation (3) can simply be estimated by ordinary least squares.

The coefficients β_h measure the h-periods ahead response of vector x_t to an innovation in $shock_t$ at time t. Thus, a plot of the sequence $\{\beta_h\}_h$ is interpreted as an impulse response function. Similarly, cumulative responses for different horizons h can be constructed as functions of $\{\beta_h\}_h$, although the precision of the estimates tends to declines with the horizon length.

The local projection method in equation (3) can be adjusted to accommodate non-linear relations as follows

$$
\begin{aligned}
x_{t+h} &= \mathbb{I}\left(s_t = \mathrm{P}\right)\left\{\alpha_{P,h} + A_{P,H} Z_{t-1} + \beta_{P,h} g_t^*\right\} \\
&+ \mathbb{I}\left(s_t = \mathrm{R}\right)\left\{\alpha_{R,h} + A_{R,H} Z_{t-1} + \beta_{R,h} g_t^*\right\} + \phi\ trend_t + \varepsilon_{t+h}
\end{aligned} \tag{4}
$$

where s_t is a variable determining whether if tax progressivity is increasing ($s_t = P$) or if it's not increasing ($s_t = R$), $\mathbb{I}(\cdot)$ is an indicator function, and g_t^* is the identified spending shock.

Key to our empirical implementation is the selection criteria for the value of s_t. We define a quarter t as having an increasing path in progressivity, if our tax progressivity measure γ_t increases on average during the following Δ quarters: $\left\{s_t = P : \gamma_t^a > \gamma_{t-1}^b\right\}$, where $\gamma_t^a \equiv \frac{1}{\Delta_a}\sum_{j=0}^{\Delta_a} \gamma_{t+j}$ and $\gamma_{t-1}^b \equiv \frac{1}{\Delta_b}\sum_{j=1}^{\Delta_b+1} \gamma_{t-j}$. The forward looking nature of our identification relies on the assumption that households have some predictive capacity on the future path of taxes. This is a reasonable assumption because the tax codes in the US has always changed sluggishly, with long periods of political discussion before the actual implementation of the tax change. In practice, we set $\Delta_a = 12$, $\Delta_b = 8$, so that a state of increasing progressivity is a period where the average tax progressivity in the next three years after the shock is higher than the tax progressivity the two years before. We also perform robustness exercises to this criteria and report it in Appendix.

Notice that $\{\beta_{s,h}\}$ depends on the state of tax progressivity, and we can thus compute impulse response functions and multipliers as a function of the state s_t. This is a key advantage of the local projection methodology, which allows to estimate state-dependent responses as the outcome of an ordinary least squares procedure.

The vector x_{t+h} contains two variables: the growth rate of GDP $\Delta^h y_{t+h} = \frac{Y_{t+h}-Y_{t-1}}{Y_{t-1}}$; and the adjusted by GDP increase in government spending $\Delta^h g_{t+h} = \frac{G_{t+h}-G_{t-1}}{Y_{t-1}}$. We use this adjusted measure of spending growth because, as initially pointed out by Hall (2009), it facilitates the multiplier computations to be interpreted as the dollar change in output after one dollar change in government spending (see equation (5) below). The control Z_t includes four lags of GDP and government spending.[12] Data is quarterly, and covers the period 1913-2006.

[12]When using the defense news variable, we also include four lags of the shock to clean for any possible serial

Let $\beta^y_{s,h}$ and $\beta^g_{s,h}$ be the response of $\Delta^h y_{t+h}$ and $\Delta^h g_{t+h}$ to g^*_t if $s_t = s$, respectively. Then, the cumulative multipliers at horizon h as

$$m_{s,h} = \frac{\sum_{j=0}^{h} \beta^y_{s,h}}{\sum_{j=0}^{h} \beta^g_{s,h}} \qquad \forall h = 0, 1, 2 \ldots, H \tag{5}$$

In practice, the state-dependent cumulative multiplier of equation (5) is computed by a two-stage linear-square estimator. In particular, we estimate the following equation

$$\begin{aligned} \sum_{j=0}^{h} \Delta y_{t+j} \quad &= \quad \mathbb{I}\left(s_t = \mathrm{P}\right) \left\{ \alpha_{P,h} + A_{P,H} Z_{t-1} + m_{P,h} \sum_{j=0}^{h} \Delta g_{t+j} \right\} \\ &+ \quad \mathbb{I}\left(s_t = \mathrm{R}\right) \left\{ \alpha_{R,h} + A_{R,H} Z_{t-1} + m_{R,h} \sum_{j=0}^{h} \Delta g_{t+j} \right\} + \phi \ trend_t + \varepsilon_{t+h} \end{aligned} \tag{6}$$

and instrument $\sum_{j=0}^{h} \Delta g_{t+j}$ by our identified shock g^*_t. Multipliers coming from equation (6) are numerically identical to the ones coming from (4)-(5). However, estimating multipliers from (6) has two advantages. First, we can use more than one instrument for $\sum_{j=0}^{h} \Delta g_{t+j}$. This is particularly appealing for us since we consider two different shocks, as well as a long sample. The second advantage of equation (6) is that it is simple to estimate confidence intervals for multipliers.[13] We estimate equation (6) by ordinary least squares, and use the Newey-West correction for our standard errors (Newey and West, 1987).

The effect of government spending on output is significantly higher during periods of increasing progressivity. Figure 3 shows this by plotting the cumulative responses $m_{s,h}$ to the BP shock for different horizons and each state $s = \{P, R\}$. The cumulative multiplier on output for the first three years is actually positive only when financed with more progressive taxes, and contractionary otherwise. The p-value for the difference in multipliers across states is always below 5% at all horizons plotted. We take this as key evidence that tax progressivity matters for the effects of government spending.[14]

correlation.

[13] Computing confidence intervals for multipliers using (4)-(5) requiers estimating a system of multiple equations and applying the delta method.

[14] In Appendix B, we provide several robustness checks of our estimates.

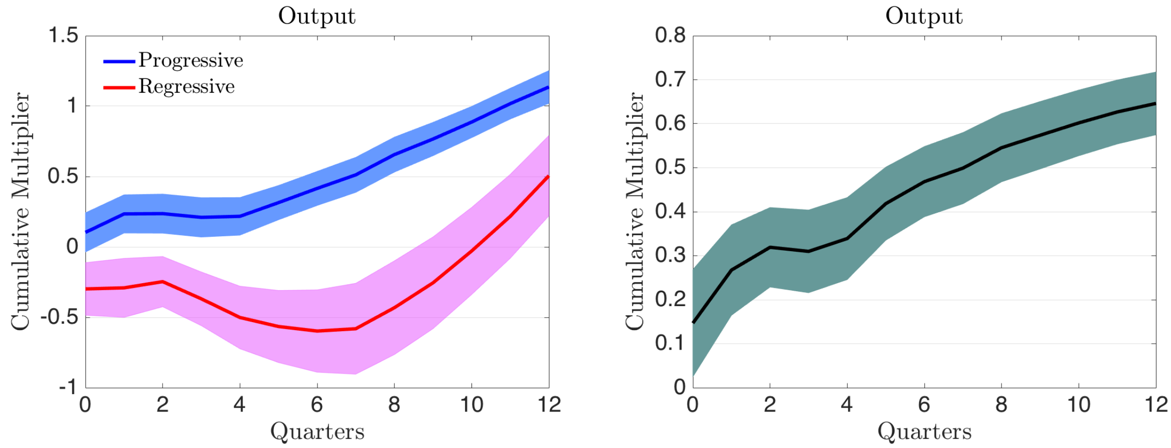


Figure 3: Cumulative multipliers on GDP

Notes: linear (left), progressive and regressive states (right). Local projection; data 1913-2006; confidence intervals: 68%; Responses to BP shocks.

Appendix B reports the results using the *RZ* shock, as well as using both *BP* and *RZ* as instruments. Our findings are robust, output multipliers are always larger when financed with more progressive taxes. For completeness, Figure 3 also shows the implied multiplier without differentiating across progressivity states.

2.3 Micro Evidence from Local Projection Method

This section concludes the empirical exercises by showing that government spending multipliers have heterogeneous effects across households with different income level. To do so, we sort and divide household in bins according to their income and compute means of pre-tax income for each income group. Our data comes from IRS public files, which are part of the TAXSIM program at the NBER and contains tax filling forms. The sample is annual, covers the period 1962-2006, and has approximately 100,000 observations per year.

Our measure of total income corresponds to Adjusted Gross Income (AGI) ignoring losses and adding capital gain deductions.[15] Finally, we transform annual income series into quarterly ones using a Chow-Lin interpolation method, where we interpolate using log of real GDP per capita, the

[15] One caveat of our data is that we do not observe whether the tax form is a household, a married couple filling separately or a single. We treat all tax forms equivalently.

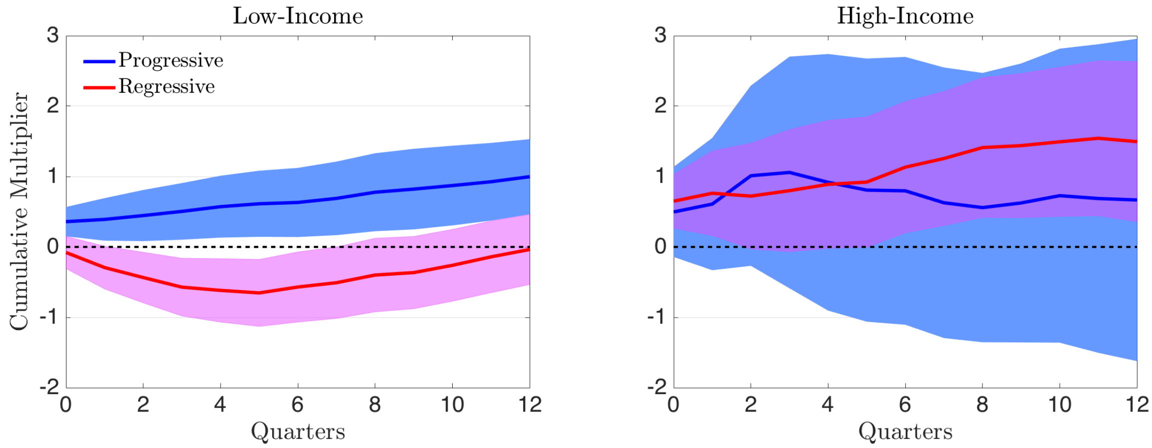


Figure 4: Cumulative multipliers on pre-tax income for different income groups

Notes: the left panel plots response to the average pre-tax income of the bottom* 40%*, the right panel of the top* 40%*. The shocks are identified using the Ramey defense news variable. Method: local projection; data 1952-2005; confidence intervals: 68%; window: 8 quarters.

log of real durable and non-durable consumption per capital, unemployment rates, interest rates, and the log of the CPI. The interpolation is constructed separately for each income group. Details can be found in Appendix A.3.

We estimate government spending multipliers following the same methodology as we did in equation (6). In particular, the left-hand side of equation (6) corresponds to the income of a given group, while the controls Z_t now includes four lags of log mean pre-tax income (for all groups), four lags of log pre-tax income of the group of interest, together with four lags of our mesure of progressivity.[16] We also normalize the government spending measure by the income of the group of interest: $\Delta^h g_{t+h} = \frac{G_{t+h} - G_{t-1}}{y_{d,t-1}}$, where $y_{d,t-1}$ is the mean income of the group. This facilitates the interpretation of the coefficients as multipliers, in the same way we did aggregate data. Finally, we instrument $\sum_{j=0}^{h} \Delta g_{t+j}$ by both BP and RZ shocks. Although not crucial for our results, this helps for identification given that government spending shocks are small for the time period in which we have micro-data.

The results are described in Figure 4, with the low-income response in the left panel and the high-income response in the right panel. Multipliers are positive for the low-income group in

[16]Notice that, since we use real GDP to interpolate the households' income measure to quarterly frequency, we cannot use as it as a control in Z_t.

progressive states, while they are negative in the regressive states. On the contrary, the responses of high income households are not statistically different.

Overall, we find evidence that government spending shocks have heterogeneous effects on heterogeneous households, depending on the progressivity of taxes used to finance them. Importantly, high income households exhibit a small responsiveness to government spending shocks even when shocks are financed with more progressive taxes. This is at the core of the mechanism in the model we develop next in Section 3.

3 A Model with Progressive Taxes

In this section, we develop a model that can account for the empirical findings described in Section 2. In particular, we show that an increase in spending induces an expansion in output only if financed with an increase in tax progressivity. Key to out result is the distribution of the tax burden towards households with lower elasticity of labor and consumption (i.e.: lower marginal propensity to consume). We first describe the steady state of the economy when government spending and taxes are constant, as well as the calibration strategy. In the following sections, we investigate the effects of government spending shocks in this economy.

3.1 Environment

Time is discrete and indexed by $t = 0, 1, 2, \ldots$. The economy is populated by a continuum of households, a representative firm, and a government. The firm has access to a constant return to scale technology in labor and capital given by $Y = K^{1-\alpha} L^{\alpha}$, where K, L and Y stand for capital, labor, and output, respectively. Both factor inputs are supplied by households. We assume constant total factor productivity.

Households: Households have preferences over sequences of consumption and hours worked given as follows:

$$\mathbb{E}_o \sum_{t=0}^{\infty} \beta^t \left[\log c_t - B \frac{h_t^{1+1/\varphi}}{1+1/\varphi} \right]$$

where c_t and h_t stand for consumption and hours worked in period t. Households have access to a one period risk-free bond, subject to a borrowing limit $\underline{a}$. They face an indivisible labor supply decision: during any given period, they can either work $\bar{h}$ hours or zero.[17] Their idiosyncratic labor productivity x follows a Markov process with transition probabilities $\pi_x(x', x)$.

Let $V(a, x)$ be the value function of a worker with level of assets a and idiosyncratic productivity x. Then,

$$V(a, x) = \max\{V^E(a, x), V^N(a, x)\} \tag{7}$$

where $V^E(a, x)$ and $V^N(a, x)$ stand for the value of being employed and non-employed, respectively. The value of being employed is given by

$$\begin{aligned} V^E(a, x) &= \max_{c, a'} \left\{ \log(c) - B\frac{\bar{h}^{1+1/\varphi}}{1+1/\varphi} + \beta \mathbb{E}_{x'} \left[V(a', x') | x \right] \right\} \\ \text{subject to} & \\ c + a' &\leq wx\bar{h} + (1+r)a - \tau(wx\bar{h}, ra) \\ a' &\geq \underline{a} \end{aligned} \tag{8}$$

where w stands for wages, r for the interest rate and $\underline{a}$ is an exogenous borrowing limit. Note that households face a distortionary tax $\tau(wxh, ra)$, which depends on labor income wxh and capital earnings ra. The function $\tau(\cdot)$ could accommodate different tax specifications, including affine taxes, and we will use to introduce different progressive tax schemes.

Analogously, the value for a non-employed household is given by

$$\begin{aligned} V^N(a, x) &= \max_{c, a'} \left\{ \log(c) + \beta \mathbb{E}_{x'} \left[V(a', x') | x \right] \right\} \\ \text{subject to} & \\ c + a' &\leq (1+r)a - \tau(0, ra) \\ a' &\geq \underline{a} \end{aligned} \tag{9}$$

[17]With indivisible labor, it is redundant to have two parameters B and φ. We keep this structure to ease the comparison with an environment with divisible labor in a later section.

If the household decides not to work, he does not obtain any labor earnings, but does not experience disutility of working. Every period, each household compares value functions (8) and (9) and makes labor, consumption and savings decisions accordingly. Let $h(a,x), c(a,x)$ and $a'(a,x)$ denote his optimal policies.

Firms: Every period, the firm chooses labor and capital demand in order to maximize current profits,

$$\Pi = \max_{K,L} \left\{ K^{1-\alpha} L^{\alpha} - wL - (r+\delta)K \right\} \tag{10}$$

where δ is the depreciation rate of capital. Optimality conditions for the firm are standard: marginal productivities are equalized to the cost of each factor.

Government: The government's budget constraint is given by:

$$G + (1+r)D = D + \int \tau(wxh, ra) d\mu(a,x) \tag{11}$$

where D is government's debt and $\mu(a,x)$ is the measure of households with state (a,x) in the economy. Notice that in steady state, government spending G as well as the fiscal policies $\tau(\cdot)$ and D are kept constant. In the next section, we will change this budget constraint in different ways and analyze its consequences.

Equilibrium: Let A be the space for assets and X the space for productivities. Define the state space $S = A \times X$ and $\mathcal{B}$ the Borel $\sigma-$algebra induced by S. A formal definition of the competitive equilibrium for this economy is provided below.

Definition 1 *A **recursive competitive equilibrium** for this economy is given by: value functions* $\left\{V^E(a,x), V^N(a,x), V(a,x)\right\}$ *and policies* $\{h(a,x), c(a,x), a'(a,x)\}$ *for the household; policies for the firm* $\{L, K\}$*; government decisions* $\{G, B, \tau\}$*; a measure* μ *over* $\mathcal{B}$*; and prices* $\{r, w\}$ *such that, given prices and government decisions: (i) Household's policies solve his problem and achieve value* $V(a,x)$*, (ii) Firm's policies solve his static problem, (iii) Government's budget constraint is satisfied, (iv) Capital market clears:* $K + D = \int_{\mathcal{B}} a'(a,x) d\mu(a,x)$*, (v) Labor market clears:*

$L = \int_{\mathcal{B}} xh(a,x)d\mu(a,x)$, *(vi) Goods market clears:* $Y = \int_{\mathcal{B}} c(a,x)d\mu(a,x) + \delta K + G$, *(vii) The measure* μ *is consistent with household's policies:* $\mu(\mathcal{B}) = \int_{\mathcal{B}} Q((a,x),\mathcal{B})d\mu(a,x)$ *where* Q *is a transition function between any two periods defined by:* $Q((a,x),\mathcal{B}) = \mathbb{I}_{\{a'(a,x)\in\mathcal{B}\}} \sum_{x'\in\mathcal{B}} \pi_x(x',x)$.

3.2 A Non-linear Tax Scheme

We assume a linear tax on capital income $\tau^K ra$, and a non-linear tax function τ^L on labor income wxh.[18] We borrow the function τ^L from Heathcote, Storesletten, and Violante (2014), which is indexed by two parameters, γ and λ: $\tau^L(y) = 1-\lambda y^{-\gamma}$. The parameter γ measures the progressivity of the taxation scheme. When $\gamma = 0$, the tax function implies an affine tax: $\tau^L(y) = 1-\lambda$. When $\gamma = 1$, the tax function implies complete redistribution: after-tax income $\left[1-\tau^L(y)\right] y = \lambda$ for any pre-tax income y. A positive (negative) γ describes a progressive (regressive) taxation scheme. The second parameter, λ, measures the level of the taxation scheme: one can think of $1-\lambda$ as a quantitatively-close measure of the average labor tax.[19] Thus, an increase in $1-\lambda$ captures an increase in the level of the taxation scheme (it shifts the entire tax function up), while an increase in γ captures an increase in progressivity. It turns the entire tax function counter-clockwise. Figure 5 shows how the tax function changes for different values of γ and λ.

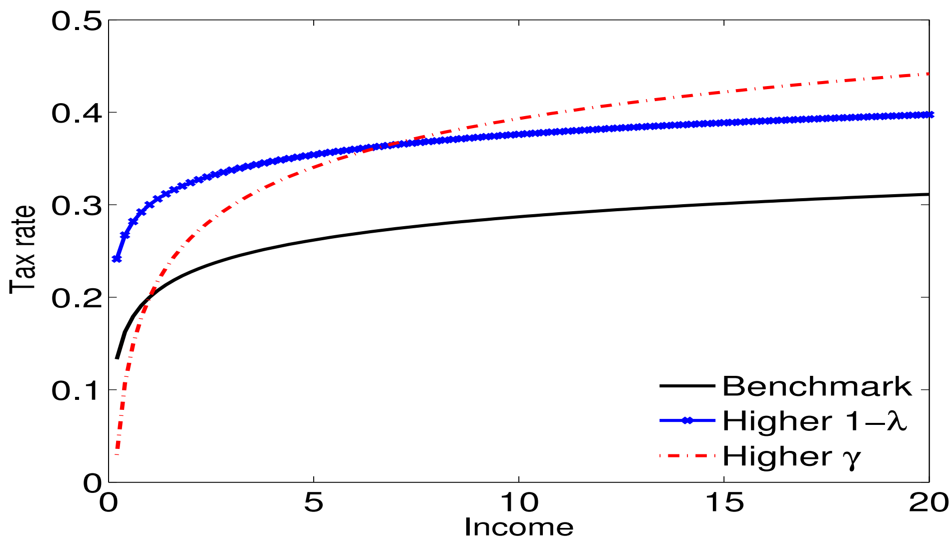
3.3 Calibration

Some of the model's parameters are standard and we calibrate them to values typically used in the literature. A period in the model is a quarter. We set the exponent of labor in the production function to $\alpha = 0.64$, the depreciation rate of capital to $\delta = 0.025$, and the level of hours worked when employed to $\bar{h} = 1/3$. We follow Chang and Kim (2007) and set the idiosyncratic labor productivity x shock to follow an AR(1) process in logs: $\log(x') = \rho_x \log(x) + \varepsilon'_x$, where $\varepsilon_x \sim \mathcal{N}(0,\sigma_x)$. Using PSID data on wages from 1979 to 1992, they estimate $\sigma_x = 0.287$ and $\rho_x = 0.989$. To obtain the transition probability function $\pi_x(x',x)$, we use the Tauchen (1986) method. The

[18] The choice of a progressive labor tax together with a flat capital tax is somehow arbitrary. However, Feenberg, Ferriere, and Navarro (2014) finde that capital taxes are well approximated by a afine tax function, while labor taxes exhibit more concavity.

[19] When $\gamma = 0$, $1-\lambda$ is exactly the labor tax. In our calibration with $\gamma = 0.1$, the average labor tax is 0.211 while $1-\lambda \approx 0.204$.

Figure 5: Non-linear tax as a function of two parameters (λ, γ).



Notes: Plots for the tax function $\tau(y) = 1 - \lambda y^{-\gamma}$, for different values (λ, γ). The parameter γ measures progressivity, while $1 - \lambda$ measures the level of the tax function.

borrowing limit is set to $\underline{a} = -2$, which is approximately equal to a wage payment and delivers a reasonable distribution of wealth (see Table 3 below).

For the tax function $\tau(wxh, ra)$, as discussed in Section 3.2, we assume affine capital taxes and non-linear labor income taxes: $\tau(wxh, ra) = \tau_L(wxh)wxh + \tau_K ra$. We set capital taxes to $\tau_K = 0.35$, following Chen, Imrohoroglu, and Imrohoroglu (2007). For labor taxes, we select the progressivity parameter γ as follows: by using PSID data on labor income for the years 2001 to 2005, Heathcote, Storesletten, and Violante (2014) find a value of $\gamma = 0.15$; with IRS data on total income for the year 2000, Guner, Kaygusuz, and Ventura (2012) find a value of $\gamma = 0.065$. We set $\gamma = 0.1$, an intermediate value between these two estimates. The value of λ is computed so that the government's budget constraint is met in equilibrium. Finally, we jointly calibrate preference parameters β and B, and policy parameters G and D to match an interest rate of 0.01, a government spending over output ratio of 0.15, a government debt-to-output ratio of 2.4, and an employment rate of 60 percent, which is the average of the Current Population Survey (CPS) from 1964 to 2003.[20] Table 2 summarizes the parameter values.

[20] We target an average 60% participation rate as observed in the CPS. As a robustness check, we compare the distribution of participation in our model with PSID data for the 1984 survey. The average participation rate in

Table 2: Parameter Calibration

$\beta = 0.987$	$B = 144$	$G = 0.21$	$D = 3.41$	$(\tau_k, \gamma, \lambda) = (0.35, 0.1, .85)$
$\alpha = 0.64$	$\varphi = 0.40$	$\delta = 0.025$	$\bar{h} = 1/3$	$\underline{a} = -2$
		$(\rho_x, \sigma_x) = (0.989, 0.287)$		

Table 3: Wealth and employment distribution in model and data

Quintiles	1st	2nd	3rd	4th	5th
Share of Wealth					
- *Model*	-0.01	0.04	0.12	0.25	0.61
- *Data (PSID)*	-0.00	0.02	0.07	0.15	0.77
Participation Rate					
- *Model*	0.83	0.63	0.57	0.52	0.45
- *Data (PSID)*	0.65	0.75	0.69	0.60	0.57

Notes: We keep all households where the head of household is 18 or above, and where labor participation is known for both the head and the spouse, if the head has a spouse. An individual is counted as participating in the labor market if he has worked or been looking for a job in 1983. Financial wealth includes housing.

Table 3 shows wealth and employment distribution in the model, compared to the PSID data for the total population over 18 years old in the 1984 survey.[21] As often in this class of models, the steady-state underestimate the right tail of the wealth distribution although it roughly matches the left part of the distribution.[22] For the labor force participation, the model predicts a strongly decreasing profile of participation rates with respect to wealth, which is only mildly observed in the data.[23] Overall, albeit simple, the model makes a reasonable fit with data. We show next that matching the wealth distribution is crucial for the key mechanism in the paper.

PSID is 65%, which is close to our target.

[21] We keep all households where the head of household is 18 or above, and where labor participation is known for both the head and the spouse, if the head has a spouse. An individual is counted as participating in the labor market if he has worked or been looking for a job in 1983. Financial wealth includes housing.

[22] See Cagetti and De Nardi (2008) for details on wealth concentration in bond economies with heterogeneous households.

[23] Matching the distribution of employment participation rate is also a hard task for bond economies with heterogeneous households. See Mustre-del Rio (2012) who allows for heterogeneity in households preferences to match the distribution of participation rates.

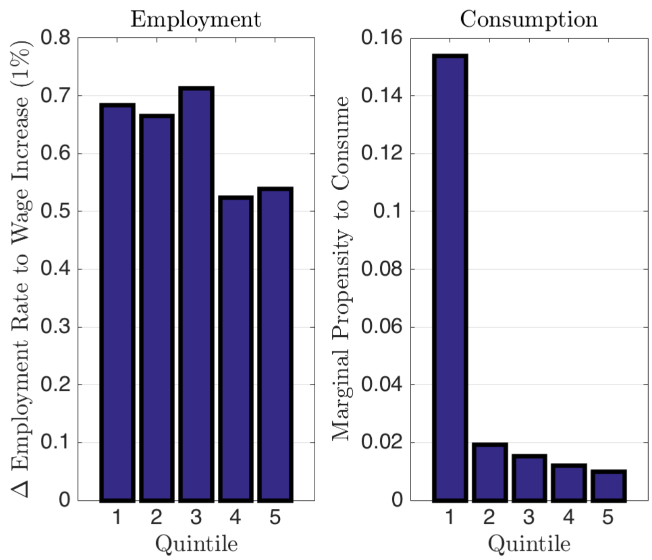


Figure 6: Participation rates and marginal propensity to consume by households wealth

Notes: Income is defined as $y(a, x) = wxh(a, x) + (1 + r)a - \tau(wxh, ar)$

3.4 A Distribution of Labor Supply Elasticities and MPCs

An increase in taxes implies a negative wealth effect, to which households respond by cutting down consumption. Furthermore, an increase in labor taxes typically induces households to work less. This is why an increase in spending financed higher taxes induces a contraction. However, the size of the contraction crucially depends on the elasticity of households' labor supply and consumption to the tax change. The smaller these elasticities are, the smaller the contraction generated.

In an economy with heterogeneous households, the individual responses to tax changes depend on the households' wealth. Figure 6 shows that poorer households have both a larger marginal propensity to consume, as well as a higher elasticity of labor supply. Accordingly, a tax increase on wealthier households will induce a smaller contraction that if taxes were increased for poor households.

The logic just described is the reason why tax progressivity shapes the effects of government spending. If the increase in spending is financed with higher tax progressivity, the response of aggregate consumption and hours will only mildly decline. However, the recession will be larger if less progressive taxes are used. This is the exercise we perform in next section.

4 Government Spending with Progressive Taxes

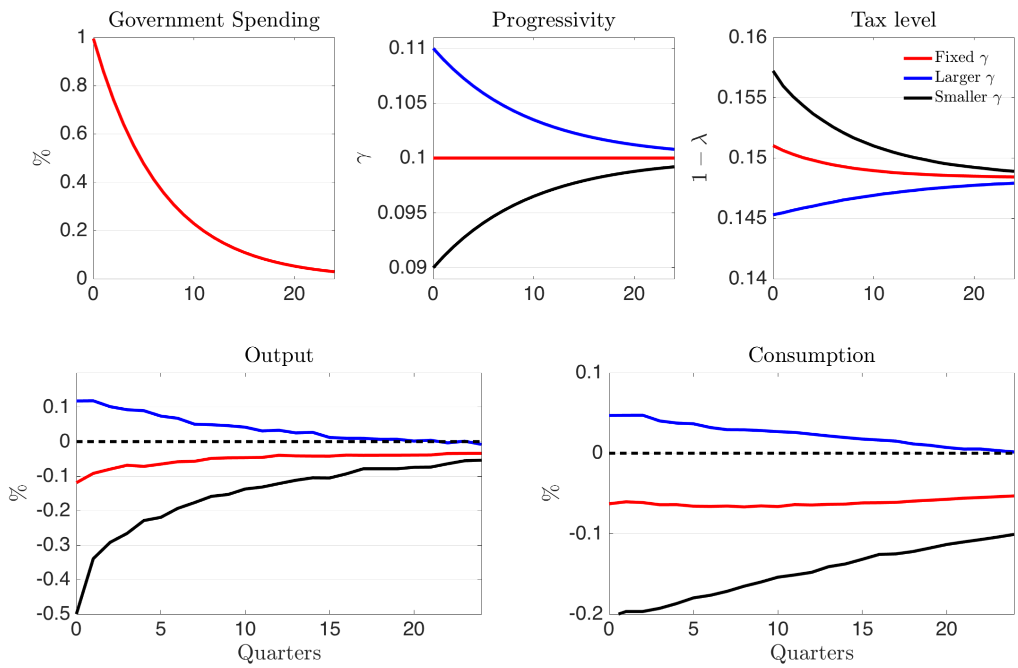
The discussion in Section 3.4 suggests that changes in the distribution of taxes can be a key driver of household's responses after a shock in government spending. In this section we analyze the effect of government spending, and how it depends on tax progressivity. We assume that at $t = 0$ the government unexpectedly and temporarily raises government spending G by one percent. Simultaneously, the government announces the taxation scheme that will be used to finance the increase in expenditures. In particular, it announces a path for the labor tax progressivity $\{\gamma_t\}$ that will be implemented jointly with the increase in spending. Capital tax and government's debt are kept at their steady-state value, and the sequence for $\{\lambda_t\}$ adjusts such that the government's budget constraint (11) is satisfied every period.

We explore the implications of three different taxation schemes: (1) **Constant Progressivity**: γ is kept at its steady state level; (2) **Higher Progressivity**: γ temporarily increases from 0.1 to 0.11; (3) **Smaller Progressivity**: γ temporarily decreases from 0.1 to 0.09. Note that the tax scheme used in every case is progressive (γ is always positive); only the level of progressivity changes. Also, all experiments generate the same revenues per period for the government. Finally, households have perfect foresight about the future paths of spending and taxes in all cases.

The top right panel of Figure 7 shows the path implied for $1 - \lambda$. When γ is constant, the level of the tax scheme has to increase since the government needs to raise more revenues: the average labor tax increases. However, when progressivity γ increases, the government can afford a mild decrease in the tax level since it is taxing higher income at a higher rate. On the contrary, a decrease in γ requires a large increase in the tax level $1 - \lambda$ to finance the new spending.

The bottom panel of Figure 7 plots the economy's responses for output and aggregate consumption in these three experiments. Our findings are threefold. First, output and consumption multipliers to a spending shock depend crucially on the taxation scheme used: not only their magnitude, but even their sign, can change. Second, with constant (or smaller) progressivity, the shock in spending results in a contraction of both output and consumption. The reason is that average tax rates, as measured by $1 - \lambda$, must increase to balance the government's budget constraint, which is contractionary. As such, our experiment with fixed γ is qualitatively similar to the result

Figure 7: Responses to a government spending shock financed with different tax systems.



Notes: Model impulse response to a government spending shock financed with progressive labor taxes. Impulse functions are computed for different choices of progressivity $\{\gamma_t\}$.

of Baxter and King (1993): in a standard real business cycle model with a representative agent, an increase in government spending financed through a larger income tax is contractionary. Third, when government spending is financed with a *more progressive* taxation scheme, the model can generate a joint increase in public and private consumption.

It is worth emphasizing that all the taxation schemes described above generate the *same* amount of revenues for the government (balanced budget). Different multipliers are obtained as a result of different levels of progressivity: the key mechanism analyzed here is how the burden of taxes is distributed across households, not over time. To the best of our knowledge, this intuitive finding is new in the literature.[24]

4.1 Expansionary progressive taxes

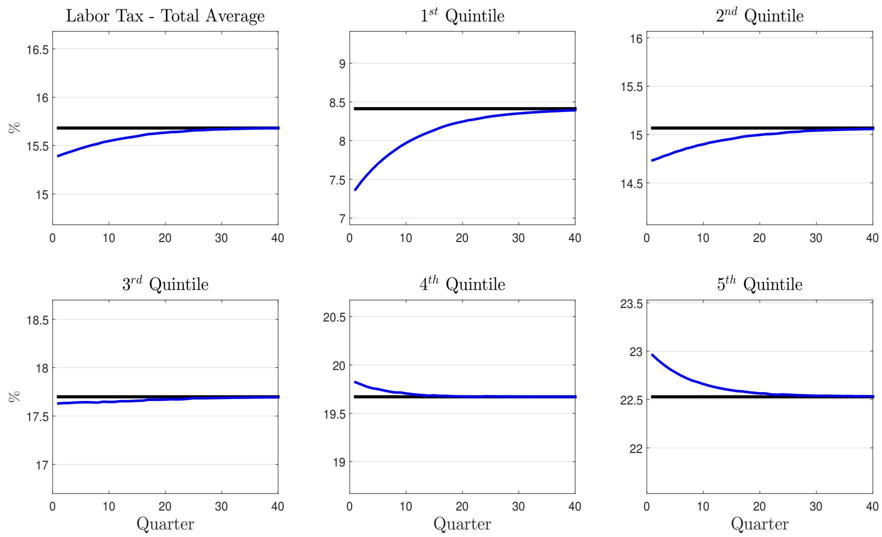
Why is it true that government spending financed with more progressive taxes is expansionary? The key difference is that progressive taxes distribute the tax burden towards wealthy agents. In turn, wealthy agents partly use their buffer savings to absorb this *temporary* shock, thus responding only mildly to the spending shock. Furthermore, with the increase in progressivity, some less wealthy households actually experience a decrease in taxes, as seen in Figure 8. This induces them to work[25] and consume more, as shown in Figure 9. Finally, the heterogeneity in marginal propensities to consume described above is such that overall consumption increases.

To conclude, notice that responses at the individual and at the aggregate level crucially depend on the taxation scheme used by the government; the heterogeneity across households does not wash out at the aggregate level. Modeling heterogeneous agents is key: in a model with a representative household, all experiments would collapse to a unique increase in the labor-tax rate faced by the representative household. In addition, the expansionary effect of government spending occurs because of the increase in tax progressivity and despite the increase in government spending. The

[24] On a related note, we provide in Appendix C robustness checks regarding the balanced budget assumption, as with heterogeneous agents and distortionary taxes, the Ricardian Equivalence does not hold. Using Uhlig (2010) formulation for debt-financed government spending, we argue that the response of tax progressivity is quantitatively of much larger importance for multipliers than the response of debt.

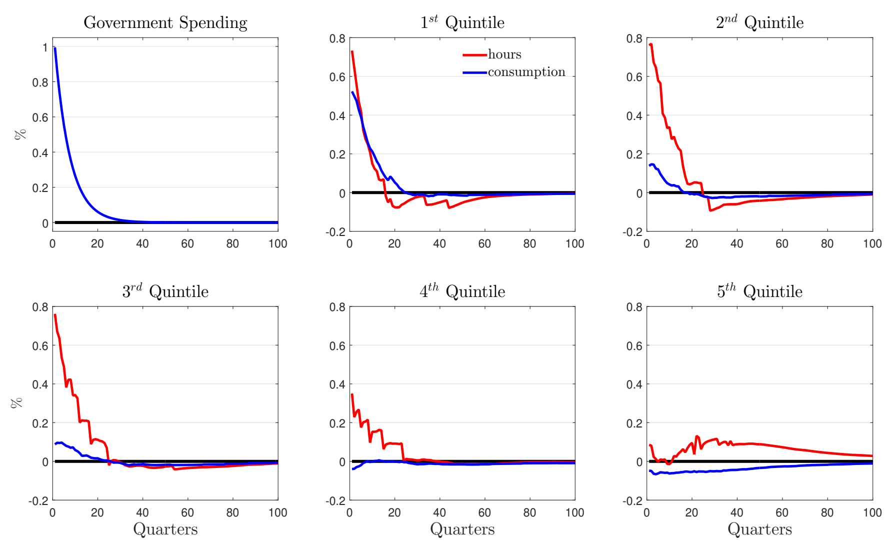
[25] Key to our result is the assumption of indivisible labor: with divisible labor, all things equal, an increase in tax progressivity decreases incentives to work for all agents; with indivisible labor, the key statistics for labor participation decision is the average rather than the marginal labor taxes.

Figure 8: Labor tax response to a government spending shock financed with more progressive taxes.



Notes: Impulse response, average and per wealthquintile, to a government spending shock financed with more progressive labor taxes.

Figure 9: Hours and consumption responses to a government spending shock financed with more progressive taxes.



Notes: Impulse response, average and per wealth quintile, to a government spending shock financed with more progressive labor taxes.

expansion would be larger if, for the same increase in progressivity, government spending were kept constant. We show this explicitly in Section 6.

5 Quantitative evaluation of the mechanism

We have shown that government spending multipliers are larger when spending are financed with more progressive taxes. In this section, we want to quantify this mechanism to understand if it can explain part of the puzzle described in introduction, that is, that government spending is typically contractionary in a representative-agent model with income taxes, while it is expansionary in the data.

To do so, we first compute the response of government spending and progressivity in the data, to a shock in military government spending.[26] Figure 10 shows the responses of these two variables. We then feed the paths for government spending and progressivity to our model, and compare the model responses when γ increases as in the data, to a counterfactual where γ is kept constant. Results are presented in Figure **??**.

Figure 10: Responses of government spending, progressivity and output, to a shock in government spending.
Notes: Data: 1951-2006, *RZ shocks, confidence intervals: 68%.*

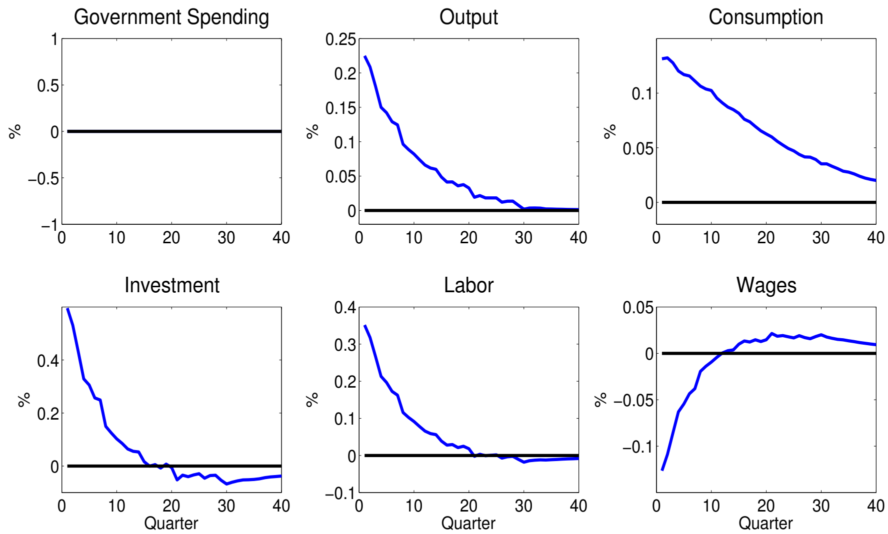
In the data output typically increases by around 0.5% to a shock in government spending. In a model without changes in tax progressivity, output decreases by -0.1% if the government does not use debt, or about 0 if it does; with the data path for progressivity, output increases by up to 0.1% without debt, up to 0.25% with debt.[27]

To summarize, we show that with a constant tax progressivity, the model is able to generate an output expansion of 0.1%. When progressivity increases as well, output increases by 0.25%: the change in tax progressivity associated with government sending can explain at least half of the

[26] We normalize the impact response of government spending to unity.

[27] Once again, we use the Uhlig (2010)'s rule for debt, setting the parameter for φ to 0.05: roughly speaking, 5% only of excess deficits generated by higher government spending and debt are paid with higher labor taxes. Note that $\varphi = 0$ would be the case where the government only uses debt, but this would violate the government's budget constraint. Hence, a positive φ is needed.

Figure 11: More progressive taxes, constant government spending



Notes:
Impulse response to a temporary increase in labor tax progressivity. Government spending is kept constant.

observed puzzle.

6 Transfers

As discussed earlier, output and private consumption in our model increase after a government spending shock because of the rise in progressivity, but despite the increase in public consumption. In other words, the economic expansion would be larger if, given the same change in progressivity, there were no increase in government spending. Indeed, if public consumption is kept constant, then revenues levied through taxes are also constant. Thus, when progressivity temporarily increases, the level of the labor tax function, $1 - \lambda$, can decrease more, resulting in a larger boom in output and consumption. Figure 11 shows the economy's response to an increase in progressivity γ as in Section 4, but with no increase in government spending.[28] Output and consumption increase by 0.22 percent and 0.14 percent respectively, versus 0.1 percent and 0.05 percent in Section 4. In other words, a temporary shock in progressivity is a powerful tool in generating expansions.

The exercise in this section suggest that changes in progressivity could have large effects on

[28] One may think of this experiment as measuring the effects of transfers: for a revenue-neutral budget, the government redistributes wealth from the wealthier to the least-wealthy households through rise and reductions of taxes.

aggregate output and consumption. This finding opens a large set of new questions, for instance, how a temporary change in progressivity differs from a permanent one, or whether a change in capital tax progressivity would have the same aggregate effects. A formal analysis of these topics is a priority for future work.

7 Conclusion

The aim of this paper is to solve the existing gap between evidence and model predictions regarding the aggregate effects of government spending. We develop a model where agents are heterogeneous in wealth and productivity, and labor is indivisible, and find that the distribution of the tax burden across households is crucial to determine the response of aggregate variables: a rise in government spending is more expansionary when financed with more progressive labor taxes. Key to our results is the model endogenous heterogeneity in households' marginal propensities to consume and labor supply elasticities.

Our empirical work provides evidence that tax progressivity has significantly moved in the US over the last century. This is important to discipline the somewhat old question of the macroeconomic effect of government spending. It also opens an avenue for future research on the aggregate and distributional effects of dynamic changes in tax progressivity.

References

Aiyagari, R. S. (1994): "Uninsured Idiosyncratic Risk and Aggregate Saving," *The Quarterly Journal of Economics*, 109, 659–684.

Auerbach, A., and Y. Gorodnichenko (2012): "Measuring the Output Responses to Fiscal Policy," *American Economic Journal Economic Policy*, (4), 1–27.

Barro, R., and C. Redlick (2011): "Macroeconomic Effects From Government Purchases and Taxes," *The Quarterly Journal of Economics*, 126(1), 51–102.

Baxter, M., and R. G. King (1993): "Fiscal Policy in General Equilibrium," *American Economic Review*, 83(3), 315–334.

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

Cagetti, M., and M. De Nardi (2008): "Wealth Inequality: Data And Models," *Macroeconomic Dynamics*, 12(S2), 285–313.

Chang, Y., and S.-B. Kim (2007): "Heterogeneity and Aggregation: Implications for Labor Market Fluctuations," *American Economic Review*, 5(97), 1939–1956.

Chen, K., A. Imrohoroglu, and S. Imrohoroglu (2007): "The Japanese Saving Rate Between 1960 and 2000: Productivity, Policy Changes, and Demographics," *Economic Theory*, 32(1), 87–104.

Feenberg, D., A. Ferriere, and G. Navarro (2014): "A Note on the Evolution of Tax Progressivity in the United States," Discussion paper.

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

Guner, N., R. Kaygusuz, and G. Ventura (2012): "Income Taxation of U.S. Households: Facts and Parametric Estimates," CEPR Discussion Papers 9078, C.E.P.R. Discussion Papers.

Hall, R. E. (2009): "By How Much Does GDP Rise if the Government Buys More Output?," *Brookings Papers on Economic Activity*, 2, 183–231.

Hansen, G. (1985): "Indivisible Labor and the Business Cycle," *Journal of Monetary Economics*, 16(3), 309–327.

Heathcote, J., K. Storesletten, and G. L. Violante (2014): "Redistributive Taxation in a Partial-Insurance Economy," Working paper.

Jorda, O. (2005): "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, 95(1), 161–182.

Mertens, K. (2015): "Marginal Tax Rates and Income: New Time Series Evidence," Working paper.

Mountford, A., and H. Uhlig (2009): "What are the Effects of Fiscal Policy Shocks?," *Journal of Applied Econometrics*, 24, 960–992.

Mustre-del Rio, J. (2012): "The Aggregate Implications of Individual Labor Supply Heterogeneity," Working paper, Federal Reserve Bank of Kansas City.

Newey, W. K., and K. D. West (1987): "A Simple, Positive Semi-definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, 3(55), 703–708.

Owyang, M. T., V. A. Ramey, and S. Zubairy (2013): "Are Government Spending Multipliers Greater During Times of Slack? Evidence from 20th Century Historical Data," *American Economic Review, Papers and Proceedings*, 2(103), 129–134.

Piketty, T., and E. Saez (2003): "Income Inequality in the United States, 1913-1998," *Quarterly Journal of Economics*, 1(118), 1–39.

Ramey, V. A. (2011a): "Can Government Purchases Stimulate the Economy?," *Journal of Economic Literature*, 3(49), 673–685.

——— (2011b): "Identifying Government Spending Shocks: It's All in the Timing," *Quarterly Journal of Economics*, 1(126), 51–102.

——— (2016): "Macroeconomic Shocks and Their Propagation," Working paper.

Ramey, V. A., and S. Zubairy (2014): "Government Spending Multipliers in Good Times and in Bad: Evidence from U.S. Historical Data," Working paper.

Rogerson, R. (1988): "Indivisible Labor, Lotteries and Equilibrium," *Journal of Monetary Economics*, 21(1), 3–16.

Tauchen, G. (1986): "Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions," *Economic Letters*, 2(20), 177–181.

Uhlig, H. (2010): "Some Fiscal Calculus," Discussion Paper 100.

A Data Sources and Definitions

A.1 Progressivity

A novel time series [P] is built to measure the progressivity of the federal income tax (including social security taxes and tax credits) since 1913, using a measure of average tax rate [ATR] and a measure of average marginal tax rate [AMTR]. The Average Tax Rate [ATR] is computed as Total Tax Liability over Total Income:

- Total Tax Liability (federal income and social security taxes, including tax credits); Source: Statistic Of Income (SOI), IRS; 1913-2014 (annual); Data, Table: "All Individual Income Tax Returns: Sources of Income and Tax Items". From 2006 to 2013, the time series are built by the SOI using another sampling; tax rates are the same until the third digit.

- Total income: Source: Piketty and Saez (2003), 1913-2014 (annual), Data, Table A0.

For the Average Marginal Tax Rate [AMTR], we use the time series of Barro and Redlick (2011) (Federal, Social Security, Data) for years 1912-1945 and Mertens (2015) (Federal, Social Security; Data) for 1946-2012; over the overlapping period, the two measures are almost undistinguishable (correlation, both in level and in growth rates: .99). Finally, the elasticity of the US federal personal income tax under fixed (1995) income distribution is computed by Daniel Feenberg using TAXSIM, 1960-2013 (annual), Data.

Finally, we construct an annual measure of federal personal income tax progressivity P as follows:

$$P = (AMTR - ATR)/(1 - ATR)$$

Should the tax system be exactly loglinear, this measure would be equal to γ. To see this, recall that under a loglinear tax system, given some income y, the after-tax income is $\lambda y^{1-\gamma}$; we define $T(y) \equiv y - \lambda y^{1-\gamma}$ the amount of taxes paid for income y, and $\tau(y) \equiv 1 - \lambda y^{-\gamma}$ the tax rate; the marginal tax rate is equal to $T'(y) = 1 - \lambda(1-\gamma)y^{-\gamma}$ and then:

$$\frac{T'(y) - \tau(y)}{1 - \tau(y)} = \frac{(1 - \lambda(1-\gamma)y^{-\gamma}) - (1 - \lambda y^{-\gamma})}{1 - (1 - \lambda y^{-\gamma})} = \gamma$$

Thus, our measure P gives us an approximation of the progressivity of the tax system, reasonably well correlated with the measure [GAMMA] computed using TAXSIM data.

A.2 Other macro variables

Fiscal data The measure for military news, borrowed from **?**, is available quarterly from 1913 to 2013 (Data). The measure for total government spending (including federal, state, and local purchases, but excluding transfer payments) is borrowed from Owyang, Ramey, and Zubairy (2013). As a robustness check, we use the quarterly measure of federal defense spending built by Ramey (2011b) (1939-2008), and the (interpolated) annual measure of federal defense spending from Barro and Redlick (2011) (1913-2006). Finally, we build a measure of federal surplus as percent of gross domestic product, as the ratio of nominal federal surplus (Source: FRED, 1913-2013, annual, interpolated per fiscal year) over nominal quarterly GDP (see below).

Business cycle data Quarterly measures for GDP, GDP deflator, and population, from 1913 to 2013, are borrowed from **?**. For consumption data, we merge the Gordon measure for real non-durable consumption (source: American Business Cycles), in real terms in \$1972, 1919-1941 and 1947-1983, quarterly), with the measure built by Ramey (2011b) (1939-2008, quarterly, in real terms, normalized to 100 in 2005). The correlation between the two variables over overlapping years is of 1.00 in levels and 0.95 in growth rates.

A.3 Micro data

Details on the micro data and interpolation to be added.

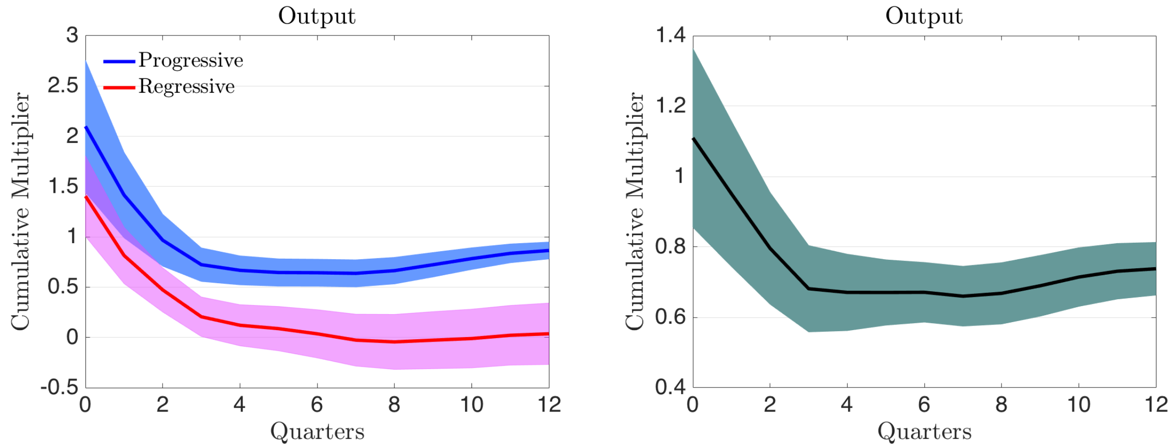


Figure 12: Cumulative multipliers on GDP

Notes: linear (left), progressive and regressive states (right). Local projection; data 1913-2006; confidence intervals: 68%; Responses to RZ shocks.

B Local Projection Method: Estimation and Inference

Table for robustness to be added.

C The role of debt

Details on Uhlig (2010) to be added.

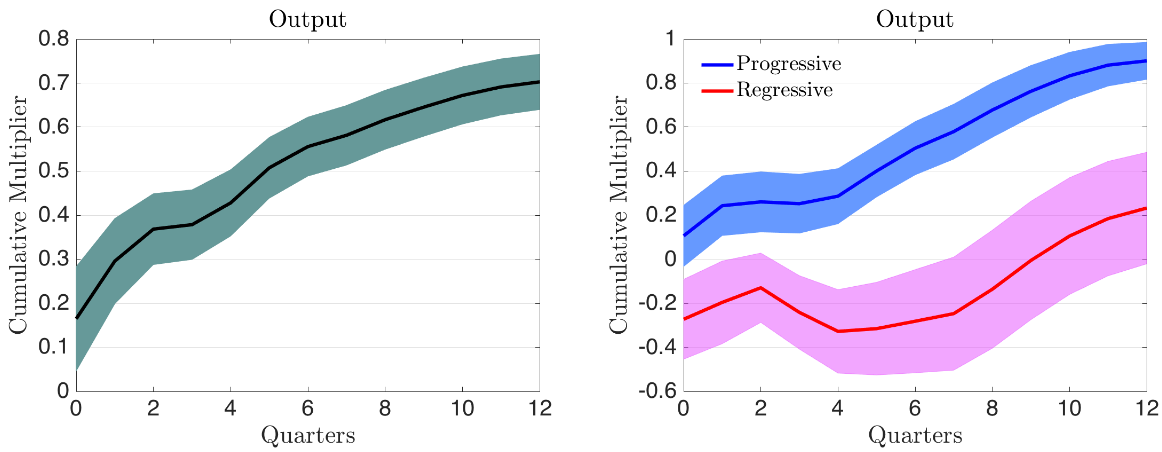
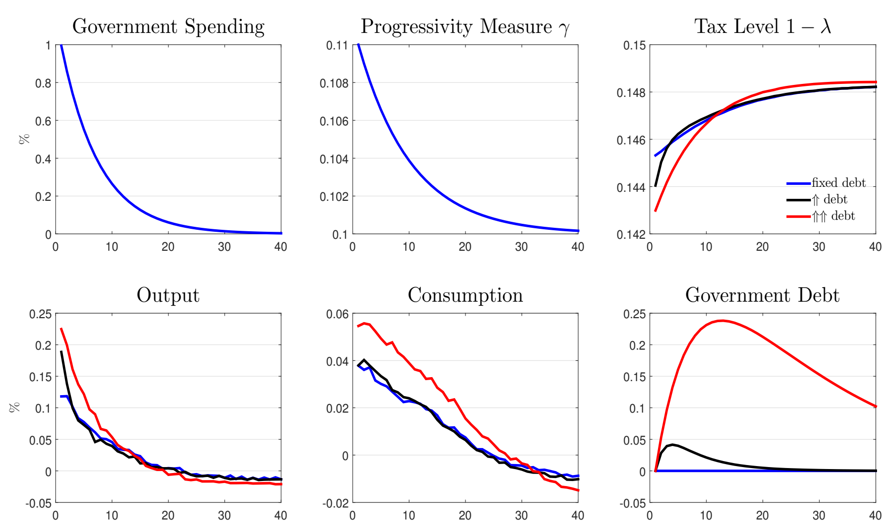


Figure 13: Cumulative multipliers on GDP

Notes: linear (left), progressive and regressive states (right). Local projection; data 1913-2006; confidence intervals: 68%; Responses to BP and RZ shocks.

Figure 14: Output and Consumption responses to a government spending shock financed with different levels of debt.



Notes: Impulse response to a government spending shock financed with more progressive labor taxes. No additional debt ($\varphi = 1$), some additional debt ($\varphi = .5$), mostly debt ($\varphi = .05$).