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

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Abstract

Empirical work suggests that while government spending induces an increase in output, it does not significantly decrease private consumption. Contrary to these findings, most representative-household models in macroeconomics predict a crowding-out of private consumption by government spending. To address this issue, we develop a model with heterogeneous households and uninsurable idiosyncratic risk as in Aiyagari (1994). In a model with heterogeneous households, progressivity of taxes is a key determinant of the effects of government spending. A rise in government spending can be expansionary, both for output and consumption, if financed with more progressive labor taxes. However, it is contractionary if financed with less progressive taxes. With a narrative approach, we use large changes in military spending to provide evidence that government spending in the United States has been expansionary *only* in periods of increasing progressivity.

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

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I Introduction

What are the effects of a temporary increase in government spending on private consumption and output? Although a recurrent question in policy debates, there exists a wide range of empirical and theoretical findings in the literature.[1] While some empirical work finds that an increase in government spending induces an expansion on private consumption, others argue that consumption only reacts mildly. At odds with these results, most commonly used models in macroeconomics predict a decrease in private consumption after an increase in government spending. In this paper, we aim to reconcile these findings by emphasizing the importance of taxes. We develop a model with heterogeneous households and idiosyncratic risk (Aiyagari, 1994) to assess the effects of government spending. As compared to models with a representative household, the new component in our paper is the existence of a distribution of taxes across households. We find that the progressivity of taxes is a key determinant of the effects of government spending. A rise in public consumption can be expansionary, both for output and private consumption, if financed with more progressive labor taxes. However, it is contractionary if financed with less progressive taxes. Finally, following a narrative approach as in Ramey and Shapiro (1998), we use events of large changes in military spending to provide evidence that, as suggested by our model, government spending in the US has been expansionary *only* in periods of increasing progressivity.

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 briefly 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.[2] These inconclusive findings are already puzzling: as we argue in Section *I.A*, 'standard' models in macroeconomics predict a crowding-out of private consumption after an increase in public consumption.[3] By analyzing the role of taxes across heterogeneous households, our paper provides new insights on how model predictions can be brought in line with empirical findings.

Our main result is that government spending multipliers depend on tax progressivity. The mechanism is simple. There is large heterogeneity in household responses after a government spending shock, and the key driver of these responses is the change in taxes associated with the shock. For instance, assume a rise

[1] Recently, the effects of government spending has been at the center of the debates on the implementation of the American Recovery and Reinvestment Act (ARRA), one of the largest fiscal stimuli in US history. See Cogan and Taylor (2012) for a recent discussion on the ARRA program and its implementation. See Alesina (2012) for a discussion of the effects of fiscal policy beyond government spending.

[2] The main exception being Blanchard and Perotti (2002) who find large positive multipliers for consumption.

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

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 (2011)	0.30 (0.10)	0.02 (0.001)

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

in public consumption that is financed through a temporary increase in tax progressivity. In this case, low-income households may actually experience a decrease in taxes. In turn, they have incentives to work and consume more during the periods of lower taxes. On the other hand, wealthy households face larger taxes, but is easier for them to smooth out the shock with their savings. Overall, the economy experiences an expansion. The same logic implies that a rise in public consumption financed with less progressive taxes results in a contraction of the economy; different revenue-neutral tax systems have different implications on aggregate quantities. The key mechanism this paper analyzes is how the burden of taxes is distributed across households.[4] To the best of our knowledge, this intuitive finding is new in the literature.

Our finding that tax progressivity shapes government spending multipliers is of particular importance for empirical work if, as is the case for the United State, progressivity of taxes has significantly changed over time. Figure 1 plots our measure of US federal tax progressivity for the years 1960-2006: progressivity increased over the sixties and the seventies, then sharply decreased over the eighties and stabilized after that.[5] In line with our model predictions, in Section VI we find positive (negative) multipliers on output

Figure 1: Federal taxes progressivity. US 1960-2006.

and consumption *only* when progressivity increased (decreased) with government spending.

I.A Breaking the Crowding-Out of Public on Private Consumption

Why can't a 'standard' model deliver a positive multiplier on consumption? 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

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

[4]See Uhlig (2010) for a recent analysis on the effects of distributing the tax burden over time in a representative household model.

[5]As a measure of progressivity, we computed the elasticity of *after-tax income* with respect to *pre-tax income*: $\gamma(y) = -\frac{\partial 1-\tau(y)}{\partial y}\frac{y}{1-\tau(y)}$, where $\tau(y)$ is the tax rate for an income level y. A higher value of $\gamma(y)$ implies a tax rate that increase faster with income, and thus a more progressive tax schedule. We use this definition of progressivity because it coincides with the measure of progressivity in our model, where we assume a tax function $\tau(y) = 1 - \lambda y^{-\gamma}$, borrowed from Heathcote, Storesletten, and Violante (2014). We describe this function in detail in Section V.A and explained the estimation of $\gamma(y)$ in Appendix E.

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.[6] Thus, as shown 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, as argued above, 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) or Chang and Kim (2007). 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 in equation (2) that can help us solve this puzzle. This is due to the endogenous wealth distribution: when labor increases, less productive households start working more; on average, these less productive households are less wealthy and exhibit a larger propensity to consume out of a discrete increase in labor income. As shown in Section IV, 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 consumption multiplier. This is the key new force that we analyze in this paper.

The rest of the paper is organized as follows. In Section II we discuss previous work and how it is related to our paper. Section III outlines the benchmark model in steady state with constant government spending and taxes. Section IV analyzes the effects of government spending when only lump-sum taxes are used. First, we find that households with different wealth levels respond very differently. Second, indivisible labor induces larger output multipliers, but does not deliver positive consumption multipliers. In Section V, we analyze progressive labor taxes. We show that output and consumption multipliers depend crucially on the tax scheme: the **size** and **sign** of multipliers depend on the changes in progressivity. Section VI uses a

[6] We are implicitly assuming a balanced budget.

narrative approach to estimate the effects of military spending during periods of different tax progressivity. In line with the model, we find that US government spending has been expansionary *only* in periods of increasing progressivity. In Section VII we shutdown government spending shocks and focuses on the effects of changes in progressivity and transfers across households.[7] We find that changes in progressivity, as well as transfers across households, are a powerful tool for inducing output and consumption expansion. Section VIII concludes.

II Literature Review

Our paper is related to three lines of research: (i) the empirical literature on the effects of government spending, (ii) models with government spending, and (iii) models with heterogeneous households. We discuss the connections of our paper to each topic.

There is a large body of empirical work that attempts to estimate the effects of government spending on aggregate output and consumption.[8] This literature can roughly be divided into two approaches: one that identifies government spending shocks using a structural VAR approach; another one using a narrative approach that focuses on periods of large changes in government spending.[9,10] Typically, papers using a structural VAR approach (Blanchard and Perotti, 2002; Gali, Lopez-Salido, and Valles, 2007; and Mountford and Uhlig, 2009, among others) find large output multipliers (close to unity) and significantly positive consumption multipliers. With varied methodological refinements, Nakamura and Steinsson (2013) and Auerbach and Gorodnichenko (2012) also find large output and consumption multipliers. Also in a structural VAR set-up, Ramey (2011) uses a "news" variable on military spending and finds significantly smaller multipliers for output and consumption. Similar results are found in Barro and Redlick (2011) when using Ramey's "news" variable. On the other hand, Ramey and Shapiro (1998), implement a narrative approach by using dummy variables on dates of military spending.[11] They find smaller output multipliers and negative or zero consumption multipliers. We contribute to this debate in Section VI by taking into account a measures of tax progressivity. Using a narrative approach, we argue that government spending multipliers in the US has been expansionary *only* in periods of increasing progressivity.

[7] Oh and Reis (2012) have recently argued that transfers across households represents a significant part of government spending.

[8] See Hall (2009) for a recent comprehensive review of the literature.

[9] See Perotti (2007) for an comprehensive comparison of both methodologies.

[10] The narrative approach literature generally uses government spending in periods of wars or military buildups, which dates are believed to be independent of the state of the economy and thus exogenous.

[11] See Burnside, Eichenbaum, and Fisher (2004) and Perotti (2007) for variations on Ramey and Shapiro (1998).

In addition, two recent empirical papers (Giavazzi and McMahon, 2012; and De Giorgi and Gambetti, 2012) have also focused on the effects of government spending on heterogeneous households. Their conclusions strongly diverge. Using PSID and CEX household-level data from the period 1996-2006, together with US military spending at the state level, Giavazzi and McMahon (2012) find that a temporary increase in government spending tends to slightly increase consumption inequality: low-income households decrease their consumption, while higher-income households do not. However, as they acknowledge, their identification strategy partly prevents them from estimating the negative wealth effects associated with increases in taxes.[12] On the contrary, De Giorgi and Gambetti (2012) argue that an increase in government spending induces a decrease in consumption inequality. They use CEX data from 1984-2008 to build average consumption per deciles, and then use a structural VAR to estimate the effect of government spending on each consumption decile. We contribute to this debate as well. We show that the findings of Giavazzi and McMahon (2012) are consistent with the effects of government spending on a subset of households that would not face any change in taxes. Typically, after an increase in government spending, wages decrease and interest rates increase. This leads to a decrease in consumption for indebted working households, but an increase in consumption for wealthy households. However, we argue that when we account for the effect of taxes, the findings of De Giorgi and Gambetti (2012) are more likely to be observed, especially in periods of increasing tax progressivity. Finally, we find that the effect of changes in taxes strongly dominates the price effect of government purchases in our model: the *"general equilibrium"* effects of government spending are small when compared to the changes in taxes (wealth effect).[13]

The theoretical literature on the government spending effects on private consumption is large and still growing. Since the seminal paper of Baxter and King (1993), which describes how public consumption crowds-out private consumption in a standard real business cycle model, theoretical research has been conducted in several directions in order to mitigate this crowding-out effect. For instance, Gali, Lopez-Salido, and Valles (2007) use sticky wages together with rule-of-thumb households in order to generate a joint increase in public and private consumption. Christiano, Eichenbaum, and Rebelo (2011) also uses a model with nominal rigidities to argue that, as in a zero lower bound scenario, if the monetary policy is not very responsive, government spending can have large expansionary effects. Similar logic is analyzed by Nakamura and Steinsson (2013). Both of these papers argue that non-separable preferences are necessary to obtain large multipliers, which is also stressed by Bilbiie (2009). In a paper more closely related to ours, Bilbiie, Monacelli, and Perotti (2012) study the effect of government spending in a New-Keynesian economy with two

[12] See page 3 of their paper.

[13] Giavazzi and McMahon (2012) also argue that their estimates are rather small.

type of agents: a saver and a borrower. With this exogenous distribution of wealth, and the use of nominal rigidities, they can also deliver positive multipliers on aggregate consumption. Lastly, Uhlig (2010) uses a real business cycle model with a representative household to point out that the distribution of distortionary taxes over time is key to analyze government spending shocks. Our contribution to this literature is to show that the distribution of taxes *across households* is crucial; small changes in the progressivity of taxes across households have first-order effects on aggregate output and consumption in a very standard macroeconomic model with a reasonable distribution of wealth.

There is a large literature regarding fiscal policy in models with heterogeneous households. Heathcote (2005) uses a similar economy to ours to analyze private consumption responses to a temporary decrease in lump-sum taxes. Similarly, Kaplan and Violante (2013) analyze the effects of tax rebates in an economy with heterogeneous households that hold liquid and illiquid assets. Oh and Reis (2012) and McKay and Reis (2013) analyze the effects of tax-and-transfers programs across households, which is the object of our study in Section VII. Heathcote, Storesletten, and Violante (2014) use a non-linear tax function to study the optimal tax progressivity level in a model with heterogeneous agents. To the best of our knowledge, our paper is the first to study public consumption in an Aiyagari (1994) economy. It is also the first to emphasize the importance of the progressivity of the taxation scheme to understand government multipliers on private consumption.

III Model

In this section, we describe the steady state of the economy when government spending and taxes are constant. We end this section by discussing our calibration strategy. In the following sections, we investigate the effects of government spending shocks in this economy.

III.A 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 and L stand for capital and labor, respectively, and Y denotes total output. Both factor inputs are supplied by households. We assume constant total 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 make an indivisible labor supply decision: during any given period, they can either work $\bar{h}$ hours or zero.[14] 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,

$$V(a, x) = \max\{V^N(a, x), V^E(a, x)\} \tag{3}$$

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

$$\begin{aligned} V^E(a, x) &= \max_{c, a'} \left\{ \log(c) - B \frac{\bar{h}^{1+1/\varphi}}{1+1/\varphi} + \beta \mathbb{E}_{x'} \left[V(a', x') | x \right] \right\} \qquad (4) \\ \text{subject to} & \\ c + a' &\leq wx\bar{h} + (1+r)a - T - \tau(wx\bar{h}, ra) \\ a' &\geq \underline{a} \end{aligned}$$

where w stands for wages, r for the interest rate and $\underline{a}$ is an exogenous borrowing limit. Note that households face two type of taxes: a lump-sum tax T and a distortionary tax $\tau(wxh, ra)$. The latter tax depends on labor income wxh and capital earnings ra. The function $\tau(\cdot)$ could accommodate different tax specifications, including affine taxes.

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

$$\begin{aligned} V^N(a, x) &= \max_{c, a'} \{ \log(c) + \beta \mathbb{E}_{x'} \left[V(a', x') | x \right] \} \qquad (5) \\ \text{subject to} & \\ c + a' &\leq (1+r)a - T - \tau(0, ra) \\ a' &\geq \underline{a} \end{aligned}$$

[14]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 (4) and (5) 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,

$$\Pi = \max_{K,L} \left\{ K^{1-\alpha} L^{\alpha} - wL - (r+\delta)K \right\} \tag{6}$$

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.

$$w = \alpha K^{1-\alpha} L^{\alpha-1} \tag{7}$$

$$r+\delta = (1-\alpha) K^{-\alpha} L^{\alpha} \tag{8}$$

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

$$G = T + \int \tau(wxh, ra) d\mu(a,x) \tag{9}$$

where $\mu(a,x)$ is the measure of households with state (a,x) in the economy. Notice that in steady state, government spending G as well as the tax policies $\tau(\cdot)$ and T 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 polices* $\{h(a,x), c(a,x), a'(a,x)\}$ *for the household; policies for the firm* $\{L, K\}$*; government decisions* $\{G, T, \tau\}$*; 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:* $K = \int_{\mathcal{B}} a'(a,x) d\mu(a,x)$*, (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:*

$$Q((a,x),\mathcal{B}) = \mathbb{I}_{\{a'(a,x)\in\mathcal{B}\}} \sum_{x'\in\mathcal{B}} \pi_x(x',x)$$

.

III.B Calibration

Some of our 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 borrowing limit is set to $\underline{a} = -2$, which is approximately equal to a wage payment and delivers a reasonable distribution of wealth.

For the remaining parameters, we calibrate two different economies: (1) an economy where taxes are only lump-sum and are equal across households; (2) an economy with distortionary taxes only. In the steady state with lump-sum taxes only, the government's budget constraint reads: $T = G$, and $\tau = 0$. In the steady state with distortionary taxes, we use affine capital taxes and non-linear labor income taxes: $\tau(wxh, ra) = \tau_L(wxh) + \tau_K ra$. We set capital taxes to $\tau_K = 35\%$, following Chen, Imrohoroglu, and Imrohoroglu (2007). For labor taxes, we follow Heathcote, Storesletten, and Violante (2014) and use a flexible non-linear tax function as follows: $\tau_L(wxh) = 1 - \lambda(wxh)^{-\gamma}$. As we discuss in Section *V.A*, $\gamma > 0$ implies a tax rate that is increasing in labor income (progressive), while $\gamma = 0$ implies an affine labor tax. 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 (no public debt). The implied average labor tax in the economy is equal to 21%, slightly below the 25% US rate (Chen, Imrohoroglu, and Imrohoroglu, 2007).[15] Finally, in each steady state we jointly calibrate β, B and G to match an interest rate of 1%, a government spending over output ratio of 20%, and an employment rate of 60%, which is the average of the Current Population Survey (CPS) from 1964 to 2003. Table 2 summarizes

[15]This could be explained by our assumption of no public debt in steady state, since the government has no interest rate payments to finance.

the parameter values.

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.[16] As often in this class of models, both of our steady-states underestimate the right tail of the wealth distribution.[17] The model with lump-sum taxes also overestimates the first quintile's share of wealth, while the model with distortionary taxes roughly matches the left part of the distribution. For the labor force participation, both steady-states predict a strongly decreasing profile of participation rates with respect to wealth. This pattern is indeed observed in the data, except for the first quintile. The model with distortionary taxes again matches the distribution better than the lump-sum taxes model, as the decreasing profile in participation rate is less pronounced.

In the following two sections, we quantitatively evaluate the model's response to an unexpected and temporary increase in government spending. In Section IV we use the model with lump-sum taxes only as a benchmark to assess the effects of indivisible labor. In Section V, we add a second layer: distortionary taxes.

IV Lump-Sum Taxes

As a first step, we analyze the case when only lump-sum taxes are used to finance government spending. The goal is twofold. First, we provide insights on the heterogeneity of household responses in consumption and hours worked. Second, we assess indivisible labor's effect in generating a countercylical labor wedge, and therefore, in solving the puzzle of aggregate private consumption described in Section I.

We analyze the economy's response to the following shock. At $t = -1$, the economy is at its steady state as described in Section III; at $t = 0$, the government announces that G will increase by 1% at $t = 1$ and then gradually come back to its steady-state value.[18] The additional government spending is financed by an equivalent, additional lump-sum tax, which is identical across agents. Thus, lump-sum taxes are used both at steady state and during the transition. The paths for taxes and spending were unexpected at $t = -1$, but perfectly foreseen from then onwards.

[16] 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.

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

[18] The increase in taxes may imply an empty feasible set for households close to the borrowing constraint. We allow agents to build up assets in order to afford the tax increase, using this one period lag in the timing of the shock. The shock follows an $AR(1)$ process with a persistence of 0.86.

Table 2: Parameter Calibration

Parameters	**Lump-Sum SS**	**Distortionary SS**
β	0.965	0.987
G	0.243	0.282
B	276	150
τ_K	–	0.35
(γ, λ)	–	$(0.1, 0.79)$

$\alpha = 0.64 \quad \varphi = 0.40 \quad \delta = 0.025 \quad \bar{h} = 1/3 \quad \underline{a} = -2$

$(\rho_x, \sigma_x) = (0.989, 0.287)$

Table 3: Wealth and employment distribution in model and data

Quintiles	1st	2nd	3rd	4th	5th
Share of Wealth					
- *Lump Sum Taxes*	0.05	0.08	0.13	0.22	0.51
- *Distortionary Taxes*	−0.01	0.04	0.12	0.25	0.61
- *Data (PSID)*	−0.00	0.02	0.07	0.15	0.77
Participation Rate					
- *Lump Sum Taxes*	0.99	0.69	0.51	0.42	0.35
- *Distortionary Taxes*	0.83	0.63	0.57	0.52	0.45
- *Data (PSID)*	0.65	0.75	0.69	0.60	0.57

How heterogeneous are the responses of private consumption and hours worked after the fiscal shock? To assess this question, we divide households into quintiles by their wealth level a every period: "Quintile 1" refers to the 20%-least wealthy households, while "Quintile 5" refers to the 20%-wealthiest households. Figure 2 shows the path for G as well as the average consumption and hours responses by quintile every period. There are significant differences across quintiles. First, the size and the persistence of consumption responses significantly decrease as agents become wealthier, being almost mute for the highest quintile. Second, responses in terms of hours worked are also very different across quintiles. In the steady state with lump-sum taxes, households in the first quintile exhibit an employment participation rate close to one (see Table 3) and cannot adjust to the spending shock by working more. Consequently, they must adjust by significantly cutting their consumption. The steady state employment rate of the second and third quintiles are lower, and these households can react by working more in order to finance the additional tax. Finally, the highest quintiles mostly use savings to finance the increase in lump sum taxes and only react mildly in terms of hours worked and consumption. Naturally, the welfare implications of the spending shock will depend drastically on the household's wealth.

Figure 3 shows the path for government spending together with responses for aggregate output, consumption, investment, labor, and wages for both our model and for an equivalent model with divisible labor.[19] First, in both models, an increase in government spending financed by a lump sum tax generates an increase in output and hours worked, together with a decrease in consumption. This logic is standard and similar to the one discussed in Section *I.A*. Second, while the decrease in consumption is of similar magnitude in both models, labor and output react by twice as much in our model as they do in the model with divisible labor. This is indivisible labor's contribution, since it generates a countercyclical labor wedge. Another way to read this result is that in the model with divisible labor, an increase in hours of the magnitude observed in our model would be associated with a much more severe decrease in private consumption. As explained in *I.A*, indivisible labor breaks the tight link implied by the household's intratemporal first-order condition.

Why does a heterogeneous households economy with indivisible labor generate a countercyclical labor wedge? Typically, after an increase in government spending, hours worked increase and less-productive households start working more. Because of the endogenous distribution of wealth, less productive households are also usually less wealthy. Thus, they exhibit a larger marginal propensity to consume out of additional income. When these relatively poor households start working $\bar{h}$, they receive a discrete increase in their labor income because labor is indivisible, and consume a larger fraction of it. Therefore, aggregate consumption

[19]The model with divisible labor is described in Appendix C. It is calibrated in order to be comparable to the benchmark model.

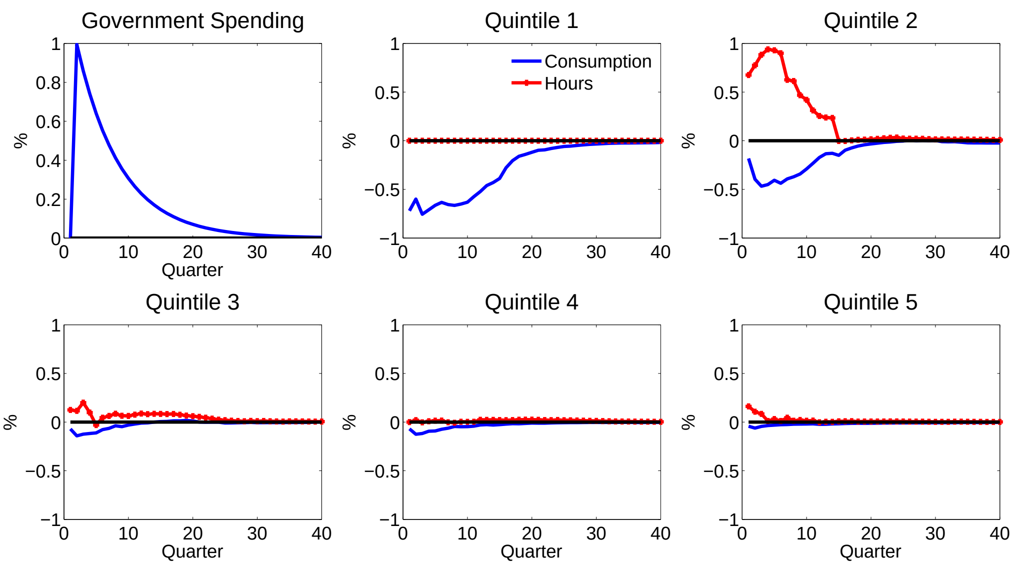

Figure 2: Impulse Response to spending shock per quintile.

decreases less. Chang and Kim (2007) discuss the importance of this channel in a similar economy with business cycle fluctuations.

We summarize this section with two remarks. First, as we can see in Figure 2, there is a large heterogeneity across household's responses to a government spending shock. Second, with lump-sum taxes, Figure 3 shows that the model predictions for aggregate consumption are very similar to those of a standard real business cycle model.[20] In other words, while responses are remarkably different across heterogeneous households, they aggregate to a path similar to the one obtained in an economy with a representative household. In Section V, we will show that this is not the case when the government uses progressive taxes: changes in progressivity make aggregate responses to spending increases very different to those obtained in a real business cycle model.

IV.A General Equilibrium Effects

An increase in government spending affects households in two dimensions: taxes and prices. As seen in Figure 4, after an increase in government spending, wages decrease -0.04% on impact and interest rates increase +0.2%. We think of this as a *price effect* of government spending. Arguably, these changes in prices

[20]For the sake of completeness, Appendix D outlines a real business cycle model with government spending shocks and Figure 15 plots the impulse response of the model to a 1% increase in government spending.

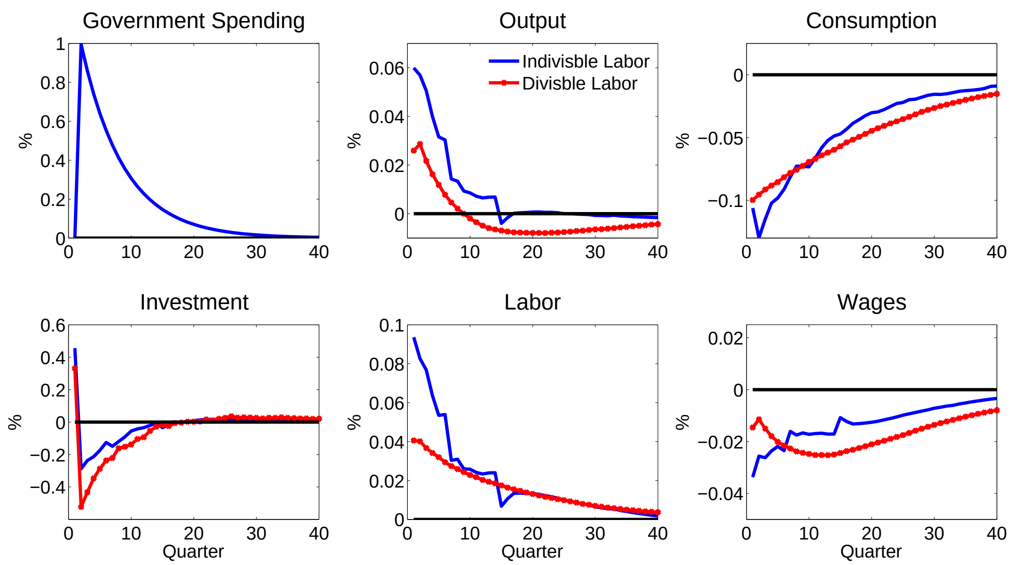

Figure 3: Impulse Response to a spending shock, aggregates.

are more harmful for working and indebted households, who now face a higher cost for borrowing and a lower income from working. At the same time, the additional lump-sum tax is also potentially more harmful for poor households since it represents a disproportionate fraction of their wealth. Which of these two elements, prices or taxes, explains the heterogeneity in responses across households? Which is more important in explaining the large consumption drop of low-wealth quintiles? To obtain a clear answer, we compute the response to a spending shock in an economy with the interest rate and wages kept at steady-state values: households still have to pay higher lump-sum taxes, but factor prices are now constant. We think of this as a partial equilibrium exercise.[21]

In Figure 5, we compute the consumption equivalent for each quintile after the spending shock - that is, the percentage of consumption that each agent will be willing to give up in every future period in order to avoid the increase in government spending. This is done for both economies: the benchmark economy of Section IV with flexible prices and the fixed prices economy with interest rates and wages kept constant. Three features are remarkable. First, consumption equivalents are always positive: no agent benefits from the increase in spending. It is also clear that the welfare loss is larger for poor households, with a consumption equivalent larger than 1% for the lowest quintile compared to 0.04% for the highest quintile. Second, consumption equivalents in both economies are virtually identical: the marginal effect of prices on welfare is

[21]In particular, we impose that labor supply equals labor demand every period, but households' assets holdings can be different than firms' capital demand. Thus, the exercise could be understood as a spending shock in a small open economy.

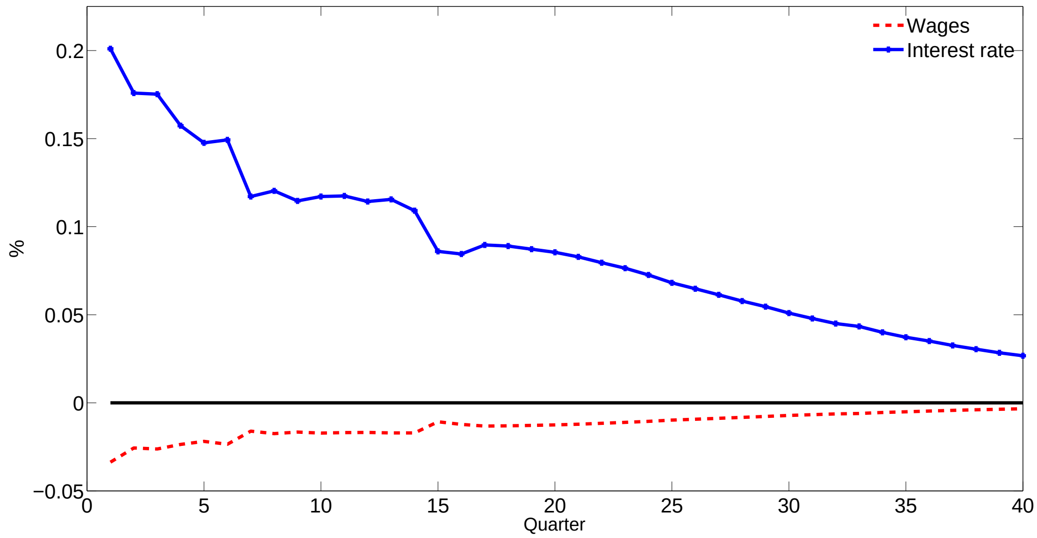

Figure 4: Price responses to a 1% increase in G.

negligible. Third, even if small, the *price effect* is not homogeneous across agents: the first quintile prefers the fixed prices economy to the benchmark economy, but the opposite is true for the highest quintile. This is because households in the latter enjoy higher returns on their savings, while working indebted households suffer from the decrease in wages and the increase in interest rates.

We also find that, in line with our second remark, the responses at the individual and aggregate levels are very similar in the benchmark and the fixed prices economy; the general equilibrium effect of government spending is quantitatively negligible in our model, both at the aggregate level and in generating larger consumption inequality after a spending shock.[22]

We conclude that the key determinant of the heterogeneous responses across households is driven by taxes. In Section V we describe how a more flexible tax policy shapes the effects of a government spending shock, both at the individual and aggregate levels.

V Progressive Taxes

The results in Section IV suggest that changes in taxes are the key driver of household's responses after a shock in government spending. The next step is to analyze the effects of government spending in an economy

[22]In a similar environment, Li (2013) argues that the price effect of government spending generates significant inequalities across households. We believe the effect measured in his model is mostly due to lump-sum taxes.

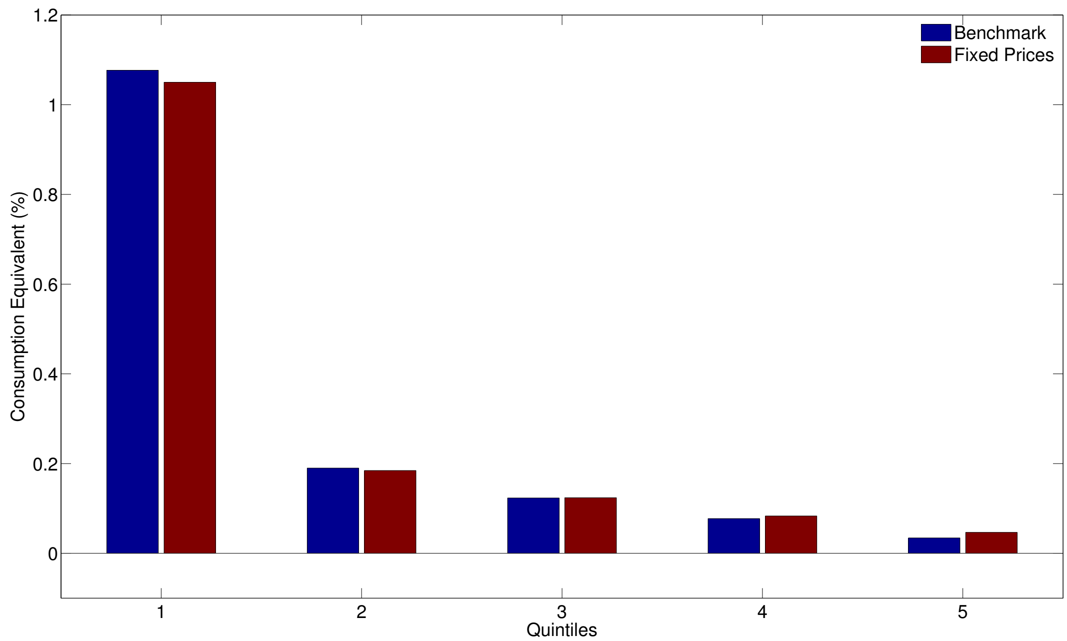

Figure 5: Consumption equivalents by quintile. Lump-sum taxes exercise: benchmark and fixed-price economy.

with a more realistic taxation scheme on income. We do so in this section and find that the response of the economy to a government spending shock drastically depends on the distribution of taxes across households. In other words, the progressivity of taxes is key.

We start our experiments from a steady state with distortionary taxes only, as described in Section III.B. We assume a linear tax on capital income $\tau^K ra$, and a non-linear tax rate on labor income wxh: $\tau_L(wxh) = 1 - \lambda(wxh)^{-\gamma}$. We explain next how this tax function captures different levels of progressivity.

V.A A Non-linear Tax Scheme

We borrow the labor income tax scheme from Heathcote, Storesletten, and Violante (2014). The function τ is indexed by two parameters, γ and λ:

$$\tau(y) = 1 - \lambda y^{-\gamma}$$

The parameter γ measures the progressivity of the taxation scheme. When $\gamma = 0$, the tax function implies an affine tax: $\tau(y) = 1 - \lambda$. When $\gamma = 1$, the tax function implies complete redistribution: after-tax income $[1 - \tau(y)]\, y = \lambda$ 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.[23] 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 6 shows how the tax function changes for different values of γ and λ.

V.B Government Spending with Progressive Taxes

As in the previous section, we assume that at $t = 0$ the government unexpectedly and temporarily raises government spending G by 1%.[24] Simultaneously, the government announces the taxation scheme that will be used to finance the increase in expenditures. In particular, the government announces a path for the labor tax progressivity $\{\gamma_t\}$ that will be implemented jointly with the increase in spending. Capital taxes are kept at their steady-state value (35%), and the sequence for $\{\lambda_t\}$ adjusts such that the government's budget constraint (9) is satisfied every period; we assume no public debt.

We explore the implications of three different taxation schemes: (1) **Constant Progressivity**: in this

[23] 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 $1-\lambda \approx 0.204$.

[24] In the previous section, the increase in spending was announced one period ahead. The reason was that, with lump-sum taxes, many households would face an empty feasible set with an unexpected increase in taxes. This is no longer the case with progressive taxes, and this lag is not necessary.

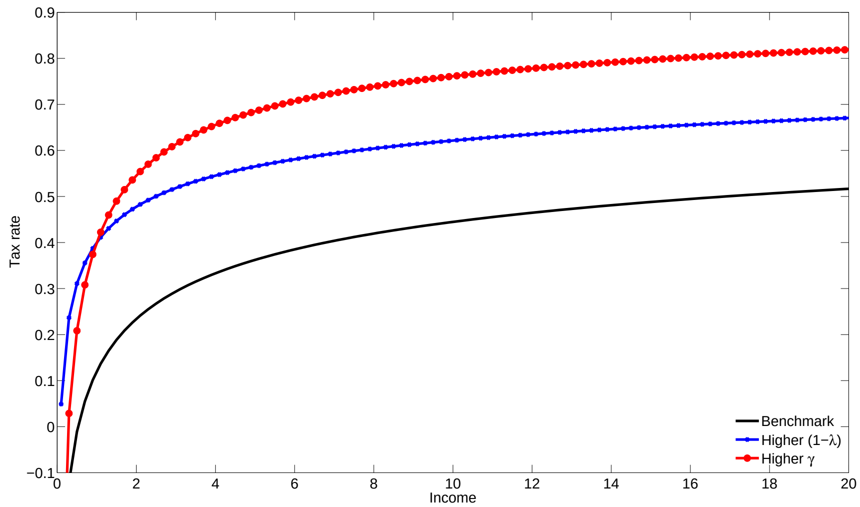

Figure 6: Non-linear tax as a function of two parameters (λ, γ).

case, 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 level of the taxation scheme 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 shows 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. It is not only the magnitude, but also the sign of the multipliers that 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.[25] Third, when

[25]Our experiment with fixed γ is qualitatively similar to the result 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.

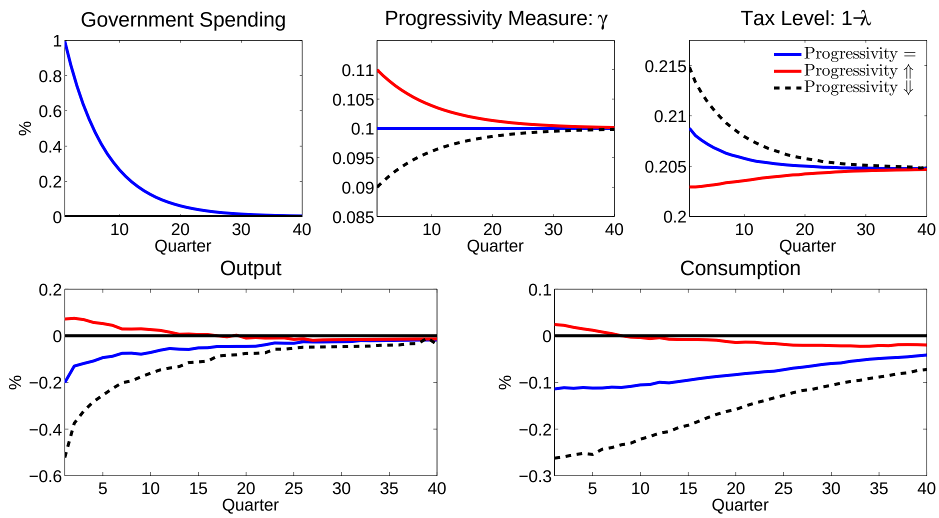

Figure 7: An increase in government spending financed with same, more and less progressive taxes on labor income.

government spending is financed with a *more progressive* taxation scheme, the model can generate a joint increase in public and private consumption. 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 the 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. This induces them to consume and work more, generating an expansion.

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.

V.C Solving the Puzzle

As highlighted in the introduction, many models encounter difficulties in generating a joint increase in public and private consumption. In our model, when an increase in government spending is financed by a more progressive tax on labor income, the effect on output and consumption is expansionary, making the model more consistent with the evidence. Table 4 shows the range of output and consumption multipliers found in previous work together with the one obtained in our model when using more progressive taxes.[26] Our

[26]See Table 1 in section I.

Table 4: Multipliers

	Output	Consumption
Data	$[0.30, 0.90]$	$[0, 0.5]$
Model	0.48	0.12

results are in the range of previous empirical studies. We argue next that these multipliers are obtained with a very small increase in progressivity.

In our experiment, together with the increase in spending, the progressivity parameter γ increases from 0.1 to 0.11. What does this mean in terms of tax rates? Are these big or small changes? Figure 8 plots the average labor tax for the entire economy, as well as the average one faced by each quintile. The tax scheme used implies an average labor tax fall from 21.12% to 20.95%, a 0.17% decrease only.[27] The distribution of the labor tax per quintile reflects the increase in progressivity: it drops for the two first quintiles, remains flat for the third one, and increases for the two highest quintiles. The drop in the first quintile is about 1% (from 14% to 13.1%) and the increase in the top quintile is 0.5% (from 27.9% to 28.4%). Not surprisingly, responses across quintiles reflect the heterogeneous change in taxes. As shown in Figure 9, the least-wealthy quintiles respond to the lower taxes by increasing hours worked and consumption. The wealthiest quintile decreases labor, but its change in consumption is minor since these households can use buffers of assets to smooth out the shock. Overall, the economy experiences an expansion.

We conclude this section with two remarks. First, responses at the individual and at the aggregate level crucially depend on the taxation scheme used by the government, and the heterogeneity across households' responses 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. Second, the expansionary effect of government spending occurs because of the increase in tax progressivity and despite the increase in government spending. The expansion would be larger if, for the same increase in progressivity, government spending were kept constant. We will show this explicitly in Section VII.

V.D General Equilibrium Effects

As in Section *IV.A*, we want to measure the importance of price changes in explaining the economy's response to the increase in government spending. As before, we evaluate the model in a *partial equilibrium* set-up to

[27] The multiplier on consumption can still be positive with a smaller increase in progressivity, resulting in a drop on the average labor tax of 0.1% only.

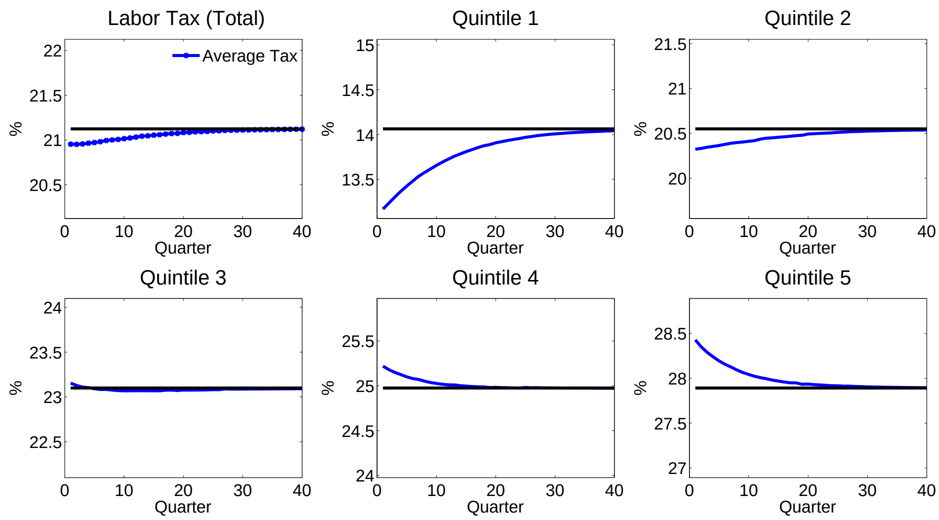

Figure 8: Average labor tax when progressivity of the taxation scheme on labor income increases.

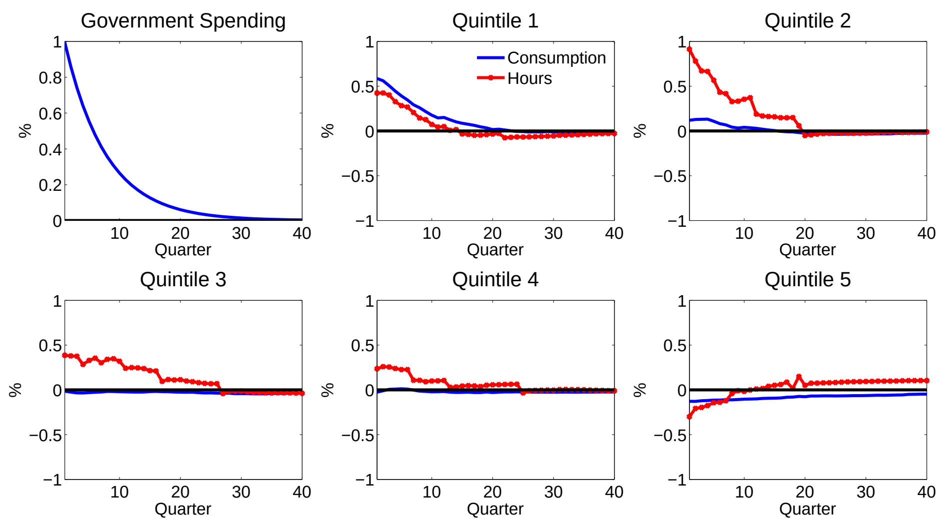

Figure 9: Responses of consumption and hours worked per quintile when progressivity of the taxation scheme on labor income increases.

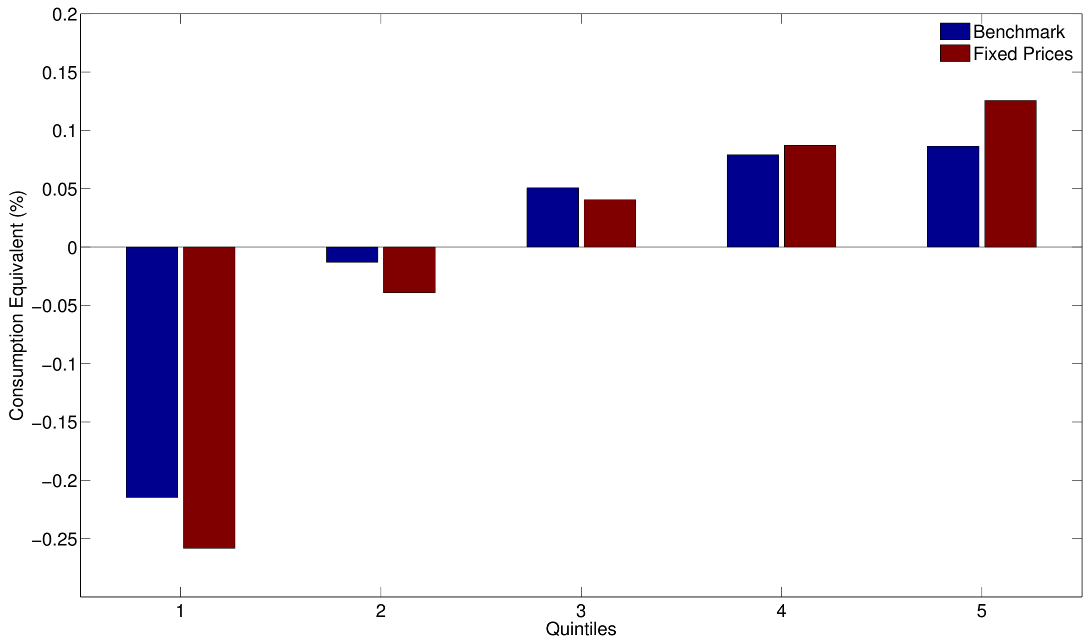

Figure 10: Consumption Equivalents per Quintile, General Equilibrium and Fixed Prices

obtain an answer: the path for government spending and progressivity $\{\gamma_t\}$ are as in Section V, but wages and interest rate are kept constant.[28] The main message of section *IV.A* remains: general equilibrium effects of government spending are small compared to the effects of changes in taxes.

Figure 10 plots the consumption equivalent for each quintile, both for the benchmark case with flexible prices and the fixed prices economy. Due to the increase in progressivity, least-wealthy households face lower taxes and are better-off with the shock (negative consumption equivalent). Analogously, wealthy households are worse-off (positive consumption equivalent) since they face higher taxes. In addition, poor households prefer the fixed price economy, while the opposite is true for wealthy households. Because wages decrease and interest rates increase with the spending shock, the price effect of government spending is more harmful for indebted working households. In other words, the price effect of government spending tends to increase inequalities across households. Finally, the difference in welfare between the benchmark and the fixed price economy is negligible. Thus, the same intuition applies as in the lump-sum case.

[28]The path for λ required to satisfy the government's budget constraint will also be different.

V.E Evidence: the Heterogeneous Effects of Government Spending

When government spending is financed with an increase in the labor tax progressivity, our model has two main predictions regarding the heterogeneity of household's responses. First, changes in taxes decrease consumption inequality at the moment of the shock, as seen in Figure 9. Second, the price effect of government spending, although small, actually increases welfare inequalities, as seen in Figure 10. We argue next that these two implications are found in empirical work using micro-data to measure the effects of government spending on households.

In a recent paper, De Giorgi and Gambetti (2012) use CEX data for the period 1984-2008 to evaluate the effects of government spending on households with different consumption levels. Using a structural VAR approach they find that consumption inequality decreases after an increase in government spending. This is in line with our model predictions. Also recently, Giavazzi and McMahon (2012) find the opposite result, with low-income households facing a (small) decrease in consumption after an increase in government spending. As they argue their estimation strategy underestimates the wealth effect of government spending, that is, the effect from changes in taxes.[29] We interpret this as capturing mainly the *price effect* of government spending. As explained in Section *V.D*, this *price effect* induces a small increase in consumption inequality, in line with Giavazzi and McMahon (2012) findings.

VI Evidence: a Narrative Approach

Section V shows that it is possible to deliver a joint increase in public and private consumption, only if the government uses more progressive taxes to finance the increase in spending. Thus, the key implication of our model is that multipliers crucially depend on the progressivity of the tax scheme used: positive (negative) output and consumption multipliers are obtained when government spending shocks are financed with more (less) progressive taxes. In this section, we provide empirical evidence that supports our model predictions.

We use TAXSIM data from 1960-2006 to construct an estimate of the progressivity parameter γ for the United States.[30] The upper panel of Figure 11 plots the time series obtained for γ, showing that there have been large changes in the progressivity of the tax system in the United States over the past 50 years, with an increase during the sixties and a sharp decline during the eighties. The lower panel of Figure 11 plots defense spending during the same time period. The vertical dashed lines are the Ramey-Shapiro events: the first one is on 1965:1 and corresponds to the Vietnam War; the second one is the Carter-Reagan military

[29] See page 3 of their paper.

[30] Appendix E contains the details on how γ was estimated

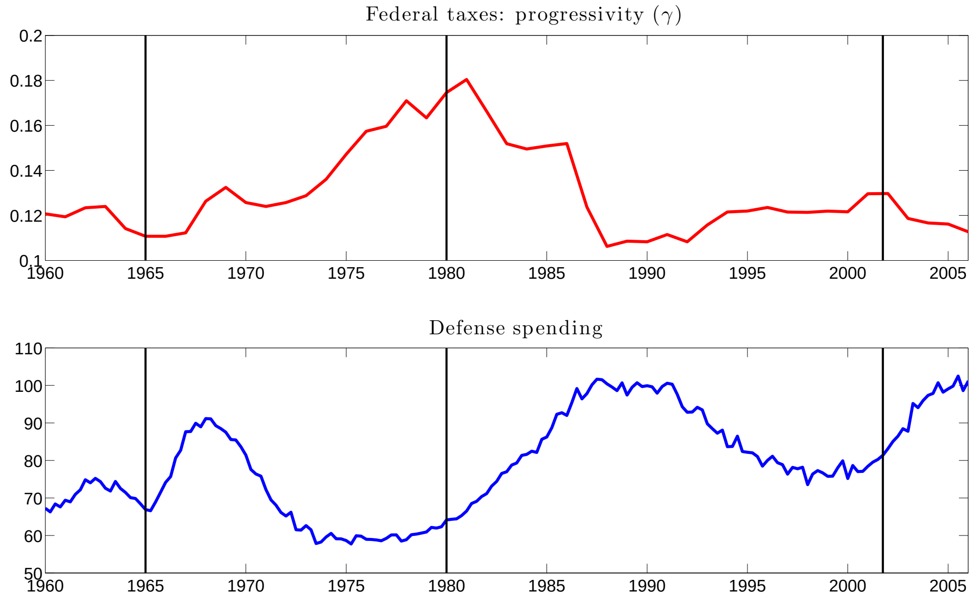

Figure 11: Taxes progressivity and defense spending. US 1960-2006.

built-up starting on 1980:1; and the last one is on 2001:4 relating to increase in defense spending after 9/11 (Bush built-up). The remarkable feature is that the US experienced a significant - and different - change in progressivity after each one of the Ramey-Shapiro events. During the Vietnam War, progressivity increased, while during the Carter-Reagan military build-up, progressivity decreased. After the Bush build-up, progressivity slightly decreased as well. To the extent that these changes in progressivity were foreseen at the moment of the Ramey-Shapiro event, we can exploit these differences in our estimation strategy to test the main model predictions. In particular, in light of our results in Section V, we expect to find positive multipliers for the Vietnam War, negative multipliers for the Carter-Reagan built-up, and negative but smaller multipliers for the Bush build-up.

We estimate a VAR including a *different* dummy variable for each one of the Ramey-Shapiro events following Perotti (2007). In particular, we estimate the following system:

$$X_t = A_0 + A_1 t + A(L)X_{t-1} + \sum_{i=1}^{3} B_i(L)D_{i,t} + \epsilon_t \tag{10}$$

where $D_{i,t},\ i = 1,2,3$ is the dummy variable for each of the three Ramey-Shapiro events. The vector $X_t = [G_t, Y_t, C_t]$ includes defense spending, GDP and private consumption of non-durables and services, all

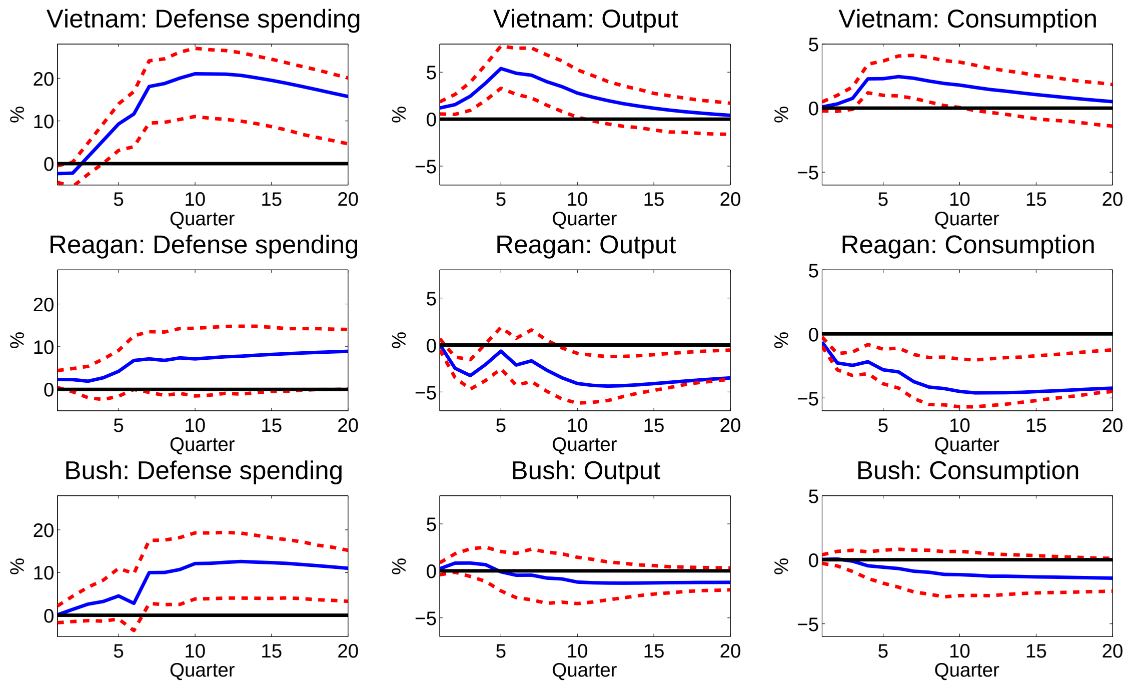

Figure 12: Impulse responses after the three Ramey-Shapiro events, 64% confidence intervals.

of them in real per capita units and in logs. We use quarterly data from 1959-2006, the matrix $A(L)$ includes four lags and $B_i(L)$ includes six lags. We also include a constant A_0 and a linear trend $A_1 t$. Note that, by having a *different* matrix of coefficients $B_i(L)$ for each dummy, we allow for different responses of X_t to an innovation in each Ramey-Shapiro event.

Figure 12 plots defense spending, output and consumption responses to each one of the dummy variables in (10). The Vietnam War resulted in an expansion of output and consumption, while the opposite happened after the Carter-Reagan military build-up. Finally, multipliers after the Bush build-up are close to zero. Thus, government spending shocks appear expansionary only in periods of increasing progressivity. This is consistent with our main prediction.

VII Transfers

As discussed earlier, private consumption in our model increases after a government spending shock because of the rise in progressivity, but despite the increase in public consumption. In other words, the expansion in private consumption 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 13 shows the economy's response to an increase in progressivity γ as in Section *V.B*, but with no increase in government spending.[31] Output and consumption increase by 0.22% and 0.14% respectively, versus around 0.1% and 0.05% in Section *V.B*. In other words, a temporary shock in progressivity is a powerful tool in generating expansions.

Similarly, a government that temporarily increases tax revenues through an increase in progressivity, and *transfers* these additional resources in a lump-sum fashion to the least-wealthy households (rather than spending it as public consumption), would also be more successful in achieving a boom in consumption. As recently emphasized by Oh and Reis (2012), these type of transfers across households accounts for a significant fraction of government spending. Figure 14 describes the economy's response to the same increase in progressivity γ, where the additional resources levied through taxes are given back lump-sum to the 10% lowest-wealth households at the moment of the shock. Private consumption increases by more than 0.2%, versus 0.05% in Section *V.B*. Consequently, a one-time redistribution of wealth can also have large effects on aggregate consumption.

The exercises in this section suggest that changes in progressivity could be an interesting tool in analyzing different public finance topics such as debt payments, deficit sustainability and welfare. A formal analysis of this is a priority for future work.

VIII Conclusion

The aim of this paper is to assess the effects of government spending in an economy with heterogeneous households. We develop a model where agents are heterogeneous in wealth and productivity. We also impose indivisible labor choice. Our findings are sharp: (1) There is a large heterogeneity in the effects that government purchases have on households. (2) What shapes this heterogeneity is the taxation scheme. In particular, the distribution of the tax burden across households is key to understand heterogeneity: we focused on *revenue-neutral* taxation schemes, that distribute taxes across households, not over time. At the aggregate level as well, multipliers depend crucially on the distribution of the taxation scheme. We find that when government expenditures are financed with a more progressive taxation scheme, multipliers on output

[31] 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.

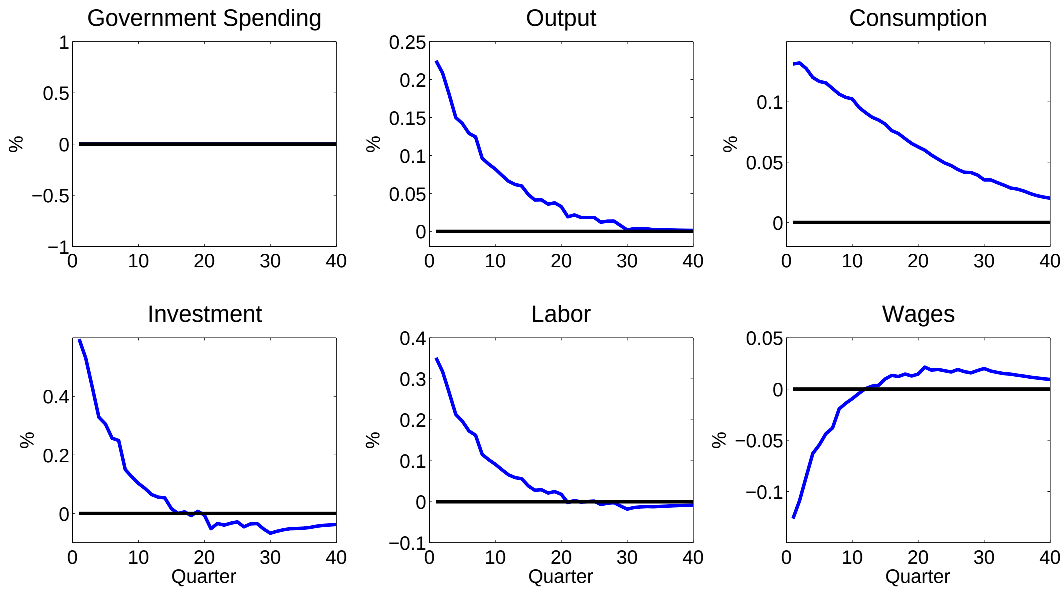

Figure 13: More progressive taxes, constant government spending

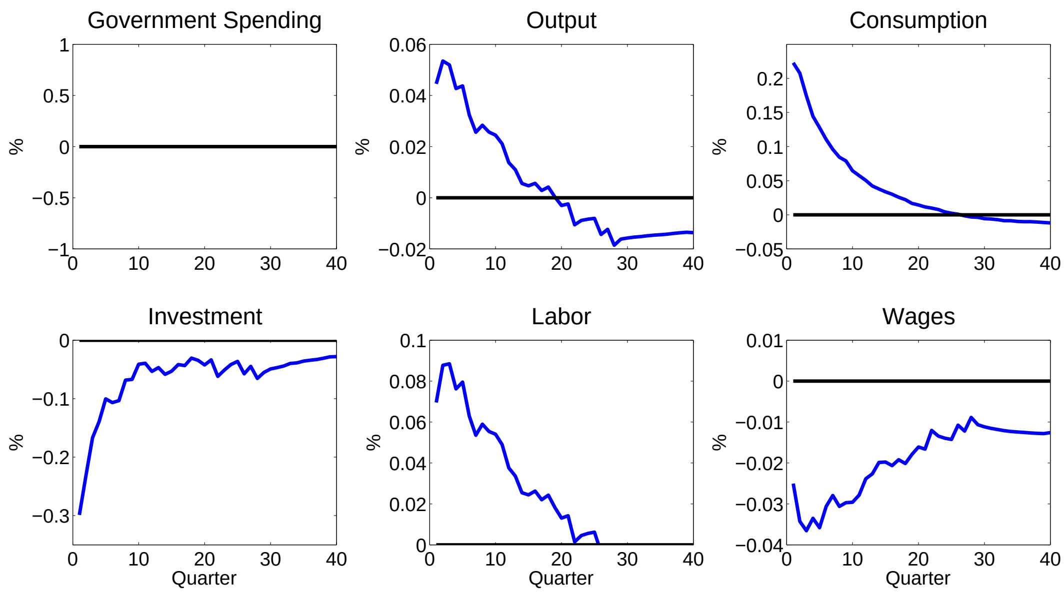

Figure 14: More progressive taxes, lump-sum transfers

and consumption can be positive, solving the puzzle stated in Section I. Finally, we find empirical support for our predictions: US output and consumption multipliers have been positive only in periods of increasing progressivity.

The crucial result in our paper is that small dynamics in the progressivity of taxes have large effects on aggregate variables. We believe that this can be very useful in addressing several questions. We leave this for future research.

New York University

Appendix

A Algorithm for Steady State Equilibrium

In this section we describe the algorithm used to compute the steady state given a set of parameters. This accounts for computing policies and an implied measure that satisfy our equilibrium definition. Also, recall that our calibration strategy is such that we target an equilibrium interest rate of 1%. We describe the algorithm for the economy with lump-sum taxes in four steps.

1. We first choose a grid of asset holdings a and idiosyncratic productivities x. For the asset grid we used $N_a = 2842$ points between $[-2,\ 340]$ with more points for low values of a. For the productivities we used a grid with $N_x = 27$ points and constructed the nodes using Tauchen (1986) method.

2. Given a set of parameters, we solved for the value functions V^E, V^N and V at each grid point of the individual state. Note in particular that, given that we are targeting $r = 0.01$, the first order condition of the firm results in an implied wage rate w because of constant returns to scale. At this point we also obtain the policies functions $a'(a, x)$, $c(a, x)$ and $h(a, x)$. This was done in the following steps:

(a) Make an initial guess of the value function $V_0(a_i, x_j)$ $\forall i = 1, \dots, N_a$ and $\forall j = 1, \dots, N_x$

(b) Update the value functions by evaluating them at the grid points

$$\begin{aligned} V_1^E(a_i, x_j) &= \max_{a' \in \{a_1, \dots, a_{N_a}\}} \left\{ \log\left(w\bar{h}x + (1+r)a - a' - T\right) - B\frac{\bar{h}^{1+1/\gamma}}{1+1/\gamma} + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_0(a', x_{j'}) \right\} \\ V_1^N(a_i, x_j) &= \max_{a' \in \{a_1, \dots, a_{N_a}\}} \left\{ \log\left((1+r)a - a' - T\right) + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_0(a', x_{j'}) \right\} \end{aligned}$$

where $\pi_x(x', x)$ is the Markov process for the idiosyncratic shock. Next update

$$V_1(a_i, x_j) = \max\{V_1^E(a_i, x_j), V_1^N(a_i, x_j)\}$$

(c) If V_0 and V_1 are close enough, we found a solution. Otherwise, use $V_0 = V_1$ and go to step (b)

3. Given the obtained policy functions in last step, we compute the measure $\mu(a, x)$ as follows:

(a) Guess an initial measure $\mu_0(a_i, x_j)$ $\forall i = 1, \dots, N_a$ and $\forall j = 1, \dots, N_x$

(b) For every $a \in \{a_1, \dots, a_{N_a}\}$ and $x \in \{x_1, \dots, x_{N_x}\}$ compute

$$\mu_1(a, x) = \sum_{i=1}^{N_a} \sum_{j=1}^{N_x} \mathbb{I}\{a = a'(a_i, x_j)\} \mu_0(a_{,i}\,, x_i) \pi_x(x, x_j)$$

(c) If μ_1 and μ_0 are close enough, we found the time invariant measure. Otherwise, use $\mu_0 = \mu_1$ and go to step (b)

4. With the measure just obtained, compute aggregate capital $K = \sum_{a,x} a'(a,x)\mu(a,x)$ and labor supply $L = \sum_{a,x} h(a,x)\mu(a,x)$. Then, form the firm's first order condition, compute $r = -\delta + \alpha(K/L)^{1-\alpha}$. If r is close to our target, we solved the model. Otherwise, update β and go back to step 2.

The equilibrium with progressive taxes requires an additional inner loop, where for a given capital tax, τ^k, and for a given level of the progressivity of the labor tax γ_L, a guess for λ_L is used to compute policies. Then, one has to check that the revenues actually levied by the government, given the policy functions and stationary measure, have to be equal to the level of government spending.

B Algorithm for the Transition

In this Section, we describe the algorithm used to compute the impulse responses to a shock in government spending. When government expenditures are financed with lump-sum taxes, the algorithm can be described in four steps.

1. Fix T arbitrarily large. Choose $\{G_t\}_{t=0}^T$ exogenously. The transition for lump-sum taxes $\{T_t\}_{t=0}^T$ is implied by the path for government spending.

2. Guess a sequence of interest rates $\{r_t\}_{t=0}^\infty$. Assuming that, in T, the economy is back to steady-state, and given the sequence for prices, compute policy functions backwards. Notice that at T we already know the value function of the household.

3. Using the steady-state measure in $t = 0$ and the policy functions computed in step 2, compute the measure along the path.

4. Using the measure and policy functions, compute aggregate variables along the path, and compute the implied path for the interest rate $\{r_t^\star\}_{t=0}^T$. If the implied path is close enough to the initial path, stop. Otherwise, update the guess for interest rates $\{r_t\}_{t=0}^\infty$ and go back to step 2.

Computing the transition with progressive taxes requires an additional inner loop, where a guess for a sequence $\{\lambda_{L,t}\}_{t=0}^T$ is made to compute policy functions in step 2, and has to be such that the revenues levied by the government are equal to the path for government spending.

C Divisible Labor Model

In this section we briefly describe the model with divisible labor used for comparison in Section IV as well as the calibration strategy.

The economy is populated by a representative household, a representative firm and a government. The firm and the government are identical to the ones in the model of the paper, so we omit their description. Household problem is as follows:

$$
\begin{aligned}
V(a,x) &= \max_{c,h,a'} \left\{ \log(c) - B\frac{h^{1+1/\varphi}}{1+1/\varphi} + \beta \mathbb{E}_{x'}\left[V(a',x')|x\right] \right\} \qquad (11) \\
\text{subject to} & \\
c + a' &\leq wxh + (1+r)a - T - \tau(wxh, ra) \\
a' &\geq \underline{a}
\end{aligned}
$$

Thus, households have the same utility as in the benchmark model, but they face a divisible labor decision.

The calibration strategy is the same as in the main model. We pick $G = 0.2525$. We choose the discount factor β and the labor disutility parameter B to obtain a interest rate $r = 0.01$, and a ratio $G/Y = 0.2$. We obtained $\{\beta, B\} = \{0.976, 240\}$.

D Real Business Cycle Model

In this section we briefly describe a real business cycle model with government expenditure.

The model equilibrium allocations are the result of the following program

$$
\begin{aligned}
U &= \max_{\{C_t, L_t, K_{t+1}\}_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t - B\frac{L_t^{1+1/\varphi}}{1+1/\varphi} \right] \\
\text{subject to} & \\
G_t + C_t + I_t &\leq Y_t \\
Y_t &= K_t^{1-\alpha} L_t^{\alpha} \\
\log G_t &= (1-\rho_G)\ \log G_{ss} + \rho_G \log(G)_{t-1} + \varepsilon_t
\end{aligned}
$$

The calibration strategy is the same as in the main model. The only parameters that obtain different values are the discount factor β and the labor disutility parameter B. We choose $G_{ss} = 0.2525$ to have the same amount of government spending as in Section IV. The value for B is set so that the government spending to output ratio is 20% on average. Similarly, the value of β is chosen so that the average interest rate, measured as the marginal productivity of capital, is 1%. We obtained $\{\beta, B\} = \{0.99, 60\}$.

Figure 15 shows the model response to a 1% increase in government spending.

E Measure of Progressivity

To construct our measure of progressivity, we estimate our tax function using TAXSIM data. We explaine the details below.

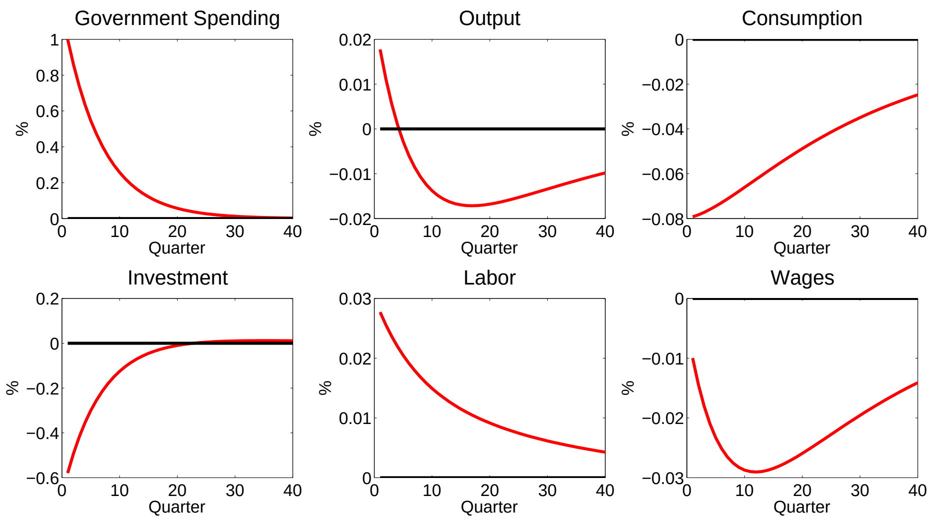

Figure 15: Real Business Cycle Model - Government Spending Shock.

On the TAXSIM website, the average tax rate and the average marginal tax rate faced by US tax payers for every year between 1960 and 2011 can be found. Using our tax function $\tau(y) = 1 - \lambda y^{-\gamma}$, the average tax rate $\bar{\tau}$ and the average marginal tax rate $\bar{\epsilon}$ are respectively given by

$$\bar{\tau} = \int \tau(y) d\mu(y) = 1 - \lambda \int y^{-\gamma} d\mu(y) \tag{12}$$

$$\bar{\epsilon} = \int \frac{\partial \tau(y) y}{\partial y} d\mu(y) = 1 - (1-\gamma)\lambda \int y^{-\gamma} d\mu(y) \tag{13}$$

where $\mu(y)$ is the distribution over income y, which we normalize to $\int d\mu(y) = 1$. Then, for every year we obtain γ as

$$\gamma = \frac{\bar{\epsilon} - \bar{\tau}}{1 - \bar{\tau}} \tag{14}$$

The data can be found at this link: http://users.nber.org/ taxsim/allyup/ally.html.

A deeper analysis of tax progressivity and its evolution in the United States can be found in Feenberg, Ferriere, and Navarro (2014).

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