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

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

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Abstract

This paper investigates how government spending multipliers depend on the distribution of taxes across households. We exploit historical variations in the financing of spending in the U.S. since 1913 to show that multipliers are positive only when financed with more progressive taxes, and zero otherwise. We rationalize this finding within a heterogeneous-household model with indivisible labor supply. The model results in a lower labor responsiveness to tax changes for higher-income earners. In turn, spending financed with more progressive taxes induces a smaller crowding-out, and thus larger multipliers. Finally, we provide evidence in support of the model's cross-sectional implications.

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

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

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1 Introduction

Government spending is frequently used to mitigate the effect of recessions—two recent examples being the European Economic Recovery Plan, proposed by the European Commission in 2008, and its American counterpart, the American Recovery and Reinvestment Act, authorized by Congress in 2009. Despite the recurrence of these types of policies, there is no consensus among economists about the size of spending multipliers, that is, on the response of output to a one-dollar increase in spending.

Some empirical work, notably using military events, suggests that multipliers are modest and typically below unity (Ramey and Shapiro, 1998; Burnside, Eichenbaum, and Fisher, 2004; Barro and Redlick, 2011; Ramey, 2011). Other studies, often relying on a structural VAR approach, estimate larger multipliers (Blanchard and Perotti, 2002; Perotti, 2008; Mountford and Uhlig, 2009).[1] This disparity in empirical findings has its counterpart in theoretical work. Standard versions of the neoclassical and New Keynesian models generate small output multipliers, with their exact magnitude depending on details of the model's specifications.[2] A crucial element in these models is the nature of the government's budget adjustment to finance the increase in spending (Ohanian, 1997; Uhlig, 2010). Multipliers are small but positive when financed with lump-sum taxes, but significantly smaller—and even negative—if more realistic income taxes are used, as first shown in the seminal work by Baxter and King (1993).[3]

In this debate, though, an important dimension has been neglected: the distribution, across households, of the fiscal burden consequent to the stimulus. This is somewhat surprising, for at least two reasons. First, from a theoretical perspective, recent work has shown that the cross-sectional dimension of fiscal policy has significant aggregate implications.[4] However, most existing studies on government spending assume a representative agent and thus cannot discuss how multipliers depend on the distribution of taxes.[5] Second, from a historical perspective, the U.S. has typically implemented substantial tax reforms to finance large changes in spending, but these reforms have not been alike. In some cases—like World War I, World War II and the Korean War—the fiscal burden was tilted toward higher-income earners, while in other cases—like

[1] For instance, Romer and Bernstein (2009) use a multiplier of 1.5 when estimating the effects of the American Recovery and Reinvestment Act.

[2] In the neoclassical model, Edelberg, Eichenbaum, and Fisher (1999) and Burnside, Eichenbaum, and Fisher (2004), show how multipliers vary depending on assumptions about preferences and technology. In the New Keynesian environment, multipliers are larger if monetary policy does not strongly react to inflation (Christiano, Eichenbaum, and Rebelo, 2011; Eggertsson, 2011; Nakamura and Steinsson, 2014), or when there is a large fraction of non-Ricardian households and spending is initially deficit financed (Gali, Lopez-Salido, and Valles, 2007). A recent assessment of the quantitative importance of several modeling assumptions can be found in Leeper, Traum, and Walker (2017).

[3] Drautzburg and Uhlig (2015) argue that, also in a New Keynesian environment at the zero lower bound, spending multipliers are substantially lower when financed with distortionary taxes.

[4] See Heathcote (2005) and Bhandari, Evans, Golosov, and Sargent (2017), among many others.

[5] A few remarkable exceptions are Bilbiie and Straub (2004), Monacelli and Perotti (2011), Hagedorn, Manovskii, and Mitman (2017), and Brinca, Holter, Krusell, and Malafry (2016).

the Vietnam War and the Reagan military buildup–the burden was more evenly distributed. Thus, the U.S. history of spending and taxation is particularly insightful to learn how the distribution of taxes shapes spending multipliers.

In this paper, we revisit the debate on the size of spending multipliers by taking into account the distribution of taxes. First, we exploit the historical variation in the financing of spending in the U.S. to estimate multipliers that depend on the progressivity of taxes used. We find that spending multipliers are larger when financed with more progressive taxes—that is, spending is more expansionary when the tax burden falls more heavily on higher-income earners. Second, we develop a heterogeneous-household model that can rationalize this finding. The key component in the model is an extensive labor-supply decision, which results in lower labor responsiveness to tax changes for higher-income earners. In turn, multipliers are larger when financed with more progressive taxes. Finally, we use tax revenue data to provide micro-evidence of the key cross-sectional implications of the model.

We use a local-projection method to assess empirically how spending multipliers depend on tax progressivity. To do so, we build a novel measure of tax progressivity for the U.S. starting in 1913 with the creation of income taxation. A long time series of progressivity is important for our purposes because the largest changes in spending, as well as most substantial tax reforms, occurred during the first half of the 20^{th} century. Albeit simple, we show that our measure of progressivity accurately reflects tax reforms. We then use this measure to estimate state-dependent multipliers. A state is defined as progressive if the increase in spending is financed with an increase in progressivity.

We find that the spending multiplier is positive only when financed with more progressive taxes, with a cumulative multiplier of between 0.8 and 1 after three years. Multipliers are initially negative otherwise, and roughly zero after three years. In other words, a government can increase output by about 90 cents if it spends one more dollar and finances it by taxing mostly higher-income earners, while there is no effect on output if financed by taxing all households more evenly.

We then analyze these findings through the lens of a model. Theory tells us that spending multipliers crucially depend on the taxes used to finance the stimulus. The rationale is as follows: a government will have to raise taxes to finance the increase in spending, and higher taxes crowd out the private sector, which limits how expansionary spending can be. The crowding-out is larger if distortionary income taxes are used, instead of lump-sum taxes. Ultimately, the larger the crowding-out, the smaller the multiplier.

An *off-the-shelf* model of heterogeneous households with an extensive labor-supply decision can account for our empirical findings because of the rationale just discussed. In this environment, higher-income earners have exceptional labor market prospects and thus face a large opportunity cost of exiting the labor market, which renders them less responsive to tax changes. Hence, an increase in spending financed with more progressive taxes induces a smaller crowding-out and, in turn, a larger spending multiplier. This effect is quantitatively large. In our benchmark specification, a spending shock evenly financed across households generates a negative multiplier of about negative 0.3 during the first three years. This negative number reflects the large crowding-out induced by distortionary income taxation. However, if the bottom 10% of workers are exempted from higher taxes, the multiplier is raised by 0.2; and if only the top 35% workers finance the spending shock, the multiplier even turns positive, reaching about 0.1 during the first three years.

The heterogeneity of labor-supply responses to tax changes is a central element in our model. Support for this heterogeneity can be found in several sources. In the micro-labor literature a consensus has emerged that labor-supply fluctuations are mostly driven by the extensive margin, and that labor participation elasticities are significantly larger for lower-income earners (Meghir and Phillips, 2010). Accordingly, labor participation elasticities that decrease with income has become a standard assumption in the public finance literature (Kleven and Kreiner, 2006; Immervoll, Kleven, Kreiner, and Saez, 2007). Further support for this heterogeneity comes from the recent work by Zidar (2017), which uses tax revenue data to investigate how tax changes for different income groups affect aggregate economic activity. It finds that tax hikes to the bottom 90% are very detrimental for total employment, while the effect is negligible when taxing the top 10%. Our calibrated model is quantitatively consistent with these findings.

We also provide direct evidence on the cross-sectional effects of government spending using tax revenue data since 1960. We find that an increase in spending is moderately expansionary for low-income households in progressive states and strongly contractionary otherwise, while higher-income earners' responses are of much smaller magnitudes and do not significantly depend on progressivity.[6] We see the lower responsiveness of higher-income earners, together with the previous work previously discussed, as compelling evidence of the mechanism explored in our paper.

Our work relates to the large literature on estimating spending multipliers, and more specifically to the small but growing literature on state-dependent multipliers. The recent work by Ramey and Zubairy (2018) and Auerbach and Gorodnichenko (2012a) discusses how spending multipliers may depend on the state of the economy (recessions versss expansions). We build on their methodological contributions to estimate how the path of tax progressivity shapes multipliers. Importantly, as we discuss in Section 2.5, the state dependence of multipliers we identify goes beyond the one discussed in these two previous papers: tax progressivity substantially affects multipliers regardless of the amount of slack in the economy. Previous empirical work had also considered how deficit financing affects spending multipliers, focusing on the intertemporal allocation

[6]See Anderson, Inoue, and Rossi (2016) for a related discussion.

of taxes (Gali, Lopez-Salido, and Valles, 2007; Broner, Clancy, Martin, and Erce, 2017). We add to this work by considering the intratemporal tax distribution, which is sensible from a theoretical perspective and shown to have substantial qualitative and quantitative consequences. We also show that the progressivity of taxes shapes spending multipliers, even if the stimulus is initially deficit-financed. More generally, we contribute to the empirical work on fiscal policy by constructing a simple measure of tax progressivity for a long period that accurately reflects tax reforms in the U.S.

A recent line of research has stressed the importance of households' heterogeneity for the aggregate effects of fiscal and monetary policies (Kaplan, Moll, and Violante, 2018; Auclert, 2017).[7] This work typically incorporates Keynesian features and focuses on how households' heterogeneity shapes aggregate demand in response to fiscal and monetary policies. The key element in these models is the distribution of marginal propensities to consume—see in particular Bilbiie (2017), which uses a two-agent New Keynesian model to show analytically how spending multipliers depend on the distribution of marginal propensities to consume; and Hagedorn, Manovskii, and Mitman (2017), which analyzes a similar mechanism in a more quantitative framework using a fully fledged heterogeneous-agent New Keynesian model. In contrast, our mechanism relies primarily on heterogeneity in labor participation elasticities and its effect on aggregate supply in response to fiscal shocks. However, because aggregate demand channels are arguably an important determinant of fiscal policies, we incorporate Keynesian features for the quantitative evaluation of our model in Section 4. In the same vein, we also explore the effects of deficit-financed spending. In all cases, progressivity remains a crucial determinant of spending multipliers.

The rest of the paper is organized as follows. Section 2 discusses our progressivity measure and the state-dependent multipliers estimation. Section 3 introduces the model and illustrates the effects of tax progressivity on spending multipliers through simple experiments. Section 4 quantitatively compares the model to the macro and micro estimates. Section 5 concludes.

2 Government Spending and Tax Progressivity: Evidence

Most substantial fluctuations in government spending occurred during the first half of the past century, as shown in Figure 1. Consequently, to estimate spending multipliers as well as how they depend on tax progressivity, it is important to use long time series. To achieve this, Section 2.1 describes a novel measure of tax progressivity for the U.S. starting in 1913, and Section 2.2 discusses how this measure accurately reflects the historical changes of the federal income tax code. This measure is then used to estimate state-dependent

[7] See also Kaplan and Violante (2014), McKay and Reis (2016), Debortoli and Gali (2017), and Gornemann, Kuester, and Nakajima (2016), among others.

spending multipliers, where the state depends on the tax progressivity. Sections 2.3 and 2.4 describe the estimation and the progressivity states, while Section 2.5 presents the results. Finally, Section 2.6 analyzes the heterogeneous effects of government spending across households. These aggregate and cross-sectional findings are the core motivation for the model developed in Section 3.

2.1 A Tax Progressivity Measure: 1913 to 2012

We build a new measure of tax progressivity for the U.S. since 1913. To do so, we assume that the federal tax code on personal income is well approximated by a log-linear tax function, where the tax rate on income level y is given by $\tau(y) = 1 - \lambda y^{-\gamma}$. The parameter γ measures the progressivity of the taxation scheme. When $\gamma = 0$, the tax rate is constant: $\tau(y) = 1 - \lambda$. When $\gamma = 1$, the tax function implies complete redistribution: after-tax income $(1 - \tau(y))\, y$ equals λ for any pre-tax income y. A positive (negative) γ describes a progressive (regressive) taxation scheme. The second parameter, λ, is a measure of the level of taxation.[8] Thus, an increase in $1 - \lambda$ captures a rise in the overall level of the taxation, while an increase in γ captures a rise in progressivity: it decreases tax rates for low income levels and increases it for higher ones, as shown in Figure 2. Albeit simple, this tax function features a remarkably good fit to the U.S. federal income tax system.[9]

An advantage of this tax function is that the progressivity parameter γ can easily computed as:

$$\gamma \equiv (AMTR - ATR)/(1 - ATR), \tag{1}$$

where $AMTR$ is the average marginal tax rate and ATR the average tax rate. Importantly, measures of $AMTR$ and ATR can be constructed for the U.S. since 1913, and we can thus compute a long time series of the progressivity measure γ.[10] This measure is plotted in Figure 3.

The computation of γ in (1) is exact when assuming the log-linear tax function, but it is also an intuitive proxy for tax progressivity more generally. In particular, γ increases when marginal tax rates increase on average more than average tax rates, which often occurs when taxes increase at the top of the income distribution without largely affecting taxes at the bottom. As such, this measure accurately tracks changes

[8]Notice that when $\gamma = 0$, the tax rate is exactly $1 - \lambda$.

[9]This tax function was initially proposed by Feldstein (1969) and has been recently used by Heathcote, Storesletten, and Violante (2014) and Guner, Kaygusuz, and Ventura (2014) among others. These papers argue that the tax function fits particularly well the U.S. federal income tax code in recent years. In a companion paper (Feenberg, Ferriere, Navarro, and Vardishvili, 2018), we use tax revenue data from the TAXSIM program to show that this log-linear approximation has a very good fit to the tax code since 1960 as well.

[10]We use the average marginal tax rates series constructed by Barro and Redlick (2011) and Mertens and Olea (2018), and IRS Statistics of Income data and the Piketty and Saez (2003) measures of income for constructing the average tax rate. See Appendix A.1 and Appendix A.2 for more details on the computations and data sources.

in the U.S. federal income tax system since its creation in 1913, as we discuss next.

2.2 A Narrative of Tax Progressivity

Most large military events in the U.S. were followed by substantial tax reforms. We briefly discuss the main historical reforms in the U.S. federal income tax code, and a more detailed discussion can be found in Appendix F.[11]

The 16th Amendment to the United States Constitution, adopted on February 3, 1913, set the legal benchmark for Congress to tax individual as well as corporate income. The Revenue Act (RA) of 1913 determined personal income tax brackets for the first time, with a modest but progressive structure. Shortly after, the entry of the United States into World War I (WWI) greatly increased the need for tax revenues, which were largely obtained by expanding personal income taxes in a progressive fashion. The revenue acts during the Wilson Administration drastically increased top marginal tax rates to a 60% to 77% range, 10 times greater than three years earlier.[12] The decade that followed WWI, with Andrew Mellon as Secretary of the Treasury, observed a persistent decline in progressivity. However, this was substantially reversed by President Hoover, who again increased top marginal tax rates to WWI levels with the RA of 1932.

The most significant increase in tax progressivity occurred during the presidency of Franklin D. Roosevelt. The RA of 1935, referred to as the "Soak the Rich" tax at that time, already included increases in top marginal tax rates.[13] An even more drastic increase in progressivity came with the U.S. participation in World War II (WWII): after a sequence of tax reforms, top marginal tax rates reached a historical maximum range of 90% to 94% with the RA of 1945. Progressivity decreased after WWII, although higher top marginal tax rates were temporarily reinstated to finance the Korean War.[14]

The next significant tax reform came more than 10 years later with the Kennedy-Johnson Tax Reduction Act of 1964, which reverted progressivity by decreasing top marginal tax rates to a 60% to 70% range. Besides a temporary increase of taxes implemented in 1968 to finance the Vietnam War, there were no substantial modifications to statutory rates in the last half of the 1960s nor the 1970s. Nevertheless, there were significant additions to tax deductions and credits during the 1970s that, together with a period of high inflation and

[11] Discussions on the history of tax reforms can be found in Brownlee (2016) and Scheve and Stasavage (2016).

[12] Importantly, personal income taxes quickly became a substantial source of tax receipts, representing about 25% of total revenues by the end of WWI. The fraction of households paying taxes also grew considerably: 7.3 million tax returns were filled in 1920, which amounts to roughly 30% of households (average household size of 4.3 and population of 106 million). Numbers come from SOI tables; see Appendix A.1 for more details.

[13] See Blakey and Blakey (1935).

[14] The RA of 1951 aimed to finance the war expenses without increasing deficits, and accordingly removed the tax cuts implemented after WWII. Nevertheless, the tax cuts were reinstated in the RA of 1954 once the Korean War was over.

non-indexed tax brackets, resulted in more progressive taxes.[15]

The most recent substantial decrease to tax progressivity occurred during the Reagan Administration, with the Economic Recovery Tax Act (ERTA) of 1981 and the Tax Reform Act (TRA) of 1986, which initially lowered top marginal tax rates from 70% to 50%, and then further to 28%.[16] Although the decrease in progressivity during Reagan's presidency was never fully reverted, the subsequent administrations of George H. W. Bush and Bill Clinton implemented a partial recovery of it. The Omnibus Budget Reconciliation Act of 1990 and 1993 increased top marginal tax rates and expanded tax credits.[17] The subsequent administrations of George W. Bush and Barrack Obama implemented tax reforms that mildly decreased progressivity. The Economic Growth and Tax Relief Reconciliation Act of 2001—which was made permanent with the American Taxpayer Relief Act of 2012—mostly decreased top marginal tax rates, but also created a bottom tax bracket with lower rates. Overall, the tax reforms after the Reagan Administration have, so far, been small from a historical perspective.

Our simple tax progressivity measure plotted in Figure 3 captures remarkably well the historical tax reforms since 1913 described in this section. Importantly, most variations in the measure γ are directly associated with tax reforms and political events and do not correspond to economic conditions.[18] Furthermore, with the exception of the Iraq War of 2003, all large military events where followed by tax reforms that are appropriately captured by our progressivity measure. Consequently, this new measure is useful to estimate how government spending multipliers depend on tax progressivity.

2.3 Local Projection Method

We use the local projection method in Jorda (2005) to estimate spending multipliers, with an instrumental variable procedure as recently done by Ramey and Zubairy (2018). This methodology has been increasingly used in applied work and can easily be extended to estimate state-dependent multipliers.[19] A linear version

[15] During these years, the most important changes to the tax code took the form of increased tax expenses; typically tax deductions and tax credits (Brownlee, 2016, ch. 6). Inflation also raised progressivity as it increased effective marginal tax rates significantly more for top income earners—see Figure 2 in Mertens and Olea (2018).

[16] The decrease in income taxes, added to the increased defense spending and the 1981 recession, resulted in large fiscal deficits, to which the Reagan Administration responded by increasing other taxes, such as the Tax Equity and Fiscal Responsibility Act (TEFRA, 1982) and the Deficit Reduction Act (DEFRA, 1984). See Appendix F for more details.

[17] The Tax Payer Relief Act of 1997 did not affect tax rates but included an expansion in Earned Income Tax Credit and the inclusion of new tax credits such as the child and education credits.

[18] With the notable exception of the 1970s, when changes in tax progressivity were partly driven by inflation. However, as we will show, there were no large shocks in spending during that time.

[19] See the recent work by Auerbach and Gorodnichenko (2012b) and the survey by Ramey (2016), among others, who also use Jorda (2005) methods to estimate state-dependent multipliers.

of the method is as follows:

$$\sum_{j=0}^{h} \Delta^j y_{t+j} \quad = \quad \alpha_h + A_h Z_{t-1} + m_h \sum_{j=0}^{h} \Delta^j g_{t+j} + \phi trend_t + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H \tag{2}$$

where $\Delta^h y_{t+h} = \frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}}$ is GDP growth, $\Delta^h g_{t+h} = \frac{G_{t+h} - G_{t-1}}{Y_{t-1}}$ is the adjusted-by-GDP increase in government spending, and Z_t is a set of controls. For each horizon h, the coefficient m_h measures the cumulative response of output to a \$1 increase in government spending.[20] Equation (2) is estimated by a two-stage least-squares procedure, where the cumulative spending growth is instrumented by an identified spending shock g_t^* to control for endogeneity.[21]

The local projection method in equation (2) can be adjusted to accommodate state-dependent relations as follows:

$$\begin{aligned} \sum_{j=0}^{h} \Delta^j y_{t+j} \quad &= \quad \mathbb{I}\left(s_t = \mathrm{P}\right) \left\{ \alpha_{P,h} + A_{P,h} Z_{t-1} + m_{P,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} \\ &+ \quad \mathbb{I}\left(s_t = \mathrm{R}\right) \left\{ \alpha_{R,h} + A_{R,h} Z_{t-1} + m_{R,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} + \phi \; trend_t + \varepsilon_{t+h} \end{aligned} \tag{3}$$

where s_t is a variable that captures the state of tax progressivity, which we discuss below, and $\mathbb{I}(\cdot)$ is an indicator function. Notice that multipliers $\{m_{s,h}\}$ now depend on the state $s_t = P$ in progressive periods and $s_t = R$ otherwise. This is a key advantage of the local projection method, which allows us to estimate state-dependent responses as the outcome of an ordinary least-squares procedure.

In the benchmark estimation, we use as instruments g_t^* the two most common measures in the literature: the government spending innovation as identified by Blanchard and Perotti (2002) (*BP* shock henceforth), and the defense news variable constructed by Ramey (2011) and updated by Ramey and Zubairy (2018) (*RZ* shocks henceforth). The control Z_{t-1} includes eight lags of GDP, government spending, and the average marginal tax rate; the trend is quartic; and data are quarterly for 1913:Q1-2006:Q4.[22] We transform the annual measure of progressivity into a quarterly one by repeating four times the annual measure. The details

[20]The GDP-adjusted measure of spending growth allows us to interpret m_h as a multiplier without further transformation, as initially discussed by Hall (2009).

[21]An alternative procedure to estimate spending multiplier is to project $\Delta^h y_{t+h}$ and $\Delta^h g_{t+h}$ on g_t^* separately, obtain coefficients β_h^y and β_h^g, respectively, and finally compute cumulative multipliers as $m_h = \left(\sum_{j=0}^{h} \beta_j^y\right) / \left(\sum_{j=0}^{h} \beta_j^g\right)$. This alternative computation of the multiplier is numerically identical to the coefficient m_h obtained in equation (2). The advantage of estimating equation (2) directly is that it allows us to use more than one shock measure g_t^* as an instrument. See Ramey and Zubairy (2018) for a further discussion.

[22]We stop our sample on 2006:Q4 to avoid using data during the Great Recession, but Appendix B shows that results are robust to using alternative time periods.

of the construction of the data set are presented in Appendix A.2. We estimate equation (3) by ordinary least squares and use the Newey-West correction for computing standard errors (Newey and West, 1987).

2.4 Progressive and Regressive States

Key to our empirical exercise is the selection criteria for the state s_t. We define a quarter t as more progressive if tax progressivity 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 $\gamma_{t-1}^b \equiv \frac{1}{\Delta_b}\sum_{j=1}^{\Delta_b+1}\gamma_{t-j}$. States that are not progressive are called regressive. Figure 4 shows the periods selected as progressive, together with the two measures of shocks.

Two points are worth discussing about the state definition. First, the state definition does not involve the level of tax progressivity, but its *change*. We focus on the change because it captures whose households observe an increase in taxes to finance the additional spending, reflecting the distributional choice faced by a government. Thus, regardless of the initial level of progressivity, the state is progressive only when the additional spending is financed with a larger tax increase to richer households, while it is regressive when the tax increase is equal for all households. As previously discussed, the increased tax burden was distributed differently on alternative occasions in history.[23]

Second, the state is forward-looking in nature to capture the tax reforms subsequent to the increase in spending. Economically, this also presumes that households have some predictive capacity on the near-future path of taxes, an assumption justified by the long periods of political discussions typically observed before tax reforms, especially around military events.[24] We select Δ_a and Δ_b so that the implied states are in line with the narrative of Section 2.2. In practice, we set $\Delta_a = 12$ and $\Delta_b = 8$, so that a state of increasing progressivity is a period where the average tax progressivity in the next three years is larger than the one during the previous two years.[25]

Our state definition categorizes spending shocks into progressive and regressive states. WWI, WWII, and the Korean War—three wars for which the fiscal burden fell undoubtedly more on wealthier households—are all in progressive states. However, the Vietnam War, as well as the military buildups during the administrations of Ronald Reagan and the George W. Bush, are in regressive states, again in line with the narrative evidence previously discussed.[26] Thus, although a simple and uniform measure of progressivity for such a long period has clear limitations, our measure yields progressivity states that are largely consistent with the

[23] In Section 3, we discuss within the context of our model how changes in γ map to changes in the distribution of taxes.

[24] This presumption is well supported by the empirical work in Kueng (2016).

[25] In Appendix B, we show that results are robust to small changes in Δ_a and Δ_b.

[26] While the biggest RZ shocks mostly appear during progressive states, the BP shocks are more balanced. We show in Appendix B that our results are robust to using each instrument separately.

discussion in Section 2.2.

2.5 Multipliers in Progressive and Regressive States

Figure 5 plots the cumulative output multipliers $\{m_{s,h}\}$ when spending is instrumented by both BP and RZ shocks, for different horizons h and states $s = \{P, R\}$. For completeness, it also reports results for the non-state-dependent (linear) estimation.

The effect of government spending on output is significantly higher during periods of increasing tax progressivity. In fact, the cumulative multiplier on output is positive only in the progressive state: it is mildly positive on impact and steadily increases to about 0.9 after three years. In the regressive state, the multiplier is initially negative and not statistically different from zero after two and three years. Finally, the p-value for the difference in multipliers across states is below 5% at all horizons plotted (see Table B.1). We take this as compelling evidence that tax progressivity shapes the effects of government spending.

Recent work in Ramey and Zubairy (2018) and Auerbach and Gorodnichenko (2012b) suggests that the level of slack in the economy may be an important determinant of spending multipliers. We argue that the state dependence of multipliers we identify goes beyond the one discussed in these two previous papers. To do so, we estimate equation (3) adding a dummy for periods of slack which divides observations into four possible bins: slack/expansion states interacted with progressive/regressive states.[27] Regardless of the level of slack, multipliers remain positive only in progressive states—still at around 0.9 after three years—and negative otherwise. Table B.1 summarizes the results of this experiment.

Empirical work also suggests that deficit financing increases multipliers.[28] In turn, if the response of fiscal deficits to spending shocks is very different across the progressive and regressive states, our results may reflect differences in deficit financing and not in progressivity. We show that is not the case in Appendix B.1. We re-estimate equation (3) using deficits as the dependent variable, which delivers a *deficit* multiplier: for each state, it measures the increase in deficits after a \$1 increase in spending. As Figure B.1 shows, the path for deficit financing is very similar across progressivity states. We conclude that progressivity does not affect multipliers because of a correlation with deficit financing.

It has also been argued that multipliers can be larger if monetary policy is constrained by a lower bound.[29] We still find larger multipliers in the progressive state when using data from 1953:Q1 to 2006:Q4 only, a period when monetary policy was not constrained (see Table B.2).

For robustness, we also control for relevant measures of fiscal and monetary policy. Controlling for fiscal

[27] Following Ramey and Zubairy (2018), we define a period as slack if unemployment is above 6.5%.
[28] See Gali, Lopez-Salido, and Valles (2007), among others.
[29] See Christiano, Eichenbaum, and Rebelo (2011) and Cogan, Cwik, Taylor, and Wieland (2010), among others.

deficits, policy interest rates, and/or the average tax rate does not change our main results. Appendix B contains details of these experiments, as well as robustness with respect to using either the RZ or the BP shock separately as an instrument, using alternative windows Δ for the progressive state definition, different lags and trend specifications, and different time periods (starting in 1953:Q1, ending in 2008:Q4). Our findings are robust—spending multipliers are positive only when financed with more progressive taxes.

2.6 Micro Evidence: Heterogeneous Effects

In this section, we consider the heterogeneous effect of government spending across households and how this depends on the progressivity of taxes. For this purpose, we estimate an equation similar to (3), but in this case we project the spending shock on household-level income. In particular, we estimate the following equation:

$$\begin{aligned} \ln y_{i,t+h} \quad &= \sum_{q\in\text{quantiles}} \sum_{s=P,R} d^q_{i,t+h} \mathbb{I}(s_t = s) \left\{ \alpha^q_{s,h} + A^q_{s,h} Z_{t-1} + \delta^q_{s,h} \ln\left(\frac{G_{t+h}}{G_{t-1}}\right) \right\} \\ &+ \sum_{q\in\text{quantiles}} d^q_{i,t+h}\, \phi^q \ \mathit{trend}_t + \varepsilon_{i,t+h} \end{aligned} \tag{4}$$

where $y_{i,t+h}$ is the income of household i in year $t+h$, $d^q_{i,t+h}$ is a dummy indicating the household's income quantile in year $t+h$, and G_t is government spending. As before, we instrument spending using the RZ and BP shocks at time t. Thus, $\delta^q_{s,h}$ measures the average response (elasticity) of income in quantile q to a spending shock, h periods ahead.[30]

For the household's income, we use tax revenue data from the NBER's TAXSIM program. The data is annual from 1960 to 2008, with an average of 83,000 observations per year. Moreover, observations are not top-coded and samples from the universe of taxpayers, which is particularly suitable to analyze the effects of fiscal policies. A drawback of this data is that we cannot keep track of households over time, and thus we rely on a repeated cross-section and not a panel.[31] An additional limitation is the short time dimension of the data, which does not cover any of the largest spending shocks. Although we read estimates with caution, we believe that these drawbacks are compensated for the large number of observations per period and the high quality of tax revenue data.

As controls we use two lags of (the log of) GDP and government spending. The time trend is quadratic,

[30] Because we order households by income, an alternative estimation strategy would be to use quantile regressions, as in Misra and Surico (2014). While this option is computationally more intensive and not easy to implement with more than one instrument, we experimented with quantile regressions using only the BP shock and found similar results.

[31] We experimented constructing a synthetic panel by grouping households into percentiles and obtained very similar results.

and we allow for quantile dependent time trends. Finally, we divide observations into five quantiles depending on the household's income. We cluster errors by year and quantiles when computing standard errors. Figure 6 shows the income response by quantile to a spending shock, for the progressive and regressive state and several horizons h.

We find very heterogeneous responses across households to a spending shock. For low-income households, spending is found expansionary in periods of higher progressivity, and strongly contractionary otherwise. As income increases, responses are of much smaller magnitudes and do not significantly depend on progressivity.[32] This lower responsiveness for higher-income earners is a key element in the model of the next section and, as we discuss, in line with previous studies.

3 A Model with Government Spending and Progressive Taxes

We develop a heterogeneous-household model that can rationalize the empirical findings of Section 2. The central implication of the model is that higher-income earners are less responsive to tax changes than lower-income ones. Consequently, a spending increase financed with more progressive taxes induces a smaller crowding-out, and thus larger multipliers. We start by describing the model environment and its calibration, and then discuss the model-implied distribution of labor supply elasticities. Because these elasticities are key to the model, we carefully discuss how they compare to previous empirical work. Finally, we present two simple experiments to understand the aggregate and cross-sectional effects of government spending under alternative paths for the distribution of taxes. Section 4 contains a more quantitative evaluation of the mechanism.

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 first present a steady state without aggregate uncertainty, and later analyze transition dynamics as a result of a temporary spending shock.

[32] We also used CPS data to estimate employment responses by income-quintile. In line with the results presented here, we find that responses are very heterogeneous. For low-income households, spending expands employment in periods of higher progressivity and contracts it otherwise. For higher-income households, responses get muted.

Households: Households value consumption and leisure. Labor supply is indivisible and, during any given period, households can either work $\bar{h}$ hours or zero (Chang and Kim, 2007). Their idiosyncratic labor productivity x follows a Markov process with transition probabilities $\pi_x(x', x)$. Labor productivity shocks are uninsurable: households can only trade a one-period risk-free bond to self-insure, subject to a borrowing limit $\underline{a}$.

Let $V(a, x)$ be the value function of a household with assets a and idiosyncratic productivity x:

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

where c and h denote consumption and hours worked, respectively, and w and r denote wages and interest rates, respectively. Households face a distortionary tax $\mathcal{T}(wxh, ra)$, which depends on labor income wxh and capital earnings ra, and receive a lump-sum transfer T. Let $h(a, x)$, $c(a, x)$, and $a'(a, x)$ denote a household's optimal policies.

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

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

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.

Government: The government's budget constraint is given by

$$
G + (1+r)D + T = D + \int \mathcal{T}(wxh, ra) d\mu(a,x) \qquad (7)
$$

where D is the government's debt and $\mu(a, x)$ is the measure of households with state (a, x) in the economy. In a steady state, government spending G is kept constant. Later in this section, we will change G and adjust the budget constraint in different ways to analyze their implications.

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 next.

Definition 1 *A* ***stationary recursive competitive equilibrium*** *for this economy is given by: a value function $V(a,x)$ and policies $\{h(a,x), c(a,x), a'(a,x)\}$ for the household; policies for the firm $\{L, K\}$; government decisions $\{G, D, T, \mathcal{T}\}$; 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 its 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: $\mu(\mathcal{B}_0) = \int_S Q((a,x),\mathcal{B}_0)d\mu(a,x)$ where Q is a transition function between any two periods defined by: $Q((a,x),\mathcal{B}_0) = \mathbb{I}\{a'(a,x) \in \mathcal{B}_0\} \sum_{x' \in \mathcal{B}_0} \pi_x(x',x)$ for any $\mathcal{B}_0 \in \mathcal{B}$.*

3.2 Calibration

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, Kim, and Schorfheide (2013) 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 $\varepsilon_x \sim \mathcal{N}(0, \sigma_x)$, with $\sigma_x = 0.287$ and $\rho_x = 0.939$.[33] 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 delivers a reasonable distribution of wealth (see Table 2).

We assume that the tax function $\mathcal{T}(wxh, ra)$ has two components: a flat tax on capital income τ_k, and a non linear tax rate $\tau_L(\cdot)$ on labor income wxh; thus, $\mathcal{T}(wxh, ra) = \tau_k ra + \tau_L(wxh)wxh$. The capital tax rate τ_k is set to 35%, following Chen, Imrohoroglu, and Imrohoroglu (2007). This number primarily reflects two flat taxes in the tax code: corporate income taxes and property taxes.[34] For the labor tax, we assume the tax function described in Section 2.1: $\tau_L(wxh) = 1 - \lambda(wxh)^{-\gamma}$. As discussed before, this simple tax function fits very well the U.S. tax code, and the parameter γ can be clearly interpreted as the progressivity of the tax system. We set $\gamma = 0.10$, which is a value in line with the estimates in Feenberg, Ferriere, Navarro, and Vardishvili (2018), as well as Heathcote, Storesletten, and Violante (2014) and Guner, Kaygusuz, and Ventura (2012). The value of λ is computed so that the government's budget constraint is met in equilibrium.

[33] These numbers are estimated using the whole sample of PSID ages 18 to 65 from 1979 to 1992.

[34] The capital income taxed at a progressive rate—i.e, as ordinary income in federal tax code—represents only a small fraction of the fiscal revenues raised on capital income. See Joines (1981).

Finally, we jointly calibrate preference parameters β and B, and policy parameters G, T, and D to match: an interest rate of 1%, a government spending-to-output ratio of 15%, a transfers-to-output ratio of 5%, an annual government debt-to-output ratio of 60%, and an employment rate of 60%, which is the average of the Current Population Survey (CPS) from 1964 to 2003.[35] Table 1 summarizes the parameter values.

Table 2 reports wealth and employment distributions in the model and in the data (PSID, 1983). Overall, the model fits the data reasonably well. It generates a wealth distribution and a labor participation profile that are comparable with the observed ones.[36] We next document how the model matches the distributions of labor participation elasticities and marginal propensities to consume, two central statistics to determine the labor and consumption responses to changes in fiscal policy.

3.3 Heterogeneous Elasticities

Table 3 reports two measures of labor participation elasticity (*lpe*): with respect to the wage and to the labor tax rate; and for the total population, top 10%, and bottom 90% income groups.[37] The model-implied *lpe* declines substantially with income. A 1% increase in labor taxes induces a 0.43% decrease in participation for the bottom 90% of earners, while the decline is only 0.03% for the top 10%. Although larger in size, the same decreasing pattern for *lpe* is found with respect to the wage.[38]

Because the distribution of *lpe* is central to our results, it is worthwhile to compare it with previous empirical findings. A large body of work has measured labor-supply elasticities across different demographic and income groups.[39] A consensus has emerged that labor supply responsiveness to tax changes is mostly due to the extensive margin (Heckman, 1993), and that *lpe*s are significantly larger for lower-income earners (Blundell, 1995). We briefly review some of the evidence supporting this view.

Using reforms to "in-work" tax credits in the U.S., Eissa and Liebman (1996) estimate an *lpe* of 1.2 for lone mothers; and Brewer, Duncan, Shephard, and Surez (2006) find similar numbers for the U.K.[40]

[35] A similar participation rate is found in the PSID of 1983, the year that we will use for comparison with our model. Adding lump-sum transfers has little impact on our results but implies a reasonable average labor tax in the model (around 15.75% in a steady state).

[36] As is common with heterogeneous-household models, the calibration underestimates wealth and labor participation for households at the right tail of the wealth distribution (Cagetti and De Nardi, 2008, Mustre-del Rio, 2012).

[37] Elasticities are computed after a one-period unexpected 1% decrease in wages, or a one-period unexpected 1% increase in the average labor tax rate. These figures should be understood as uncompensated elasticities. The computation is performed in partial equilibrium. See Appendix C.2 for more details.

[38] The model average *lpe* with respect to the wage is large compared to standard micro estimates, which are typically below unity. This discrepancy reflects the well-known gap between macro and micro labor elasticities (Chetty, Guren, Manoli, and Weber, 2011).

[39] Two outstanding recent surveys of the literature are Meghir and Phillips (2010) and Keane (2011).

[40] In line with these findings, Meyer and Rosenbaum (2001) argue that 62% of the increase in lone mother labor participation between 1984 and 1996 in the U.S. is due to changes in tax credits.

Estimates for males are on average lower than for women, but they are also found to be larger for lower-income groups. Meghir and Phillips (2010) find an *lpe* of 0.32 for prime-age males with low education levels in the U.K., while the elasticity is only 0.03 for households with the highest education.[41] Similarly, in the U.S., Moffit and Wilhelm (2000) find an *lpe* of 0.2 for medium income households and essentially zero for top-income earners.[42]

Based on this evidence, the public finance literature has typically used *lpe*s that substantially decrease with income. For instance, Kleven and Kreiner (2006) and Immervoll, Kleven, Kreiner, and Saez (2007) assume an *lpe* between 0.4 and 0.8 for the lowest-income deciles, and an elasticity of zero for the highest-income deciles. Our model-implied elasticities are well within this range.

We exclude an intensive labor-supply margin from our model because the elasticity of hours worked is typically seen as small and—more importantly—homogeneous across workers (Mroz, 1987).[43] An important exception arises when measuring the elasticity of taxable income, which is found to be larger for very high income earners (Saez, 2004). This higher elasticity, while inconsistent with our model, is concentrated at the top 1% and thus likely to have contained effects on aggregate labor supply in our set up. Furthermore, evidence shows that the higher elasticity of taxable income at the top is a short-run effect and the result of income-shifting rather than hours worked (Goolsbee, 2000; Piketty and Saez, 2013).[44]

Additional support for low *lpe*s of higher-income earners can be found in the recent work by Zidar (2017). This paper combines tax reforms and tax return data (TAXSIM) to construct a yearly measure of *tax shocks* for two income groups: the bottom 90% and the top 10%. An increase in taxes—equivalent to 1% of GDP—to the top 10% is found to have no effect on total employment nor output. On the contrary, a tax shock of the same magnitude supported by the bottom 90%, contracts employment by about 2% per year on average over a three-year period. These experiments are very informative about the distribution of

[41] Meghir and Phillips (2010) use their estimated model to simulate the outcome of a tax reform, and find mute labor supply-responses for top-income earners and substantial ones for bottom-income earners (see pages 248-251). For Italy, Aaberge, Colombino, and Strøm (1999) also find that *lpe* decreases with income, especially for women.

[42] The estimates of Moffit and Wilhelm (2000) should be understood as a combination of the intensive and extensive labor elasticities.

[43] For instance, when considering the intensive margin in addition to the extensive one, Kleven and Kreiner (2006) and Immervoll, Kleven, Kreiner, and Saez (2007) assume an elasticity of hours worked equal to at most 0.1, and constant across households. A homogenous intensive labor supply-elasticity across households is also assumed by Diamond (1998) and Saez (2001), among others. See also Triest (1990) for an empirical evaluation of this assumption.

[44] Using detailed data on executives compensations, Goolsbee (2000) finds a short-run elasticity of taxable income larger than one but at most 0.4 and probably closer to zero after one year. Furthermore, the large short-run responses comes from highest-income executives exercising stock options in anticipation of the rate increases, while more conventional forms of taxable compensation (such as salary and bonuses) show little responsiveness to tax changes. Similar findings are in Piketty and Saez (2013): *"To our knowledge, none of the empirical tax reform studies to date have shown large responses due to changes in real economic behavior such as labor supply or business creation"* (pg. 430).

*lpe*s. We compute the employment response in our model to tax shocks comparable to those in Zidar (2017) and find quantitatively consistent responses (Table 4).[45] We see this as compelling quantitative validation of the model-implied distribution of *lpe*s.

Table 5 documents the heterogeneity in marginal propensities to consume (*mpc*) in the model. Households closer to their borrowing constraint feature a larger *mpc*, implying a larger consumption response to a tax change. Of a rebate equal to 1% of the average labor income in a quarter, the bottom 10% of the wealth distribution exhibit an *mpc* of 0.2, five times larger than the average *mpc*.[46] However, the *mpc* heterogeneity in the model is rather conservative relative to data—*mpc*s are estimated to be as high as 0.5 for the liquidity constrained households (Kaplan and Violante, 2014; Misra and Surico, 2014). Overall, this second aspect will only play a minor quantitative role to the mechanism described next.

3.4 Spending and Tax Progressivity: Two Illustrative Experiments

We turn next to the effect of government spending in our model. We present two simple experiments to isolate the effect of tax progressivity on spending multipliers. A more comprehensive quantitative evaluation of the model is presented in Section 4.

The experiments are as follows. At $t = 0$, while the economy is at steady state, the government unexpectedly announces a 1% increase in spending, which then gradually returns to steady state. We assume that the increase in spending is entirely financed through an increase in labor taxes.[47] In particular, the government chooses the path for tax progressivity $\{\gamma_t\}$, and the level of taxes $\{\lambda_t\}$ is then determined to meet the government's budget constraint (7) every period. Thus, jointly with the spending increase, the government announces the distribution of taxes that it will implement to finance the stimulus. While the change in spending and taxes is unexpected at $t = 0$, households have perfect foresight after the announcements.

We explore the implications of two different tax schemes: (1) *constant progressivity* in which γ is kept at its steady-state level; and (2) *higher progressivity* in which γ temporarily increases from 0.1 to 0.11. Note that the tax scheme used in every case is progressive (γ is always positive), but the level of progressivity changes. Importantly, both experiments generate the same fiscal revenues per period, and only the distribution of the (labor) tax burden across household changes.

Figure 7 shows the output response to the spending shock under the two taxation schemes. When

[45] Appendix C.3 provides a complete description of the experiment in the model, together with many robustness checks.

[46] A rebate of this size is comparable to the tax decrease described in Section 3.4. For larger shocks, *mpc*s are smaller, reflecting the nonlinearity of the model.

[47] We explore the role of debt in Section 4.

progressivity is constant, output contracts by more than 0.1%. This case resembles a representative-agent real business cycle (RBC) model, where an increase in spending financed with income taxes typically results in a contraction (Baxter and King, 1993). However, when the government uses more progressive taxes, output expands by more than 0.1%. Hence, shifting the distribution of labor taxes across households changes not only the size but even the sign of the output response.[48]

This striking difference in output responses at the aggregate level has two sources. First, tax changes across households are very different under the two tax schemes. Second, households respond heterogeneously to tax changes. Thus, depending on who pays more taxes, the aggregate responses differ. We discuss this next by showing the hours and consumption responses across the distribution for each taxation scheme.

We first analyze the case when progressivity γ is kept constant and only the level of the tax scheme adjusts. The top three panels of Figure 8 show the average labor tax for three income subgroups of the population: the bottom 50%, the 50% to 90%, and the top 10%. The steady-state level of labor taxes is different across groups, reflecting the initial progressivity of the tax system. However, when progressivity is kept constant, the tax increase subsequent to the spending shock is roughly equal across households—about 25 basis points for all groups. As shown on the bottom panels, higher-income households, who have low *lpe* and *mpc*, respond very little to the tax increase, both in terms of hours and consumption. However, the bottom 50% of the distribution, who have larger *lpe*, reduces hours worked sharply by almost 2%. In aggregate, output contracts.

Results are very different when higher progressivity is used to finance a spending shock (Figure 9). The tax increase for the top 10% is now more than twice as large than in the constant progressivity case. Nevertheless, their reaction to the tax increase remains muted. However, the increase in γ tilts the tax function counter clockwise, such that the lower part of the distribution actually experiences a tax decrease.[49] Poor households, who react more strongly to a tax change, provide substantially more hours. As a result, output expands.

It is worth emphasizing that both experiments generate the *same* amount of tax revenues every period. Different output responses are a result of different levels of progressivity because households exhibit heterogeneous responses to tax changes. Consequently, the distribution of the tax burden is crucial to the aggregate effects of spending.

[48]We also explored the case when the government uses less progressive taxes to finance a spending shock. In this case, the output contraction is even more severe than in the case with constant progressivity.

[49]In Section 4, we adjust the tax function so that an increase in taxes for high-income earners does not necessarily involve a decrease of taxes for low-income earners.

4 Spending and Tax Progressivity: A Quantitative Exploration

The previous section used an *off-the-shelf* model of heterogeneous households to argue that government spending multipliers crucially depend on the distribution of taxes. To perform a quantitative evaluation of this mechanism, this section extends the model to incorporate features typically deemed important in the literature on spending multipliers. In particular, we add two of these features: public debt, to initially smooth the effects of distortionary taxation; and New Keynesian elements, to add a "demand channel" effect.

More importantly, we also modify the tax function so that, unlike in the previous section, higher progressivity increases taxes for high-income earners without decreasing taxes for low-income earners. This change is sensible from a historical perspective. As discussed in Section 2.2, taxes often increased at different rates across households to finance large spending shocks (wars) but seldom decreased for anyone during these periods.

Next, we briefly explain the additions to the model and then evaluate how spending multipliers depend on tax progressivity in the augmented model.

4.1 A Modified Tax Function

We modify the tax function such that, after a spending shock, households pay a labor tax rate that is at least as large as the one faced in steady state. In particular, while the steady-state tax scheme remains unchanged, labor income y along the transition is now taxed at rate $\hat{\tau}_t(y) = \max\{\tau_{ss}(y), \tau_t(y)\}$, where $\tau_t(y) = 1 - \lambda_t y^{1-\gamma_t}$, and $\tau_{ss}(y) = 1 - \lambda_{ss} y^{1-\gamma_{ss}}$ is the steady-state tax rate. An example of the new tax scheme is plotted in Figure 10.

Interestingly, as the government needs to increase tax revenues to finance the shock, selecting the level of tax progressivity γ_t along the transition boils down to selecting the fraction of households that face higher taxes. In particular, if γ_t is constant, all households face higher taxes than in steady state as revenues must increase – and $\hat{\tau}_t(y) = \tau_t(y)$. On the contrary, as γ_t increases, only households with higher income face a higher tax rate. The higher the γ_t, the smaller the fraction of (higher-income) households that shoulder the stimulus.

4.2 Deficit Financing

When spending is financed with distortionary taxes only, Ricardian equivalence does not hold and debt issuance can affect spending multipliers. To address this, we allow for deficit financing after a spending shock in the model.

We follow Uhlig (2010) and assume that debt dynamics after a spending shock are given by:

$$D_{t+1} - D_{ss} = (1-\theta)(d_t - d_{ss}) \qquad \theta \in (0,1], \tag{8}$$

where $d_t \equiv G_t + r_t D_t - \tau^k r_t A_t + T_t$ represents fiscal deficits before labor tax revenues; $A_t = \int a d\mu_t(a,x)$ is total assets holdings by households in period t; and d_{ss} and D_{ss} represent the steady-state values of d_t and D_t, respectively. Thus, $(1-\theta)$ is the fraction of additional spending financed through deficits, while θ is the fraction financed with increased labor taxes. When $\theta = 1$, all additional spending is financed with labor taxes, and when $\theta = 0.1$, 10% of the additional spending is financed with higher labor taxes.

4.3 New Keynesian Features

The literature on spending multipliers often uses models with nominal rigidities so that increases in government spending affect output through a "demand channel".[50] Thus, we incorporate a New Keynesian dimension to our model by adding monopolistic competition and costly price adjustment as in Rotemberg (1982).

In particular, we include intermediate goods producers under monopolistic competition who can adjust prices only subject to a quadratic cost. They demand capital and labor from households in frictionless markets and sell their output to a final good producer who combines all intermediate goods into a final consumption bundle. We assume that monetary policy follows a simple Taylor rule that responds to deviations of inflation with a coefficient of $\phi_\Pi = 1.5$, as commonly used in the literature. Because the New Keynesian features we add are standard, we defer a detailed explanation of the model and its calibration to Appendix E.[51]

4.4 Aggregate Multipliers

We analyze government spending multipliers in the augmented model. The experiment is similar to the one in Section 3.4: at $t = 0$, while in steady state, the government unexpectedly announces a 1% increase in spending that returns to steady state at a rate $\rho_G = 0.97$.[52] Simultaneously, the government announces a path for the progressivity of taxes $\{\gamma_t\}$ that, as previously discussed, pins down the fraction of households

[50] Recent work analyzing a "demand channel" in economies with heterogeneous households include Hagedorn, Manovskii, and Mitman (2017), Kaplan, Moll, and Violante (2018), and Auclert and Rognlie (2018).

[51] The production side of the economy is the standard New Keynesian environment as described in Galí (2015), chapter 3. The only differences are the inclusion of physical capital and household heterogeneity.

[52] We use a persistence for spending as estimated by Smets and Wouters (2007).

that will pay higher labor taxes—capital taxes are kept constant. Finally, the government also announces the fraction $(1-\theta)$ of additional spending that will be financed with deficits.

We consider three cases for the path of progressivity. First, a *constant progressivity* case, where all working households finance the spending shock. Second, a *small increase in progressivity* case, where progressivity increases slightly—from $\gamma = 0.1$ to $\gamma = 0.1025$ on impact—and only the top 90% of workers support the fiscal effort. Third, a *larger increase in progressivity* case, where progressivity increases more significantly—to $\gamma = 0.11$ on impact—so that only the top 35% of workers finance the stimulus.[53] In the last two cases, γ returns to steady state at a rate $\rho_\gamma = 0.9$.[54]

Settling on a value for θ is not straightforward, as the extent to which deficits were used to finance spending varied substantially across historical periods. As a benchmark, we use an intermediate case where 50% of additional spending is financed with deficits ($\theta = 0.5$).[55] We also consider the two polar cases of no additional debt ($\theta = 1$), and 90% of additional spending financed with deficits ($\theta = 0.1$).

Multipliers vary substantially depending on the distribution of taxes. Figure 11 shows the cumulative multiplier for the benchmark case of $\theta = 0.5$ and the three paths for tax progressivity previously described. Multipliers are negative at all horizons when taxes increase for all households (*constant progressivity*), with a two-year cumulative multiplier of negative 0.34. On the contrary, multipliers increase to a close-to-zero effect when only the top 90% face higher taxes (*small increase in progressivity*). Furthermore, multipliers become positive—at 0.13 after two years—when only the top 35% face higher taxes (*larger increase in progressivity*). Thus, tax progressivity shapes spending multipliers.

As expected, deficit financing is expansionary: multipliers reach 0.2 at a two-year horizon in the case of a *larger increase in progressivity* and high deficit financing (Figure 12). Importantly, the distribution of taxes remains a key determinant of spending multipliers for all levels of deficit financing. When no additional debt is issued, using more progressive taxes increases multipliers by 0.5 after two years. As the government runs larger deficits, the distribution of taxes becomes less important; yet, when 90% of additional spending is financed with deficits, using more progressive taxes still increases multipliers by 0.2 after two years.

Note that spending multipliers are lower than their estimated counterparts, especially at longer hori-

[53] This fraction represents the number of households facing higher taxes during the first year. To put these numbers into historical perspective, the fraction of households filling tax returns at the end of WWI is about 30%.

[54] To compute this persistence ρ_γ, we proceeded in two steps. First, we projected the spending shock on our progressivity measure γ at different horizons h and obtained coefficients $\{\beta_h^\gamma\}$. Second, we computed the autocorrelation of $\{\beta_h^\gamma\}$.

[55] For instance, while WWII was initially heavily financed with debt, the Korean War was entirely financed with taxes. Financing 50% of the stimulus with debt is in line with the average response of deficits to a spending shock as reported by Ramey and Zubairy (2018) (see Section 4 of the Online Appendix). We report similar numbers in Appendix B.1.

zons.[56] This is the result of distortionary income taxes, as initially argued in Baxter and King (1993) and more recently in Drautzburg and Uhlig (2015). Interestingly, we find that adding New Keynesian features to the model affects multipliers only mildly, as Appendix E.4 shows.[57] Allowing for a less responsive monetary policy, or targeting higher *mpc*s, could boost multipliers. Similarly, as recently discussed in Leeper, Traum, and Walker (2017), multipliers would increase if we were to add utility-complementarity between private and government consumption, habit consumption, and/or a large degree of wage stickiness. Multipliers could also be higher if government spending were to be productivity enhancing, as argued in Cozzi and Impullitti (2010) or Dyrda and Rios-Rull (2012). We refrained from adding these features to focus the analysis on the distribution of taxes and *lpe*s, which is the novelty in our paper.

On net, our analysis confirms that who pays for the stimulus matters: the distribution of taxes is key to the aggregate effects of spending. We considered combinations of deficit financing and changes in the distribution of taxes that accurately capture of how large spending shocks (wars) were historically financed. Despite distortionary taxes, the model is able to generate positive multipliers when the lower-income households are exempted of heavier taxation. Although at longer horizons multipliers are lower than estimated, at shorter horizons the model is close to the aggregate evidence presented in Section 2.5. More importantly, the model captures well the empirical difference in multipliers found between progressive and regressive states.

4.5 Cross-sectional Responses

Next, we analyze the cross-section implications of the model and compare them with the micro-evidence of Section 2.6. Figure 13 shows, by quintile, the average income response after a spending shock for both the *constant progressivity* and *large increase in progressivity* case.

Responses are very heterogeneous across households. Income at the lowest quintile markedly contracts if spending is financed by taxing all households, while it expands when the stimulus is financed with more progressive taxes. As the income quintile increases, the responses are smaller in magnitude and do not depend as much on the tax scheme. This pattern of responses is comparable to the one estimated in Section 2.6, which we take as further evidence in support of the model.[58]

[56] Lower multipliers at longer horizons are not uncommon in quantitative work. See Uhlig (2010) and Leeper, Traum, and Walker (2017), who also find this pattern.

[57] A similar finding can be found in Gali, Lopez-Salido, and Valles (2007) when using a competitive labor market, as we do.

[58] Arguably the estimated contraction for the bottom quintile in the regressive state is larger than in the model counterpart. Nevertheless, this empirical response is imprecisely estimated and all other responses are quantitatively closer to the model implications.

4.6 Why Indivisible Labor?

A key ingredient in our model is the indivisible labor-supply assumption, which delivers the decreasing profile for labor-supply elasticities documented in the data. In fact, if we were to use a divisible labor model, elasticities would be flat across income levels, at odds with the evidence of Section 2.[59] Consequently, as Figure D.1 shows, multipliers would be less expansionary when using more progressive taxes, a result that contradicts our empirical findings.

5 Conclusion

We exploited the historical variation in the financing of spending in the U.S. since 1913 to show that government spending multipliers depend on the distribution of taxes across households. We built a new measure of personal income tax progressivity to estimate state-dependent multipliers, where the state depends on tax progressivity. We found that multipliers have been larger when financed with more progressive taxes. We argued that this finding can be rationalized within an *off-the-shelf* model of heterogeneous households, to the extent that labor-supply elasticities decrease with income. Although multipliers are lower than estimated, the model can account for a large fraction of the empirical difference in multipliers between progressive and regressive states. As an important policy implication, our results advocate an increase in progressivity to finance a stimulus aimed at boosting output.

At a more general level, an important contribution of this paper is to put the focus on the heterogeneity in labor-supply elasticities across households. The decreasing income profile of labor elasticities, which is well supported by evidence, has substantial implications on the aggregate effects of fiscal policy. We believe this calls for more research on tax progressivity, in at least three directions.

First, the optimal level of tax progressivity is likely to be quantitatively higher when incorporating this heterogeneity in labor elasticities. Similarly, the aggregate effect of transfers—such as unemployment benefits or the earned income tax credit—are likely to be larger. Developing a model with an extensive labor-supply decision to quantify the effect of these margins on the optimal tax system seems a research priority. This line of work would continue the recent contributions in Kindermann and Krueger (2017), and is the motivation of ongoing work in Feenberg, Ferriere, Navarro, and Vardishvili (2018).

Second, tax progressivity may play a large role in stabilizing the business cycle. As we show in Appendix C.4, temporary increases in tax progressivity lead to substantial output expansions in our model. These results, which are driven by the heterogeneity in labor elasticities, may merit reconsidering the role of

[59] All details about the divisible labor-supply model can be found in Appendix D.

(changes in) tax progressivity to stabilize the business cycle. This line of work would continue the recent contributions in McKay and Reis (2017).

Finally, the focus on heterogeneity in labor elasticities should not conceal the importance of the well-known heterogeneity in marginal propensities to consume. In fact, the interaction of these two dimensions of heterogeneity across households is likely to have interesting implications for the coordination of fiscal and monetary policies. While we incorporated some New Keynesian features, extending our model in this direction would certainly provide interesting insights.

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Government	$G = 0.22$	$T = 0.07$	$D = 3.46$	$\tau_k = 0.35$	$(\gamma, \lambda) = (0.1, 0.77)$
Households	$\beta = 0.989$	$B = 2.24$	$\bar{h} = 1/3$	$\underline{a} = -2$	$(\rho_x, \sigma_x) = (0.989, 0.287)$
Technology	$\alpha = 0.64$	$\delta = 0.025$			

Table 1: Parameter Calibration

	Share of wealth					Participation rate				
Wealth quintile	1	2	3	4	5	1	2	3	4	5
Model	-0.01	0.05	0.13	0.25	0.58	0.79	0.64	0.59	0.54	0.49
Data	-0.00	0.02	0.07	0.15	0.77	0.65	0.75	0.69	0.60	0.57

Table 2: Wealth and Employment Distribution: Model and Data

Notes: Households are sorted by wealth. 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. We measure participation of individuals, where 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.

	Average	Bottom 90%	Top 10%
W.r.t. labor tax	-0.36	-0.43	-0.03
W.r.t. wages	1.33	1.59	0.06

Table 3: Labor Participation Elasticity

Notes: Elasticities are computed after a one-period unexpected 1% increase in the labor tax, or a 1% decrease in wage. Households are sorted by income. See Appendix C.2 for more details.

	Bottom 90%	Top 10%
Data	-0.26%	0.00%
Model	-0.23%	0.00%

Table 4: Aggregate Employment Response to Tax Shocks

Notes: Aggregate employment response (average over 3 years) to a tax shock supported by the top 10% (left column) and the bottom 90% (right column). Data responses are imputed from Zidar (2017). See Appendix C.3 for more details on the model computations.

	Average	Bottom 10%	Top 90%
Rebate of 1% wage	0.04	0.20	0.02
Rebate of 10% wage	0.03	0.06	0.03

Table 5: Marginal Propensities to Consume

Notes: Marginal propensities to consume are computed after a one-period unexpected rebate; the rebate is expressed as a percentage of the mean quarterly wage. Households are sorted by wealth.

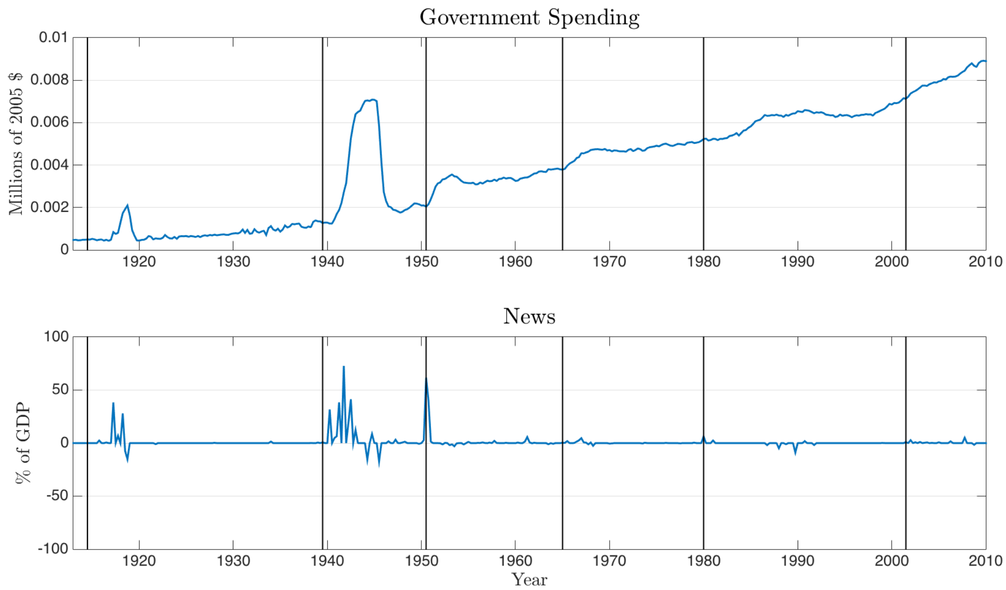

Figure 1: Defense Spending and Ramey Defense News

Notes: Government spending corresponds to all spending excluding transfers, in 2005 dollars and per-capita terms. News represents the present discounted value of military spending news, in percentage terms of lag GDP. 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 of Afghanistan), 2001:Q3 (9/11).

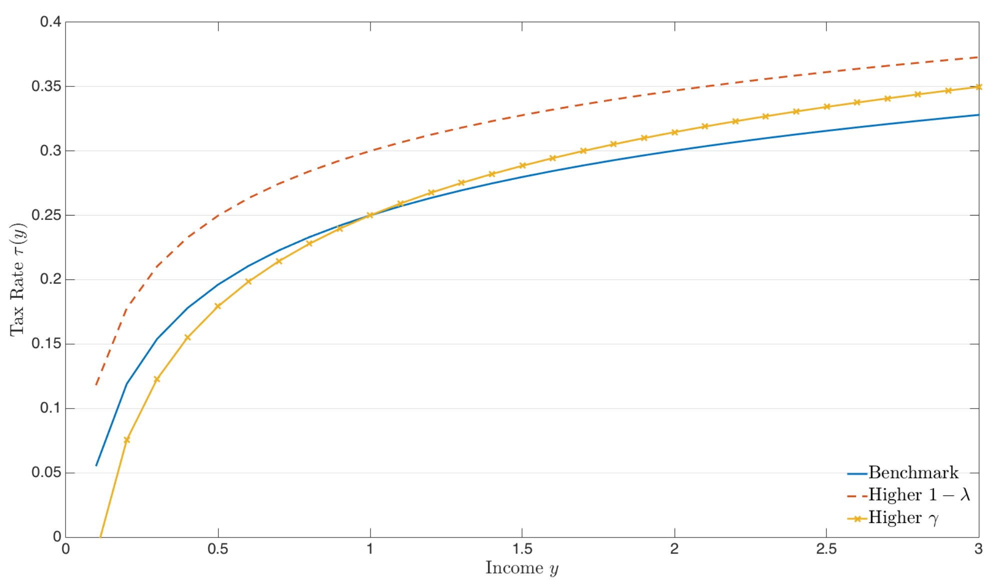

Figure 2: A Nonlinear Tax Scheme

Notes: The tax function $\tau(y) = 1 - \lambda y^{-\gamma}$ is plotted for varied measures of γ (tax progressivity) and λ (tax level).

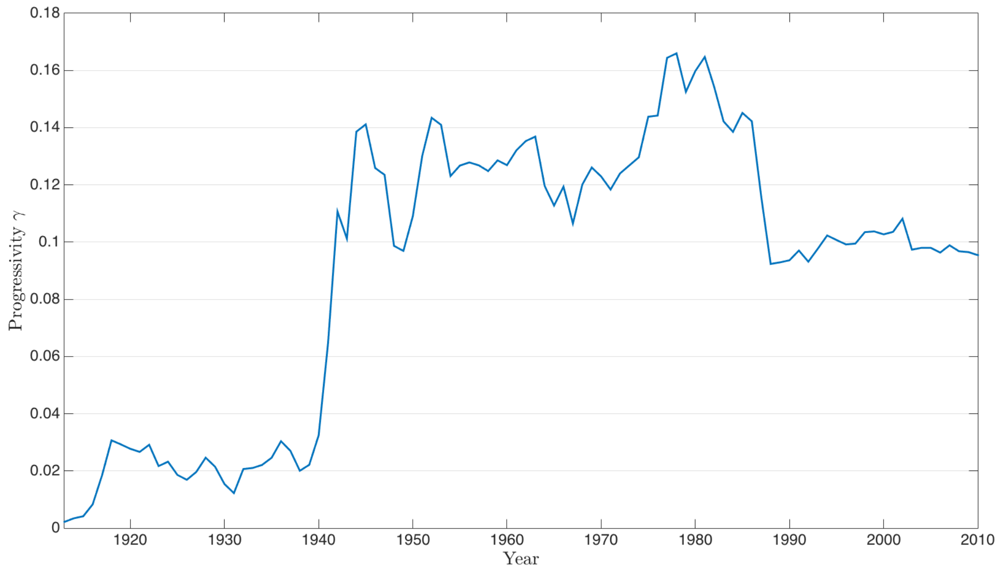

Figure 3: U.S. Federal Tax Progressivity

Notes: Authors' computations. See Appendix A.1 for details on computations.

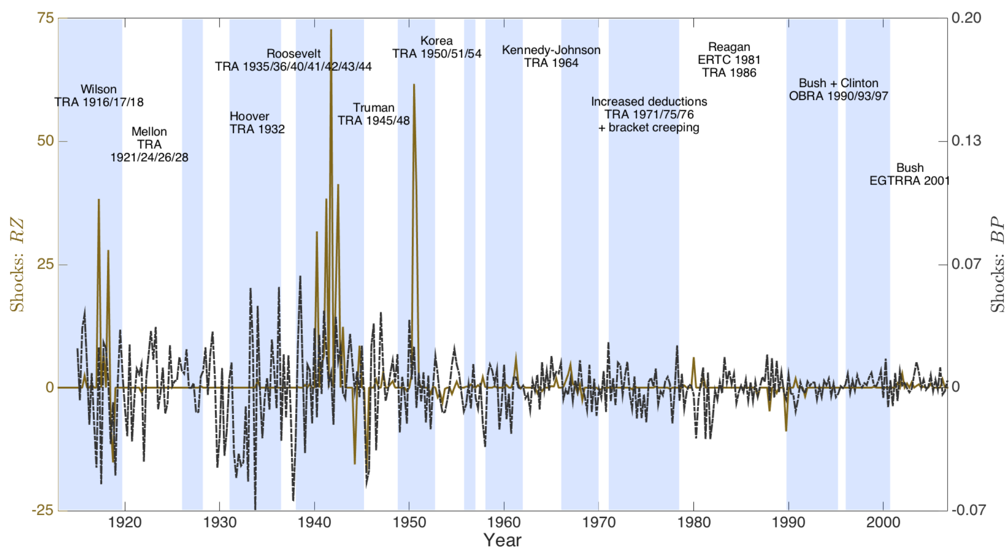

Figure 4: Progressive States and Spending Shocks

Notes: The brown line (left axis) plots the RZ shocks as in Figure 1 (bottom panel); the black line (right axis) plots the BP shocks. Shaded areas correspond to periods of increased progressivity, $s_t = P$; white areas depict $s_t = R$.

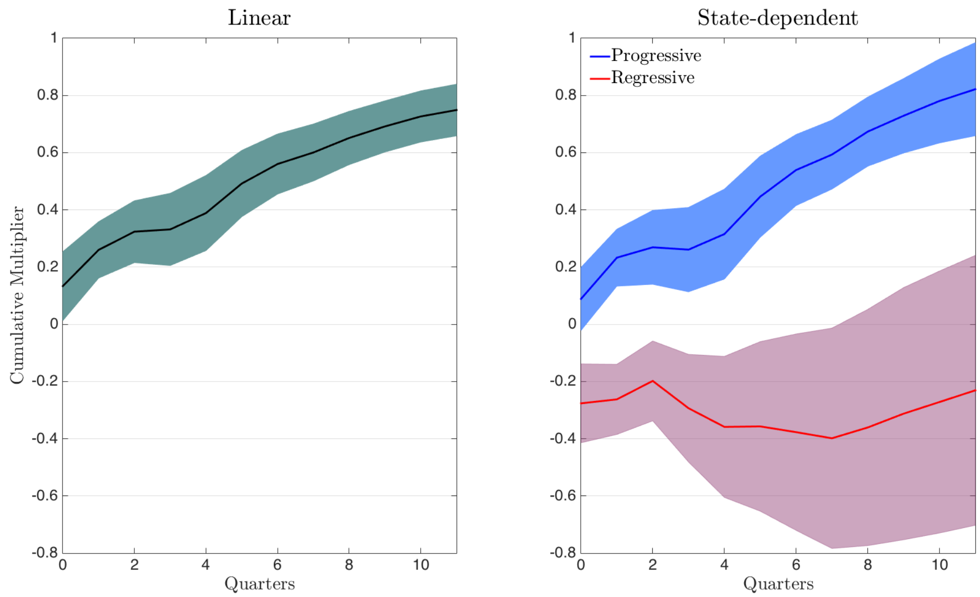

Figure 5: Cumulative Multipliers on Output

Notes: Cumulative spending multipliers for output for 3 years; linear (left panel), progressive and regressive states (right panel). Multipliers are estimated by local projection method; data: quarterly 1913 to 2006; confidence intervals: 68%.

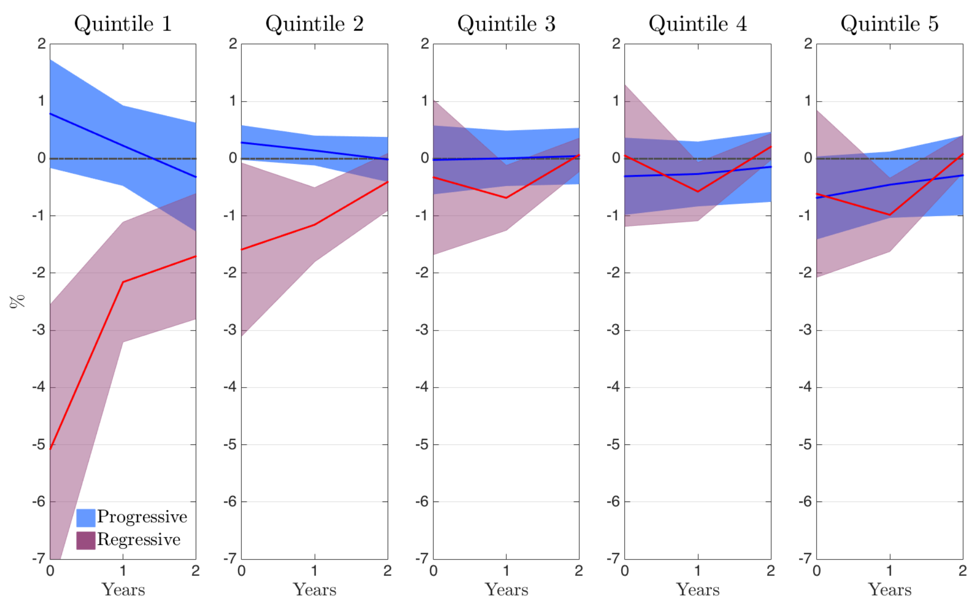

Figure 6: Income Response by Quintile to a Spending Shock

Notes: Pre-tax income response by quintile to a spending shock; progressive and regressive states. Elasticities are estimated by local projection method; data: TAXSIM, annual 1960 to 2006; confidence intervals: 68%.

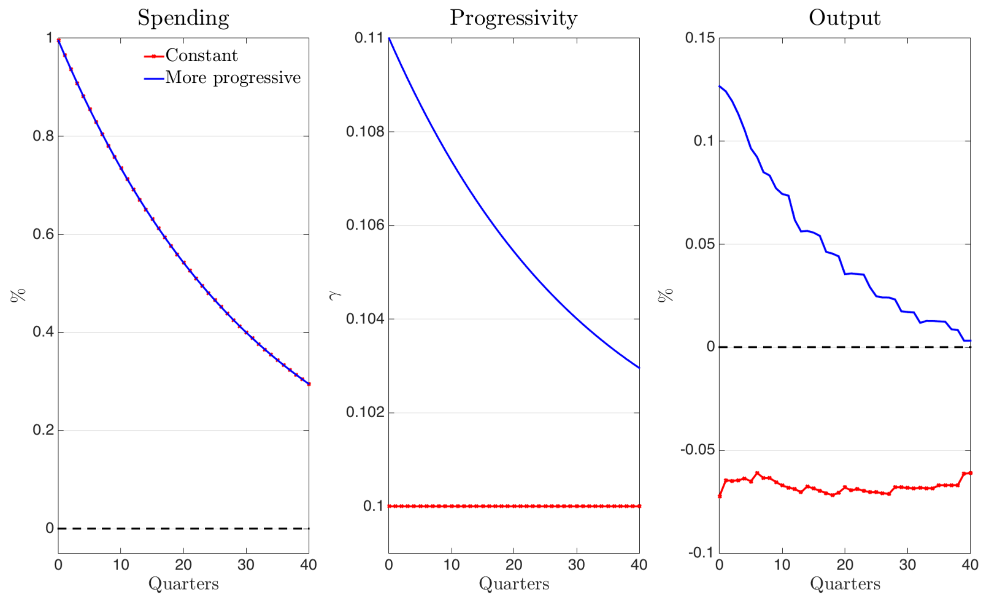

Figure 7: Model Responses to a Spending Shock Financed with Different Progressivity Paths

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

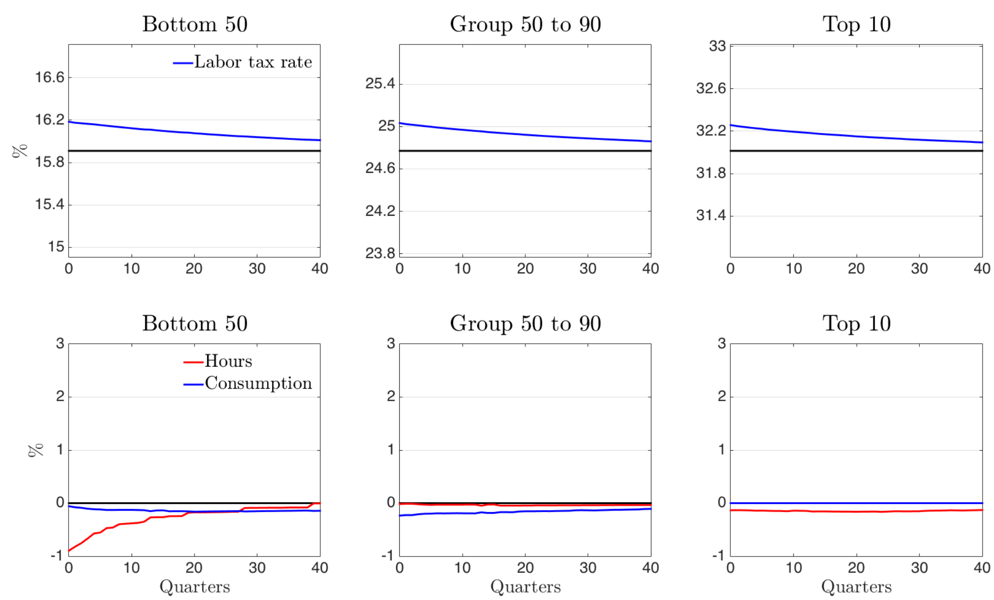

Figure 8: Model Responses to a Spending Shock Financed with Constant Tax Progressivity

Notes: Model impulse responses of average labor taxes (top panels) and hours and consumption (bottom panels), per income quantile, to a government spending shock financed with labor taxes only, keeping progressivity constant.

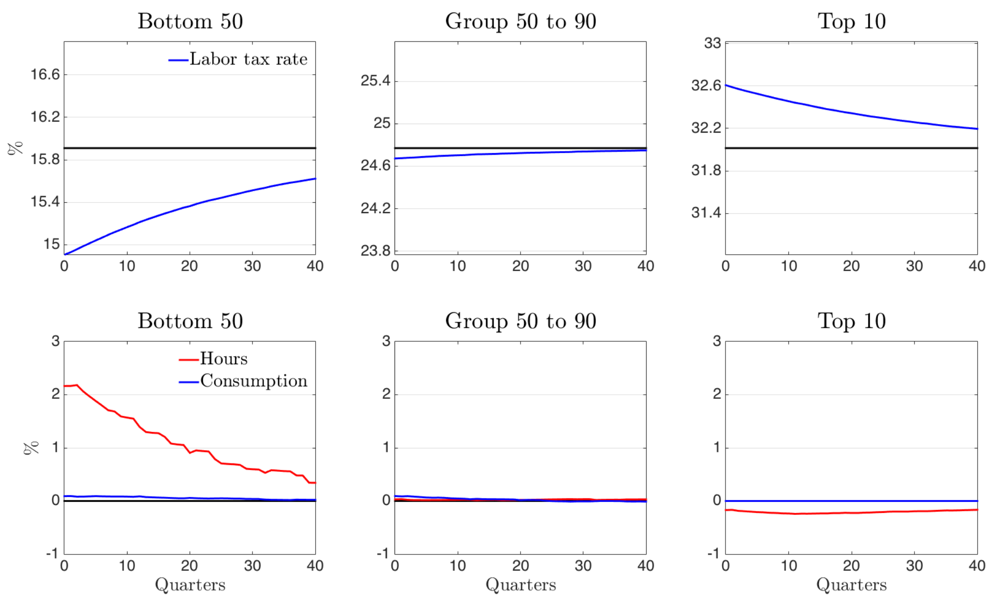

Figure 9: Model Responses to a Spending Shock Financed with Higher Tax Progressivity

Notes: Model impulse responses of average labor taxes (top panels) and hours and consumption (bottom panels), per income quantile, to a government spending shock financed with more progressive labor taxes.

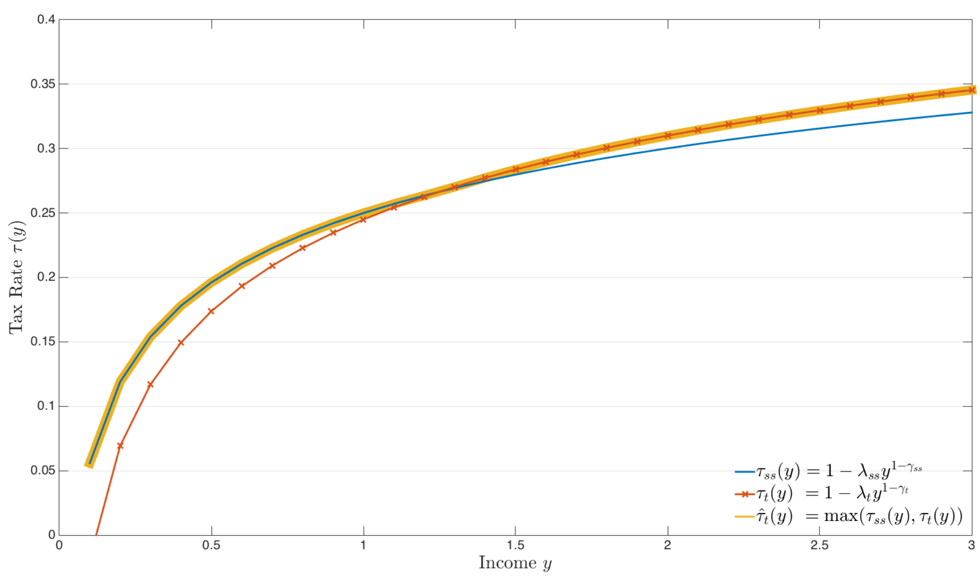

Figure 10: Modified Tax Function

Notes: The modified tax function $\hat{\tau}_t(y) = \max\left(1 - \lambda_t y^{-\gamma_t}, 1 - \lambda_{ss} y^{-\gamma_{ss}}\right)$ is such that the tax scheme during the transition is at least as high as in steady state.

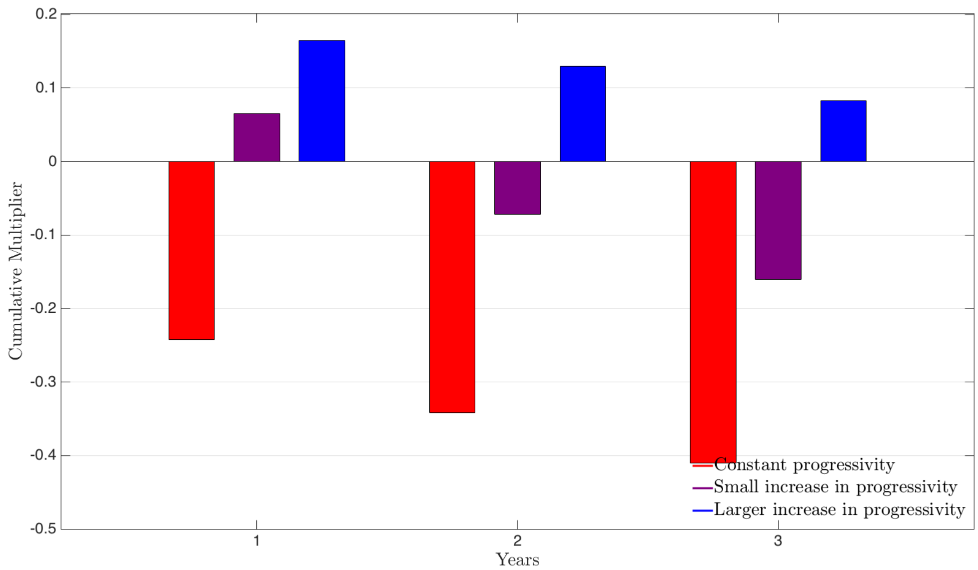

Figure 11: Output Multipliers with Different Progressivity Paths

Notes: Cumulative output multipliers to a spending shock financed with deficits ($\theta = 0.5$) and labor taxes. Multipliers are reported for three distributions of taxes: *constant progressivity*, *small increase in progressivity*, and *larger increase in progressivity*, corresponding to, 100%, 90%, and 35% of workers, respectively, financing the stimulus.

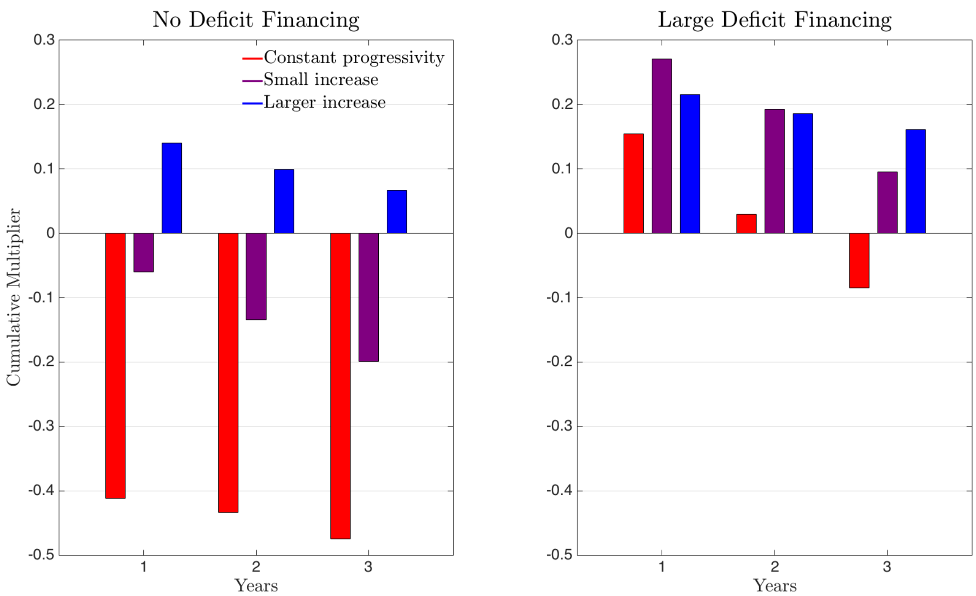

Figure 12: Output Multipliers with Different Levels of Deficit Financing

Notes: Cumulative output multipliers to a spending shock financed with deficits and labor taxes. Multipliers are reported for three distributions of taxes. The left panel plots no deficit financing ($\theta = 1$), and the right panel plots large deficit financing ($\theta = 0.1$).

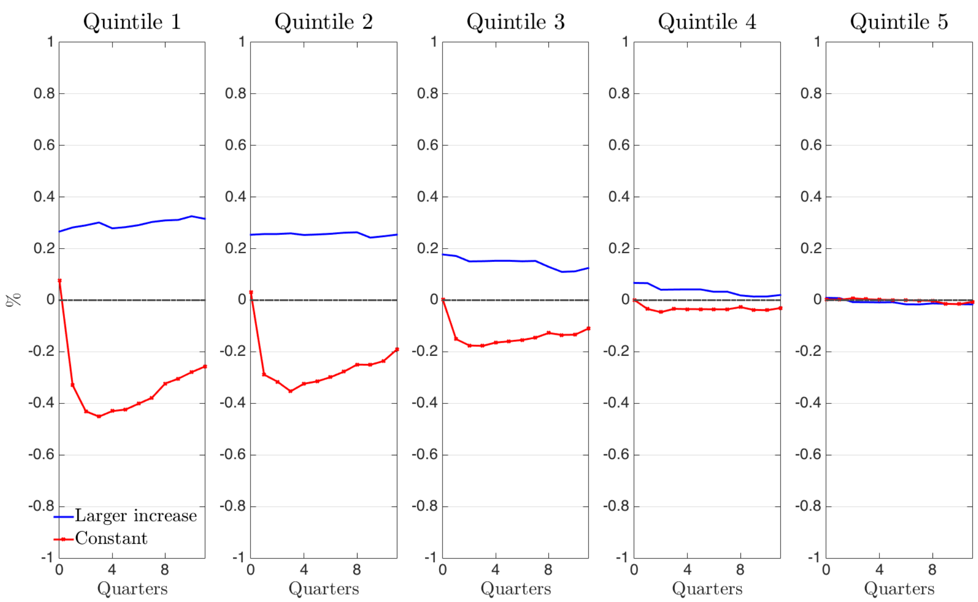

Figure 13: Model Responses to a Spending Shock with Different Progressivity Paths

Notes: Model impulse responses of average pre-tax income, per income quantile, to a government spending shock financed with deficits ($\theta = 0.5$) and labor taxes. Responses are reported for two distributions of taxes: *constant progressivity* and *larger increase in progressivity.*

A Data Sources and Definitions

A.1 Progressivity

We build a novel time series to measure the progressivity [P] of the federal income tax since 1913, using measures of average tax rate [ATR] and average marginal tax rate [AMTR]. The Average Tax Rate [ATR] is computed as Total Tax Liability over Total Income, where Total Tax Liability is computed for federal taxes including tax credits (Source: Statistic Of Income (SOI), IRS; 1913-2014 (annual), current dollars; data: SOI Bulletin article - Ninety Years of Individual Income and Tax Statistics, 1916-2005, Table 1, Col. L, for years 1913-2005; data: Individual Complete Report (Publication 1304), Table A, line 189, for 2006 onwards), and the measure for Total Income is borrowed from Piketty and Saez (2003) (data: Table A0, years 1913-2014). For the Average Marginal Tax Rate [AMTR], we use the time series of Barro and Redlick (2011) (data: federal, until 1945) and Mertens and Olea (2018) (data: federal, years 1946-2012).[60]

The measure [P] is constructed as follows: $P = (AMTR - ATR)/(1 - ATR)$. Should the tax system be exactly loglinear, this measure would be equal to the parameter capturing the curvature of the tax function. 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 $T(y) \equiv y - \lambda y^{1-\gamma}$ as the amount of taxes paid for income y, and $\tau(y) \equiv 1 - \lambda y^{-\gamma}$ as the tax rate; the marginal tax rate is equal to $T'(y) = 1 - \lambda(1-\gamma)y^{-\gamma}$ and then

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

Of course, one could be worried that our measure, based on effective tax rates, reflects changes in the distribution rather than changes in the tax code itself. The TAXSIM program of the NBER, which we describe in more detail in Appendix A.3, provides an annual measure of marginal and average tax rates over all taxpayers, using a *fixed* sample of taxpayers (data: years 1960 to 2008, fixed distribution of 1984). We compute the P implied by their tax rates and find a correlation to our measure of progressivity of 0.79 in levels and 0.80 in growth rate on overlapping periods.

A.2 Other Macro Variables

We use the measure of Ramey and Zubairy (2018) for military news (data: quarterly, 1913 to 2008), and the measure of Owyang, Ramey, and Zubairy (2013) for total government spending (including federal, state, and local purchases, but excluding transfer payments). Quarterly measures for GDP, GDP deflator,

[60] Over the overlapping period, these two measures are almost undistinguishable, with a correlation of 0.99.

unemployment, population, and fiscal deficits from 1913 to 2008 are borrowed from Ramey and Zubairy (2018). To perform our robustness exercises, we also use the 3-month T-bill (data: 1953 to 2008, quarterly, source FRED).

A.3 Micro Data

Our data source for income at the micro level comes from IRS public files, which are part of the TAXSIM program at the NBER.[61] The sample is annual for 1960 to 2008 and has approximately $100,000$ observations per year.[62] Importantly, the data is not top coded, which makes it particularly useful to analyze tax distributions at the very top. Unfortunately, we do not have identification data and can only construct repeated cross-sections over time but not a panel. For the same reason, an observation in our sample is a tax filling 1040 form, which could be a joint or a single filling. Our measure of total income corresponds to *Adjusted Gross Income* (AGI) ignoring losses and adding capital gain deductions.

B Local Projection Method: Robustness

The benchmark estimation is as follows: spending is instrumented by two shocks, RZ and BP; the control Z_t includes eight lags of $\log GDP$, $\log G_t$, and $AMTR_t$; the trend is quartic; the time period is 1913:Q1 to 2006:Q4; the state is defined with $\Delta_a = 12$ and $\Delta_b = 8$.

Tables B.1 and B.2 present numerous robustness checks. In particular, Table B.1 documents multipliers by expansion/slack states and under different sets of controls: without the marginal tax rate, with the average tax rate, with fiscal deficit, and with T-bill. Table B.2 explores robustness to the shock, the time period, the lags, the trend, and the definition of the state. In almost all cases, the results hold; the noticeable exception is when using only the *RZ shocks* from 1953 onwards, a finding that might be explained by the limited amount of RZ shocks on that sample.

B.1 Deficit Financing Across States

We compute the response of fiscal deficits after a spending shock in both the progressive and the regressive state. To do so, we re-estimate equation (3) using deficits as a dependent variable. In particular, we estimate

[61] See http://users.nber.org/∼taxsim/

[62] The minimum and maximum number of observations are $59,037$ for 1986 and $171,751$ for 1979, respectively.

	Linear			Progressive			Regressive			p-values		
	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y
Benchmark	0.33	0.60	0.75	0.26	0.59	0.82	-0.29	-0.40	-0.23	0.01	0.00	0.01
	(0.12)	(0.10)	(0.09)	(0.14)	(0.12)	(0.16)	(0.18)	(0.49)	(0.47)			
Expansions & slack												
- expansion states				0.35	0.63	0.86	-0.86	-0.66	-0.63	0.00	0.01	0.07
				(0.12)	(0.16)	(0.24)	(0.32)	(0.56)	(0.97)			
- slack states				0.49	0.58	0.82	1.82	-5.81	-6.30	0.16	0.18	0.16
				(0.19)	(0.22)	(0.21)	(0.94)	(4.41)	(5.04)			
Controls												
- no MTR				0.38	0.58	0.71	0.07	0.11	0.23	0.05	0.03	0.05
				(0.12)	(0.06)	(0.07)	(0.15)	(0.25)	(0.25)			
- with ATR				0.26	0.62	0.95	-0.18	-0.25	0.14	0.06	0.01	0.02
				(0.15)	(0.12)	(0.15)	(0.21)	(0.37)	(0.49)			
- with deficit/GDP				0.29	0.57	0.77	-0.21	-0.68	-1.03	0.12	0.07	0.02
				(0.11)	(0.12)	(0.19)	(0.31)	(0.68)	(0.82)			
- with T-bill⋆				1.46	1.61	1.28	-0.51	-1.15	-1.52	0.00	0.00	0.00
				(0.57)	(0.57)	(0.62)	(0.51)	(0.49)	(0.85)			

Table B.1: Local Projection Methods: Robustness.

Notes: *This table shows robustness of the results with respect to the expansion/slack state, and several controls. The ⋆ indicates that the sample starts in* 1953*:Q1.*

the following:

$$\sum_{j=0}^{h} \Delta^j d_{t+j} = \mathbb{I}(s_t = \mathrm{P}) \left\{ \alpha_{P,h} + A_{P,h} Z_{t-1} + m^d_{P,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} + \mathbb{I}(s_t = \mathrm{R}) \left\{ \alpha_{R,h} + A_{R,h} Z_{t-1} + m^d_{R,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} + \phi \; trend_t + \varepsilon_{t+h} \tag{B.1}$$

where $\Delta^h d_{t+h} = \frac{D_{t+h} - D_{t-1}}{Y_{t-1}}$ and D_t is the fiscal deficit in quarter t. Thus, $\Delta^h d_{t+h}$ is the adjusted-by-GDP deficit growth. The coefficient $m^b_{s,h}$ is the cumulative *deficit* multiplier: it measures, for each state, the accumulated increase in deficits after a $1 increase in spending. The specification of equation (B.1) is the same as in Section 2.3 (controls, lags, and instruments) and only the dependent variable changes.

The response of fiscal deficits to a spending shock are very similar in the progressive and regressive states, as Figure B.1 shows. If at all, deficits increase slightly more in the regressive state. In the progressive state, deficits cover around 50% of the stimulus initially, which increase up to 80% after a year before decreasing. In the regressive states, deficits initially cover 75% of spending and reach around 90% after a year before declining.

	Linear			Progressive			Regressive			p-values		
	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y
Period												
- 1953:Q1-2006:Q4				2.08	2.95	2.93	0.25	0.33	0.90	0.04	0.00	0.00
				(0.68)	(0.74)	(0.62)	(0.54)	(0.42)	(0.39)			
- 1913:Q1-2008:Q4				0.26	0.59	0.82	-0.30	-0.36	-0.22	0.01	0.00	0.00
				(0.15)	(0.12)	(0.16)	(0.19)	(0.38)	(0.46)			
Shocks												
- *BP* only				0.24	0.59	0.95	-0.34	-0.52	-0.08	0.03	0.03	0.11
				(0.15)	(0.14)	(0.19)	(0.25)	(0.54)	(0.75)			
- *BP* only*				2.12	3.35	3.40	0.22	0.29	0.81	0.04	0.00	0.00
				(0.68)	(0.85)	(0.78)	(0.55)	(0.44)	(0.54)			
- *RZ* only				0.52	0.54	0.69	-0.24	-0.59	-0.96	0.08	0.01	0.04
				(0.21)	(0.18)	(0.23)	(0.45)	(0.58)	(0.96)			
- *RZ* only*				0.98	4.34	4.09	-2.56	13.88	6.73	0.59	0.83	0.34
				(1.93)	(16.38)	(2.07)	(7.83)	(60.09)	(3.32)			
Specification												
- lag = 4				0.30	0.62	0.84	-0.02	-0.03	0.09	0.07	0.01	0.01
				(0.12)	(0.07)	(0.12)	(0.14)	(0.24)	(0.25)			
- trend = 2				0.25	0.59	0.81	-0.10	-0.15	-0.09	0.10	0.00	0.00
				(0.15)	(0.09)	(0.11)	(0.16)	(0.25)	(0.23)			
Windows												
$\Delta_a = 08$				0.16	0.51	0.75	-0.07	0.00	0.28	0.02	0.00	0.01
				(0.15)	(0.15)	(0.15)	(0.15)	(0.25)	(0.27)			
$\Delta_a = 16$				0.32	0.63	0.86	-0.08	-0.06	-0.02	0.13	0.08	0.06
				(0.20)	(0.15)	(0.13)	(0.21)	(0.41)	(0.53)			
$\Delta_b = 04$				0.36	0.54	0.72	0.15	0.26	0.25	0.23	0.13	0.12
				(0.14)	(0.11)	(0.13)	(0.14)	(0.20)	(0.28)			
$\Delta_b = 12$				0.24	0.57	0.86	-0.15	-0.24	0.00	0.05	0.00	0.00
				(0.16)	(0.15)	(0.18)	(0.16)	(0.30)	(0.36)			

Table B.2: Local Projection Methods: Robustness

Notes: *This table shows robustness of the results with respect to the sample, the shock, the lag, the trend, and the windows to define the state. The $\star$ indicates that the sample starts in* 1953*:Q1.*

C Model Details

C.1 Steady-State Solution and Transition Computations

C.1.1 Steady State

For a given guess on taxes and prices, we solve the household problem by value function iteration and use the optimal policies to compute aggregate outcomes. We iterate on taxes and prices so that government budget constraint holds and markets clear. Practically, given a value for r, firm's first order conditions imply wages are $w = \alpha\left(\frac{r+\delta}{1-\alpha}\right)^{-\frac{1-\alpha}{\alpha}}$. Thus we only to loop in r and the tax parameter λ. More formally, we proceed as follows:

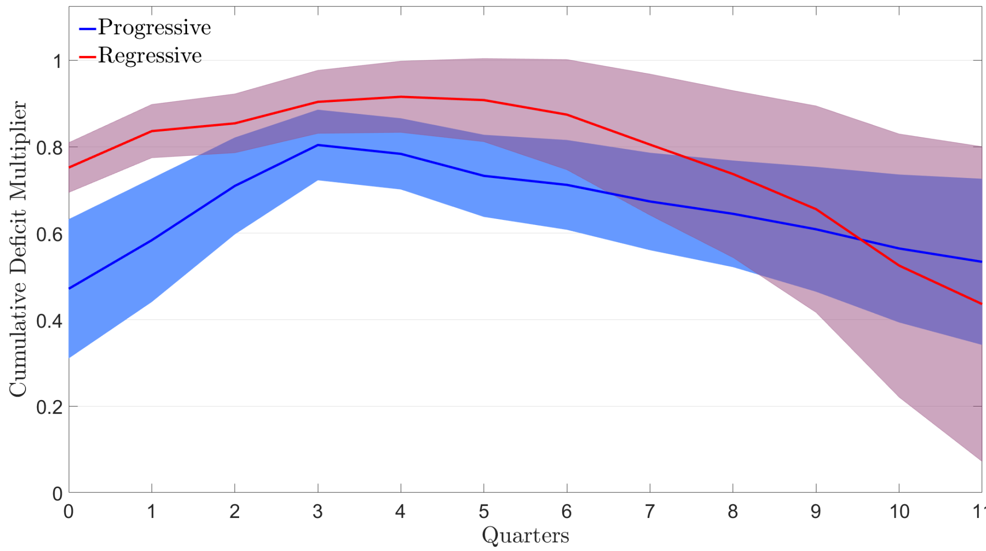

Figure B.1: Deficit Financing Across States

Notes: Cumulative *deficit*-multiplier after a spending shock. Multipliers are estimated by local projection method; data: quarterly 1913 to 2006; confidence intervals: 68%

0. Set grids for assets $\vec{a}$ and productivity levels $\vec{x}$, let N_a and N_x be the number of points in each grid respectively. Compute the transition matrix of productivities $\pi_x(x', x)$ using Tauchen (1986) method.

1. Guess values for the interest rate r and the tax parameter λ. Compute the implied w.

2. Solve for household policies by value function iteration. In particular, for a given guess of the value of working $V_0^E(a, x)$ and not working $V_0^N(a, x)$, compute $V_0(a, x) = \max\left\{V_0^E(a, x), V_0^N(a, x)\right\}$ and update the value function as

$$V_1^E(a_i, x_j) = \max_{a' \in \vec{a}} \left\{ \log\left(wx_j\bar{h} + (1+r)a_i - \mathcal{T}(wx_j\bar{h}, ra_i) + T - a'\right) - B\bar{h} + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_0(a', x_{j'}) \right\}$$

$$V_1^N(a_i, x_j) = \max_{a' \in \vec{a}} \left\{ \log\left((1+r)a_i - \mathcal{T}(0, ra_i) + T - a'\right) + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_0(a', x_{j'}) \right\}$$

where $\mathcal{T}(wxh, ra) = \tau_k ra + wxh - \lambda(wxh)^{1-\gamma}$. Compute $V_1(a, x) = \max\left\{V_1^E(a, x), V_1^N(a, x)\right\}$ and iterate until $\|V_1 - V_0\| < \varepsilon^V$.

3. Compute the stationary measure implied by the optimal policies of step 2. In particular, for a given

guess $\mu_0(a,x)$, update the measure as

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

Iterate until $\|\mu_1 - \mu_0\| < \varepsilon^{\mu}$.

4. Compute $\hat{\lambda}$ so that, given the household policies of step 2 and the measure of step 3, the government budget constraint holds. This is $\hat{\lambda} = \left[\int (y_\ell(a,x) + \tau_k a)\, d\mu(a,x) - (G + rD + T)\right] / \left[\int y_\ell(a,x)^{1-\gamma} d\mu(a,x)\right]$, where $y_\ell(a,x) = wxh(a,x)$ is labor income. Similarly, compute the interest rate implied from firm's first order conditions $\hat{r} = -\delta + \alpha\,(K/L)^{1-\alpha}$, where $K = -D + \sum_{a,x} a\mu(a,x)$ and $L = \sum_{a,x} xh(a,x)\mu(a,x)$.

5. If $\left\|\hat{\lambda} - \lambda\right\| < \varepsilon^{\lambda}$ and $\|\hat{r} - r\| < \varepsilon^{r}$, the model converged. Otherwise, update r and λ and go to step 2.

C.1.2 Transition

We solve for the transition using a *shooting algorithm.* We assume the economy returns to its steady state $\bar{T}$ periods after the shock. During the transition, we know the paths $\{G_t, \gamma_t\}_{t=1}^{\bar{T}}$. We also know that the value function at $t = \bar{T}$ is equal to its steady-state value $V_{\bar{T}}(a,x) = V(a,x)$ and that the measure at time $t = 1$ is equal to the steady-state value $\mu_1(a,x) = \mu(a,x)$. Then, given a guess for taxes and interest rate $\{\lambda_t, r_t\}_{t=1}^{\bar{T}}$ such that $(\lambda_{\bar{T}}, r_{\bar{T}}) = (\lambda, r)$, we solve the household problem backwards and iterate on the sequence $\{\lambda_t, r_t\}_{t=1}^{\bar{T}}$ until markets clear. More formally, we proceed as follows:

1. Guess a sequence for taxes and interest rates $\{\lambda_t, r_t\}_{t=1}^{\bar{T}}$, such that $(\lambda_{\bar{T}}, r_{\bar{T}}) = (\lambda, r)$. Compute the implied sequence of wages $\{w_t\}_{t=1}^{\bar{T}}$.

2. Solve for the household problem backwards. In particular, given the value function $V_{t+1}(a,x)$ in period $t+1$, solve for period t's value as

$$\begin{aligned}
V_t^E(a_i, x_j) &= \max_{a' \in \vec{a}} \left\{ \log\left(w_t x_j \bar{h} + (1+r_t)a_i - \mathcal{T}_t(w_t x_j \bar{h}, r_t a_i) + T - a'\right) - B\bar{h} + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_{t+1}(a', x_{j'}) \right\} \\
V_t^N(a_i, x_j) &= \max_{a' \in \vec{a}} \left\{ \log\left((1+r_t)a_i - \mathcal{T}_t(0, r_t a_i) + T - a'\right) + \beta \sum_{j'=1}^{N_x} \pi_x(x_{j'}, x_j) V_{t+1}(a', x_{j'}) \right\}
\end{aligned}$$

where $\mathcal{T}_t(w_t xh, r_t a) = \tau_k r_t a + w_t xh - \lambda_t (w_t xh)^{1-\gamma_t}$. Compute $V_t(a,x) = \max\left\{V_t^E(a,x), V_t^N(a,x)\right\}$ and move to $t-1$. As terminal condition, use $V_{\bar{T}}(a,x) = V(a,x)$.

3. Compute the time $t+1$ measure using the household's policies of step 2. In particular, given $\mu_t(a,x)$, compute $t+1$ measure as

$$\mu_{t+1}(a_{i'},x_{j'}) = \sum_{i=1}^{N_a}\sum_{j=1}^{N_x} \mathbb{I}\left\{a_{i'} = a'_t(a_i,x_j)\right\}\pi_x(x_{j'},x_j)\mu_t(a_i,x_j)$$

Use as initial condition $\mu_1(a,x) = \mu(a,x)$.

4. Compute $\hat{\lambda}_t$ so that, given household policies of step 2 and the measure of step 3, the government budget constraint holds every period. This is

$$\hat{\lambda}_t = \frac{\int \left(y_{\ell,t}(a,x) + \tau_k a\right) d\mu_t(a,x) - \left(G_t + r_t D + T\right)}{\int y_{\ell,t}(a,x)^{1-\gamma_t} d\mu_t(a,x)},$$

where $y_{\ell,t}(a,x) = w_t x h_t(a,x)$ is labor income. Similarly, compute the interest rate implied from firm's first order conditions $\hat{r}_t = -\delta + \alpha\left(K_t/L_t\right)^{1-\alpha}$, where $K_t = -D + \sum_{a,x} a\mu_t(a,x)$ and $L_t = \sum_{a,x} x h_t(a,x)\mu_t(a,x)$.

5. If $\left\|\hat{\lambda}_t - \lambda_t\right\| < \varepsilon^{\lambda}$ and $\|\hat{r}_t - r_t\| < \varepsilon^{r}$, the transition converged. Otherwise, update $\{\lambda_t, r_t\}_{t=1}^{\bar{T}}$ and go to step 2.

C.2 Elasticities Computations

Elasticities are computed as the response to a one-period unexpected 1%change in (i) the labor tax rate and (ii) the pre-tax wage.

Recall that in a steady state, a working household with productivity x receives a pre-tax labor income $y_\ell = wx\bar{h}$; thus, its tax rate is equal to $\tau(y_\ell) = 1 - \lambda y_\ell^{1-\gamma}$, and its after-tax labor income is $\left(1-\tau(y_\ell)\right)y_\ell$, that is, $\lambda y_\ell^{1-\gamma}$. To compute elasticities with respect to the tax, we assume that, while in a steady state, the tax rate increases unexpectedly by 1% for one period for all households $\tilde{\tau}(y_\ell) \equiv (1+1\%)\left(1-\lambda y_\ell^{1-\gamma}\right)$ so that the after-tax labor income becomes $\left(1-\tilde{\tau}(y_\ell)\right)y_\ell$. We then aggregate hours worked by income groups during the period of the tax change to report elasticities as the ratio of the percentage change in hours worked over by the percentage change in the tax rate.

To compute elasticities with respect to the pre-tax wage, we assume that for each household, the wage drops unexpectedly by 1% $\tilde{y}_\ell \equiv (1-1\%)wxh(a,x)$ so that the after-tax labor income becomes $\left(1-\tau(\tilde{y}_\ell)\right)\tilde{y}_\ell$. We then aggregate hours worked by income group to infer elasticities.

C.3 Effect of Tax Shocks – Zidar (2017)

The main finding in Zidar (2017) can be summarized as follows. An increase in taxes to the top 10%—such that fiscal revenues increase by 1% of GDP—has no effect on total employment nor on output. On the contrary, a tax shock of the same magnitude supported by the bottom 90% contracts employment by about 2% per year on average over a three-year period.

We conduct a few experiments to assess the quantitative effect of tax increases on different income groups in our model. We show that our model delivers results similar to those reported in Zidar (2017).

In particular, we proceed as follows. We assume that the government increases fiscal revenues by 1% of its steady-state level of spending and revenues then return to their steady-state level with a persistence of 0.5.[63] The increase is unexpected, but there is perfect foresight after it occurs. The exercise is performed in partial equilibrium, as the budget constraint of the government is not balanced every period—no change in spending nor debt.[64]

We analyze the effect of this fiscal shock on employment for two cases. In the first case, we assume that the fiscal shock is financed with more progressive taxes, so that only the top 10% of income earners face higher taxes. In a second case, we assume that the shock is financed with less progressive taxes, so that only the bottom 90% faces higher taxes. For this purpose, we use the modified tax function described in Section 4.1.[65] In each case, we report the model change in employment per year (average over four quarters) for the year of the shock and the two following years. We use the estimates in Zidar (2017) to infer (rescale) the empirical counterpart of a shock the size we analyze.

Detailed results for the benchmark exercise are reported in Table C.1. While more front-loaded than in the data, the average model response of employment over three years is comparable to its empirical counterpart. With higher persistence, the employment contraction for the bottom 90% is a bit larger in the model than in the data; with larger shocks, it is a bit smaller. Overall, our model predicts that employment contracts much more when the fiscal shock is shouldered by the bottom 90%—a finding qualitatively and quantitatively in line with Zidar (2017).

[63] As the model is nonlinear, the size of the shock matters for the results. The size of the fiscal shock is chosen to be in line with the quantitative exercises of Section 3.4. We also report results for a larger shock (1% of steady-state output). Similarly, as persistence matters, we also report results for $\rho = 0.9$.

[64] We also assume fixed factor prices (interest rate and wages).

[65] In the first case, we assume that γ increases to 0.11 and reverts to its steady-state level at the same rate as the fiscal shock. In the second case, γ decreases to 0.09, which corresponds to a tax shock supported by the bottom 90%. Following Zidar (2017), in each case we compute the fraction of households facing larger taxes during the first four quarters by using the steady-state policy functions—this is, behavioral responses are omitted.

		Benchmark				More persistent	Larger shock
		3-year avg.	Year 1	Year 2	Year 3	3-year avg.	3-year avg.
Top 10%	Model	0.00	-0.00	0.00	0.00	0.01	-0.46
	Data	0.00	*0.04*	*0.01*	*-0.03*	*0.01*	*-0.95*
Bottom 90%	Model	-0.23	-0.85	0.07	0.09	-0.67	-0.80
	Data	-0.26	*-0.02*	*-0.27*	*-0.50*	*-0.44*	*-1.33*

Table C.1: Employment Response to Tax Shocks

Notes: Employment response (%) to tax shocks: model responses versus empirical estimates of Zidar (2017). The benchmark case assumes a fiscal shock equal to 1% of steady-state government spending and a persistence of 0.5; the more persistent case uses a persistence of 0.9; the larger shock case uses a shock equal to 1% of steady-state output. The first column is reported in Table 4.

C.4 A Temporary Change in Tax Progressivity

Figure C.1 plots the model response to a temporary increase in tax progressivity. As in Section 3.4, we assume that, unexpectedly, γ increases to 0.11 and goes back to a steady state with persistence. However, government spending remains constant in this case and there is no need to increase fiscal revenues. Consequently, compared to the case with higher spending, the increase in taxes for top-income earners now induces a larger decline in taxes at the bottom. This results in a significantly larger output expansion.

D Divisible Labor Model

We assess the importance of the indivisible labor assumption by comparing our results to an alternative model with divisible labor. This model is equivalent to the one described in Section 3.1, except for the households' problem (5) which becomes

$$V(a,x) = \max_{c,h,a'} \left\{ \log(c) - B\frac{h^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} + \beta \mathbb{E}_{x'}\left[V(a',x')|x\right] \right\} \tag{D.1}$$

subject to

$$c + a' \leq wxh + (1+r)a - \mathcal{T}(wxh, ra) + T$$

$$h \in [0,1], \qquad a' \geq \underline{a}.$$

The parameter φ is equal to 0.4 following Chang and Kim (2007). The rest of the calibration is similar to the indivisible labor case, with one exception: as we cannot target an employment rate, we set the steady-state output to be equal to the one of the indivisible labor economy, so that the two economies are of comparable size.

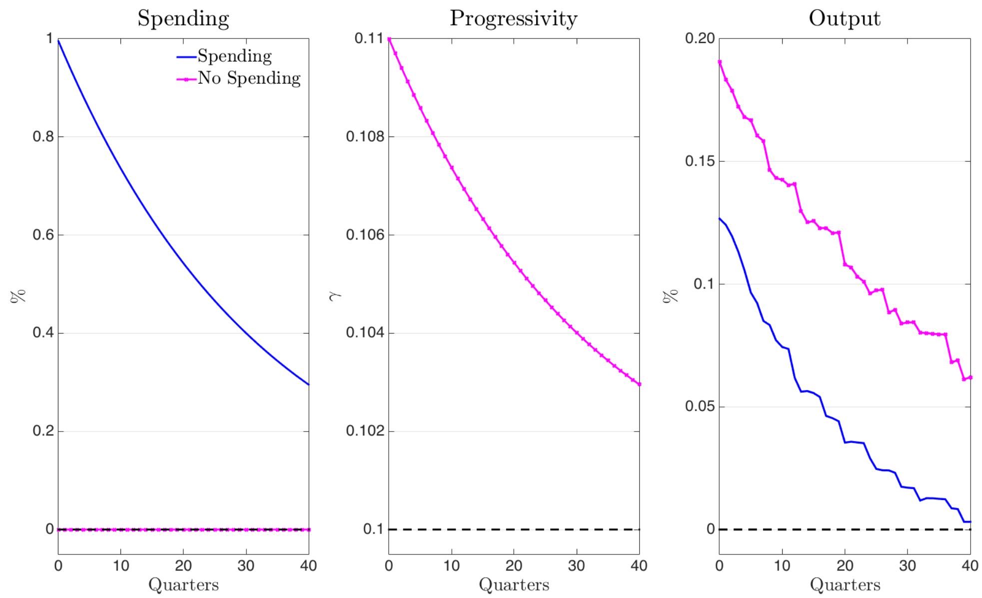

Figure C.1: Model Responses to an Increase in Tax Progressivity: No Spending Shock

Notes: The blue lines depict the model impulse response to a government spending shock financed with more progressive labor taxes, as in Figure 7. The magenta lines depict the model impulse response to a temporary increase in tax progressivity, but no change in government spending.

In this case, labor-supply elasticities with respect to the wage are flat across income groups: about 0.33 for the bottom 90% and 0.34 for the top 10%. We conduct the two experiments of Section 3.4 and report results in Figure D.1. In the *Divisible Labor* model, output contracts more when using more progressive taxes. As discussed in Section 4.6, we conclude that the indivisible labor assumption is needed to match our empirical findings.

E New Keynesian Model

In this Appendix, we describe the New Keynesian model. The features we incorporate are reasonably standard as discussed in Galí (2015) and, more recently, in Kaplan, Moll, and Violante (2018) and Hagedorn, Manovskii, and Mitman (2017) when adding heterogeneous households.

E.1 Environment

The economy is populated by a continuum of households, a government, a representative final good producer, and a continuum of intermediate goods producers under monopolistic competition. We start describing the economy's equilibrium in a steady state without aggregate uncertainty, and we later analyze transition

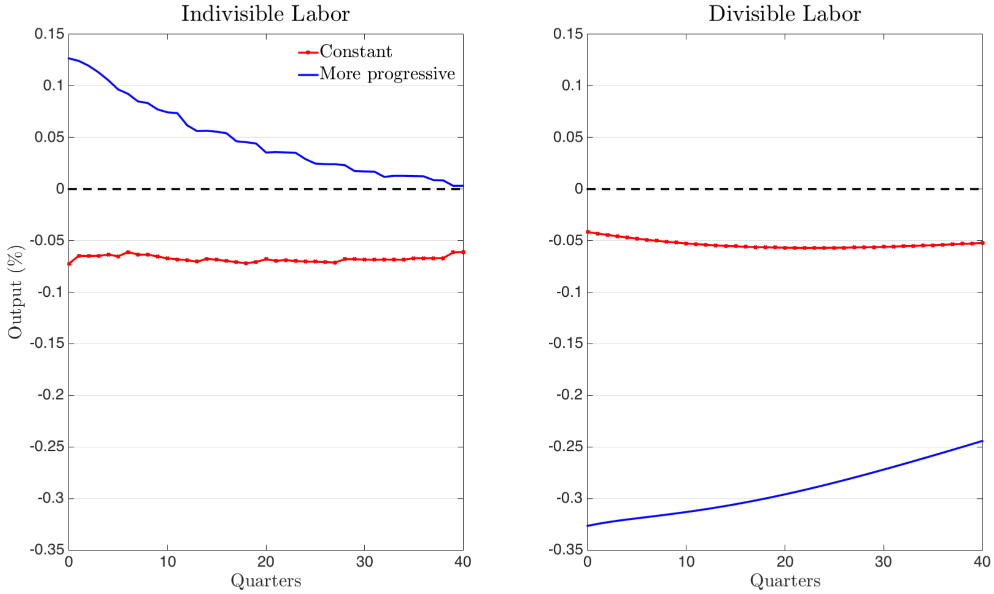

Figure D.1: Model Responses to a Spending Shock: Indivisible vs Divisible Labor

Notes: Model impulse response to a government spending shock financed with progressive labor taxes. Impulse functions are computed for two choices of progressivity $\{\gamma_t\}$: constant progressivity and higher progressivity. The left panel plots the indivisible labor model, as in Figure 7. The right panel plots the counterpart for the divisible labor model.

dynamics to a spending shock. As we explain next, we set up the environment so that the steady state is identical to the one in the benchmark model of Section 3.

Households Households make an indivisible labor-supply decision $h \in \{0, \bar{h}\}$ and receive a real wage w per unit of time worked. We assume that households can save/borrow in real assets, which pay a return r. Thus, households' problem is identical to the one in Section 3, and the value is given by (5).

Final Good Producers Final output Y_t is produced with a measure-one continuum of intermediate goods $\{y_{jt}\}_j$. The production function is given as $Y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}}$. The final good producer demands intermediate inputs to maximize profits as

$$\max_{\{y_{jt}\}_j} \left\{ P_t Y_t - \int_0^1 p_{jt} y_{jt} dj : \quad Y_t \leq \left(\int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \right\}$$

where P_t and p_{jt} stand for the (nominal) price of the final and the intermediate good, respectively. Optimal demand for intermediate goods then reads

$$y_{jt} = \left(\frac{p_{jt}}{P_t} \right)^{-\epsilon} Y_t \tag{E.1}$$

From (E.1) we have that the price level is given by $P_t = \left(\int_0^1 p_{jt}^{1-\epsilon} dj\right)^{\frac{1}{1-\epsilon}}$.

Intermediate Goods Producers There is a continuum of intermediate goods producers who sell their goods in a market under monopolistic competition. Intermediate goods producers choose the price at which they sell their goods but face a quadratic adjustment cost on price adjustments (Rotemberg, 1982). They demand capital and labor from households in frictionless markets, which are used as inputs for production.

Let $p_{j,t-1}$ be the price of firm j in period $t-1$. The cost of adjusting to price level p_{jt} is given by $\Theta(p_{jt}, p_{j,t-1}) = \frac{\theta_\Pi}{2}\left(\frac{p_{jt}}{p_{j,t-1}} - \bar{\Pi}\right)^2 Y_t$, where $\bar{\Pi}$ is the average inflation level in the economy. Let $J_t(p_{jt-1})$ be the value to a firm with price p_{jt-1} last period, then

$$\begin{aligned} J_t(p_{jt-1}) &= \max_{p_{jt}, y_{jt}, L, K, d_{jt}} \left\{ d_{jt} + \frac{1}{1+r_t} J_{t+1}(p_{jt}) \right\} \\ \text{s. to} & \\ d_{jt} &= \frac{p_{jt}}{P_t} y_{jt} - (1-\tau_{\mathcal{C}})\mathcal{C}_t(y_{jt}) - \Theta(p_{jt}, p_{jt-1}) - \Phi \\ y_{jt} &= \left(\frac{p_{jt}}{P_t}\right)^{-\varepsilon} Y_t \\ \mathcal{C}_t(y_{jt}) &= \min_{K,L} \left\{ w_t L + (r_t + \delta) K : L^\alpha K^{1-\alpha} = y_{jt} \right\} \\ \Theta(p_{jt}, p_{j,t-1}) &= \frac{\theta_\Pi}{2}\left(\frac{p_{jt}}{p_{jt-1}} - \bar{\Pi}\right)^2 Y_t \end{aligned} \tag{E.2}$$

where Φ is a fixed cost for production.

Note that the firm discounts future values at rate r_t. Thus, all agents in the model face the same real, risk-free interest rate, which a sensible assumption in an environment without aggregate uncertainty.[66] Furthermore, we assume a subsidy $\tau_{\mathcal{C}}$ on productions cost, as well as a fixed cost on production Φ. We set the subsidy $\tau_{\mathcal{C}}$ to eliminate mark-up distortions in a steady state. Similarly, we set the fixed cost Φ so that steady-state profits are zero. These two assumptions result in a steady state that is identical to the one Section 3.

Phillips Curve Because all firms are identical, we solve for a symmetric equilibrium where $p_{jt} = P_t$ and $y_{jt} = Y_t \; \forall j$. Introducing these equilibrium conditions in the optimal firm's price choice p_{jt} in problem (E.2), we obtain

$$\frac{\theta}{\varepsilon - 1}\left(\Pi_t - \bar{\Pi}\right)\Pi_t + 1 = (1-\tau_{\mathcal{C}})\mathcal{M}_t \frac{\varepsilon}{\varepsilon - 1} + \frac{\theta}{\varepsilon - 1}\frac{1}{1+r_t}\left(\Pi_{t+1} - \bar{\Pi}\right)\Pi_{t+1}\frac{Y_{t+1}}{Y_t} \tag{E.3}$$

[66] Similar assumptions are made in Kaplan, Moll, and Violante (2018) and Hagedorn, Manovskii, and Mitman (2017). See Gornemann, Kuester, and Nakajima (2016) for a more general approach in the case of aggregate uncertainty.

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is inflation, and $\mathcal{M}_t$ is marginal costs given as $\mathcal{M}_t = \frac{w_t^\alpha (r_t+\delta)^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha}}$.[67] Equation (E.3) is the (nonlinear version of the) New Keynesian Phillips curve. As we will describe this is an essential equation when solving for the model response to a spending shock.

Government We assume that government fully owns (the profits of) the intermediate goods producers. Then, the government's budget constraint now reads

$$G_t + (1 + r_t)D_t + T_t = D_t + \int \mathcal{T}(w_t xh, r_t a) d\mu_t(a, x) + \bar{d}_t \tag{E.4}$$

where $\bar{d}_t \equiv \int_0^1 (d_{jt} - \tau_c \mathcal{C}_t(y_{jt}))\, dj$ is the sum of all dividends and taxes paid by intermediate goods producers. Thus, the government budget constraint is identical to the one in the benchmark model, with the addition of firms' contributions to the government's income.

Monetary Authority We assume monetary policy is fully described by a Taylor rule, which responds to deviations of inflation from its target. In particular, the nominal interest rate i_t is given as

$$\ln\left(\frac{1 + i_t}{1 + \bar{i}}\right) = \phi_\Pi \ln\left(\frac{\Pi_t}{\bar{\Pi}}\right) \tag{E.5}$$

The link between the nominal and the real interest rate is given by the Fisher equation as

$$(1 + i_t) = (1 + r_{t+1})\,\Pi_{t+1} \tag{E.6}$$

This relation can be obtained if we assume that households can save/borrow in a nominal asset that is in zero net supply. We set $1 + \bar{i} = (1 + r_{ss})\bar{\Pi}$, where r_{ss} is the real interest rate in a steady state.

Equilibrium Definition We define a stationary equilibrium, which largely mirrors the definition in our benchmark model. Our definition already incorporates a symmetric equilibrium, where all intermediate goods producers follow the same policies.

Definition 2 *A* ***stationary recursive competitive equilibrium*** *for this economy is given by: a value function $V(a, x)$ and policies $\{h(a, x), c(a, x), a'(a, x)\}$ for the household; policies for the intermediate goods producers firms $\{L, K, p, y\}$; policies for the final good producer firm $\{y_j, Y\}$; government decisions $\{G, D, T, \mathcal{T}, \tau_c\}$; a monetary policy $\{i\}$; a measure μ over $\mathcal{B}$; and prices $\{r, w\}$ such that, given prices and government decisions: (i) the household's policies solve its problem and achieve value $V(a, x)$, (ii) policies for intermediate goods producers solve its dynamic problem, (iii) policies for final goods producers solve its static problem, (iv) the government's budget constraint is satisfied, (v) the monetary authority sets the interest rate according*

[67] Constant returns to scale in (E.2) yield a linear cost function $\mathcal{C}_t(y_{jt}) = \mathcal{M}_t y_{jt}$.

to the Taylor rule, (vi) the capital market clears $K + D = \int_{\mathcal{B}} a'(a,x)d\mu(a,x)$, (vii) the labor market clears $L = \int_{\mathcal{B}} xh(a,x)d\mu(a,x)$, (viii) the goods market clears $Y = \int_{\mathcal{B}} c(a,x)d\mu(a,x) + \delta K + G$, (ix) the measure μ is consistent with the household's policies $\mu(\mathcal{B}_0) = \int_S Q((a,x),\mathcal{B}_0)d\mu(a,x)$, where Q is a transition function between any two periods defined by $Q((a,x),\mathcal{B}_0) = \mathbb{I}\{a'(a,x) \in \mathcal{B}_0\} \sum_{x' \in \mathcal{B}_0} \pi_x(x',x)$ for any $\mathcal{B}_0 \in \mathcal{B}$.

E.2 Calibration

There are only three new parameters in the New Keynesian model—namely ϵ, θ_Π, and $\bar{\Pi}$. We set $\epsilon = 6$ following **?**, and $\theta_\Pi = 200$ such that the slope of the Philips curve is 0.03. The inflation target $\bar{\Pi}$ is set so that annual inflation equals 2%. Additionally, we set the cost subsidy to $\tau_{\mathcal{C}} = 1/\epsilon$ to eliminate the mark-up distortion, and Φ to eliminate steady-state profits for intermediate goods producers.

E.3 Transition Computations

We solve for the transition using a *shooting algorithm*. We assume the economy returns to its steady-state $\bar{T}$ periods after the shock. During the transition, we know the paths $\{G_t, \gamma_t\}_{t=1}^{\bar{T}}$. We also know that the value function at $t = \bar{T}$ is equal to its steady-state value $V_{\bar{T}}(a,x) = V(a,x)$ and that the measure at time $t = 1$ is equal to the steady-state value $\mu_1(a,x) = \mu(a,x)$. Then, given a guess for taxes, interest rates, and output, $\{\lambda_t, r_t, Y_t\}_{t=1}^{\bar{T}}$ such that $(\lambda_{\bar{T}}, r_{\bar{T}}, Y_{\bar{T}}) = (\lambda, r, Y)$, we solve the firms' problem to compute the path for wages and then the household problem by backwards induction; then, we iterate on the sequence $\{\lambda_t, r_t, Y_t\}_{t=1}^{\bar{T}}$ until markets clear. More formally, we proceed as follows:

1. Guess a sequence for output and interest rates $\{r_t, Y_t\}_{t=1}^{\bar{T}}$, such that $(r_{\bar{T}}, Y_{\bar{T}}) = (r, Y)$.
2. Compute the implied sequence of wages $\{w_t\}_{t=1}^{\bar{T}}$ and firms' contribution to the government's budget constraint $\{\bar{d}_t\}_{t=1}^{\bar{T}}$. That is use (E.5) and (E.6) to compute the path for inflation $\{\Pi_t\}_{t=1}^{\bar{T}}$, and (E.3) to compute $\{\mathcal{M}_t\}_{t=1}^{\bar{T}}$. Then, use the firms' problem (E.2) to obtain the two sequences of interest.
3. Guess a sequence for taxes $\{\lambda_t\}_{t=1}^{\bar{T}}$.
4. Solve for the household problem backwards using the path for taxes, interest rates, and wages; then solve the measure frontwards using the household policies just computed. This step is exactly as described in C.
5. Compute $\hat{\lambda}_t$ so that, given household policies, the measure of step 4, and the firms' contribution

$\{\bar{d}_t\}_{t=1}^{\bar{T}}$ of step 2, the government budget constraint holds every period. This is

$$\hat{\lambda}_t = \frac{\int (y_{\ell,t}(a,x) + \tau_k a)\, d\mu_t(a,x) - \left(G_t + r_t D + T - \bar{d}_t\right)}{\int y_{\ell,t}(a,x)^{1-\gamma_t} d\mu_t(a,x)},$$

where $y_{\ell,t}(a,x) = w_t x h_t(a,x)$ is labor income. If $\left\|\hat{\lambda}_t - \lambda_t\right\| < \varepsilon^{\lambda}$, move to the next step. Otherwise, update $\{\lambda_t\}_{t=1}^{\bar{T}}$ and go to step 4.

6. Compute the interest rate implied from firm's first order conditions $\hat{r}_t = -\delta + \alpha\,(K_t/L_t)^{1-\alpha}$, where $K_t = -D + \sum_{a,x} a\mu_t(a,x)$ and $L_t = \sum_{a,x} x h_t(a,x)\mu_t(a,x)$. Similarly, compute the implied output: $\hat{Y}_t = L_t^{\alpha} K_t^{1-\alpha}$. If $\left\|\hat{Y}_t - Y_t\right\| < \varepsilon^{Y}$ and $\|\hat{r}_t - r_t\| < \varepsilon^{r}$, the transition converged. Otherwise, update $\{r_t, Y_t\}_{t=1}^{\bar{T}}$ and go to step 2.

E.4 New Keynesian vs Neoclassical Multipliers

The New Keynesian elements appear to have little effects on multipliers in our model. Figure E.1 plots the cumulative output multiplier at two years for two paths for progressivity—*constant progressivity* and *larger increase in progressivity*—and for two model environments—the New Keynesian model described in Section 4 and its neoclassical counterpart. The quantitatively limited effect of the aggregate demand channel is likely due to the absence of sticky wages, combined with the relatively low marginal propensity to consume of the bottom 10% of the population, as documented in Table 5.[68]

[68]See Gali, Lopez-Salido, and Valles (2007) for the importance of sticky wages relative to sticky prices in a New Keynesian model with hand-to-mouth households.

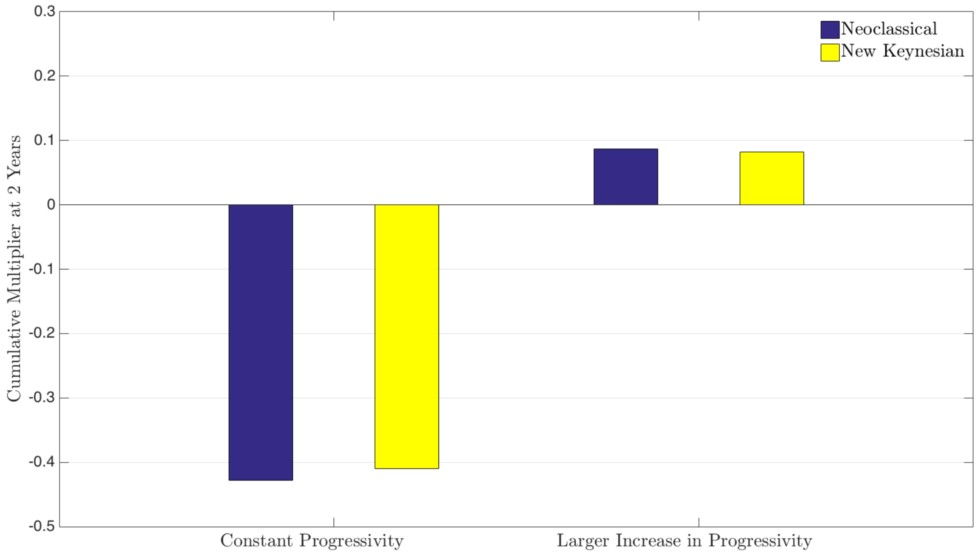

Figure E.1: Output Multipliers in Neoclassical and New Keynesian Frameworks

Notes: Cumulative output multipliers after two years to a spending shock financed with deficits ($\theta = 0.5$) and labor taxes. Multipliers are reported for two distributions of taxes—*constant progressivity* and *larger increase in progressivity*—and for two model environments—neoclassical and New Keynesian.

F U.S. Tax Progressivity: A Brief Historical Discussion

In this section, we discuss the main changes in the U.S. federal income tax code since its creation in 1913. We argue that our simple tax progressivity measure tracks remarkably well these changes. Importantly, we argue that virtually all changes to the tax code are the result of political events and emergencies, predominantly wars.

F.1 Income Taxes 1913 to 1932: Wilson and World War I, then Andrew Mellon and Hoover

The 16th Amendment adopted on February 3, 1913, set the legal benchmark for Congress to tax individual as well as corporate income.[69] The Revenue Act of 1913 determined personal income tax brackets for the first time, with a modest but progressive structure: the lowest marginal tax rate was 1% for income below $\$20,000$

[69] The amendment specifies the following: "The Congress shall have power to lay and collect taxes on incomes, from whatever source derived, without apportionment among the several States, and without regard to any census or enumeration." The text is particularly vague on its definition of income, which opened the possibility of several types of individual income. Previously, income taxes had temporarily been adopted during the Civil War, but a permanent legal framework had not been established. See Brownlee (2016).

and increased steadily, reaching a 7% marginal rate for income above $500,000. The tax was progressive because of its structure, as well as because only wealthier households actually paid at the moment.

The entry of the United States into World War I (WWI) greatly increased the need for tax revenues, which were largely obtained by expanding income taxes in a progressive fashion. The Revenue Acts of 1916, 1917 and 1918 drastically increased top marginal tax rates to a 60% to 77% range, 10 times more that they were three years before. Although tax rates also increased at the bottom, including a temporary 4% tax for income over $4,000 for years 1919 and 1920, the Revenue Act of 1918 included exemptions that dampened the effect for poor income tax payers. By the end of WWI, personal income taxes quickly became a substantial source of tax receipts, representing about 25% of total revenues. The fraction of households paying taxes also grew considerably: 7.3 million tax returns were filled in 1920, which amounts to roughly 30% of households (average household size of 4.3 and population of 106 million).

The decade that followed WWI observed a decreased and recovery of tax progressivity. The end of WWI reduced the need for tax revenues, and with Republicans assuming control of the presidency and a Congress majority, there was a partial reversal of tax progressivity. Under Secretary of Treasury Andrew Mellon, the Revenue Acts of 1921, 1924, 1926, and 1928 successively declined top marginal tax rates on individual income back to 25%, roughly one-third of what it was during war time.[70] Later, under the belief that budget deficits were crowding out the private sector, President Hoover promoted the Revenue Act of 1932, which increased top marginal tax rates to 56% to 63%, restoring rates to WWI levels.

Our simple tax progressivity measure γ in Figure 3 captures remarkably well the previously discussed increase, decline, and recovery of tax progressivity during the first 20 years of the federal income tax system. The early increases are in 1917 and 1918, where the revenue acts drastically increased taxes at the top. Similarly, the decline in the early 1920s corresponds to the Revenue Acts of 1924 and 1926, which brought back top marginal taxes to pre-WWI values. Finally, the increase in the early 1930s corresponds to Hoover's Revenue Act of 1932, which reinstated high top marginal tax rates.

F.2 Income Taxes 1933 to 1945: Roosevelt Regime

Tax progressivity increased significantly during the presidency of Franklin D. Roosevelt, initially as a continuation of President Hoover's last tax reform, and later because of the financial needs implied by World War II (WWII). The Revenue Acts of 1934, 1935, 1936, and 1938 were popularly known at the time as the "Soak the Rich" tax.[71] The acts of 1934 and 1936 kept top marginal tax rates fixed but increased tax rates

[70] However, corporate income tax rates did not decline as much.

[71] See Blakey and Blakey (1935) for instance.

at the top by lowering the thresholds above which higher marginal tax rates brackets started. Furthermore, top marginal tax rates increased from 63% to 79% with the Revenue Act of 1936, which pushed top marginal tax rates to the 66% to 79% range.

A more drastic increase in progressivity came with the U.S. participation in WWII. The Revenue Acts of 1940, 1941, 1942, 1943, and 1944 repeatedly increased top marginal tax rates, reaching a 90% to 94% range by 1945, which was slightly reduced with the Revenue Act of 1945. The Revenue Act of 1942 was perhaps the most important because it broadened the base of taxpayers while simultaneously increasing tax rates. Although taxes increased for all income levels, the reforms shifted the burden of new revenues significantly toward top-income households. Importantly, these changes established public expectations that any significant new taxes would be progressive.[72]

Again, our progressivity measure γ in Figure 3 captures well the changes previously discussed. In particular, the last half of the 1930s exhibits a mild increase in progressivity, which reflects the changes implemented in the Revenue Acts of 1934, 1936, and 1936. Although these changes were not trivial, they were small relative to the tax modifications introduced by the Revenue Acts of 1942 and 1945, a massive increase in progressivity that our γ measure clearly captures.

F.3 Income Taxes 1945 to 1980: The Era of Easy Finance

The tax regime that emerged from WWII proved more resilient than the one that emerged from WWI. There were only few legislative changes on tax code during the 25 years that followed WWII, especially when compared to the inter-wars period. The Korean War, and partially the Vietnam War, were the only events that induced significant—albeit temporary—changes in the tax code. Economic growth in a progressive tax system, as well as inflation in a non-indexed tax code, substantially grew tax revenues, which allowed governments to increase spending without substantial tax reforms. Furthermore, this period observed the first substantial deductions and credits from tax liabilities. Appropriately, this period is often referred to as the *era of easy finance*.

With the end of WWII, individual income taxes decreased with the Revenue Acts of 1945 and 1948 by a range of 5% to 13%, with a higher decline at the top. For instance, the Revenue Act of 1948 imposed a 77% upper-bound to effective tax rates, which effectively was a decrease in tax progressivity. However, these adjustments did not last long, and higher taxes were temporarily reinstated to finance the Korean War. The Revenue Acts of 1950 and 1951 removed the Tax Acts of 1945 and 1948, as well as temporary increased corporate taxes. By the end of the Korean War, some of these measure were reverted with the

[72] See discussion in Brownlee (2016), pg. 142.

Internal Revenue Code of 1954. As a result of all these changes, the effective tax rate on the top 1% was around 25% by the end of the 1950s, which was high relative to pre- WWII values but still lower than the peak observed during the wars (Brownlee, 2000).

The next significant change came a decade later with the Revenue Act of 1964 from the Kennedy-Johnson Administration, which was also known as the Tax Reduction Act. It essentially decreased marginal tax rates across the board, and particularly at the top, pushing down top marginal tax rates to a 60% to 70% range from the 80% to 91% previous range. Further tax cuts were probably prevented because of the increased participation of the U.S. in the Vietnam War.[73] In order to afford the war expenses, the Revenue and Expenditure Control Act of 1968 included a temporary 10% income tax surcharge on individuals and corporations for one year, as well as a decrease in domestic spending. By the end of the decade, President Nixon signed the Tax Reform Act of 1969, which implemented a minimum tax rate on top-income earners.

Although there were no legislative changes to tax rates for most of the 1970s, two important components affected personal income effective tax rates during the decade. First, because the tax system was progressive, (real) economic growth during these years effectively increased tax rates and thus tax revenues. At the same time, the high inflation of this decade, jointly with a non-indexed tax code, also resulted in higher tax rates and revenues. This "effortless" increase in tax revenues is the reason to label these years as *the era of easy finance*.[74]

Again, our progressivity measure γ in Figure 3 captures well the changes previously discussed. Progressivity decreased after WWII and temporarily recovered during the Korean War, reflecting the measures implemented during the Truman and Eisenhower presidencies respectively. Progressivity remained reasonably flat for almost a decade and decreased in 1964, reflecting the Tax Reduction Act of the Kennedy-Johnson Administration. Finally, progressivity increased in the 1970s because of growth and inflation.

F.4 Income Taxes 1980 to 1988: Reagan Tax Reform(s)

The latest significant changes to the U.S. tax code were implemented during the Reagan Administration. The first of these changes was the Economic Recovery Tax Act (ERTA) of 1981, which reduced tax rates across the board. Top marginal tax rates where drastically reduced from 70% to 50%, which implied a significant drop in the overall progressivity of the tax system. It also decreased taxes on capital gains and corporate profits. Additionally, tax brackets started to be indexed by inflation for the first time.

The tax reduction of the ERTA, added to the increased defense spending and the 1981 recession, induced

[73]U.S. involvement escalated following the 1964 Gulf of Tonkin incident, after which the President authorized to increase U.S. military presence. Regular U.S. combat units were deployed beginning in 1965.

[74]See discussion in Brownlee (2016), ch. 6.

large fiscal deficits. The Reagan Administration responded by increasing taxes other than personal income statutory tax rates. The Tax Equity and Fiscal Responsibility Act (TEFRA, 1982) and the Deficit Reduction Act (DEFRA, 1984) increased several taxes and reduced tax expenses, while the Social Security Amendments (SSA) of 1983 also increased payroll taxes. Overall, the TEFRA, DEFRA, and SSA are likely to have decreased progressivity even further.

After a year-long debate in Congress and public spaces alike, the Tax Reform Act (TRA) of 1986 was the second (and last) substantial change to federal income taxes during the Reagan Administration. It essentially implemented changes along three lines. First, it massively simplified the tax code, reducing it to only five brackets (a 11%/15%/28%/35%/38.5% structure), which was further simplified to three brackets in 1988 (a 15%/28%/33% structure). It also eliminated many tax deductions and credits looking for more "horizontal equity". Second, it significantly reduced tax rates, especially at the top. Top marginal tax rates decreased from 50% to 28%, while taxes at the bottom virtually did not change.[75] Third, it notably expanded the Earned Income Tax Credit (EITC), which effectively moved many poor income households into negative tax rates.

The overall effect of the Reagan "tax cuts" into progressivity is not entirely obvious. On the one hand, both the ERTA of 1981 and the TRA of 1986 significantly decreased taxes at the top without largely affecting taxes at the bottom. On the other hand, the increase in credits and reduction in deductions—the latter which typically benefited high-income taxpayers—may have compensated for some of the decrease in top marginal tax rates. As a rough approximation, overall progressivity decreased during the Reagan Administration but by less than what was implied by the change in statutory tax rates. Nevertheless, a clear group that undoubtedly benefited from Reagan tax reforms was the top 1%, whose effective tax rate declined from 28% to 23% during the Reagan Administrations.[76]

Our progressivity measure γ in Figure 3 clearly reflects the decrease in progressivity during the Reagan Administration. It also captures the quantitative importance of these changes, which were never fully reverted and only comparable in size to the ones implemented during the Roosevelt Administration.

F.5 Income Taxes 1988 to 2001: Bush and Clinton

"Read my lips, no new taxes", *George W. H. Bush*

"It's the economy, stupid", *Bill Clinton*

[75] There was a 33% bubble marginal tax rates for intermediate levels of income. However, because there was maximum effective tax rate of 28%, the marginal tax rate returned to 28% after a certain level of income.

[76] See Brownlee (2016), pg. 207, for a similar opinion. Also see Feenberg, Ferriere, Navarro, and Vardishvili (2018) for a more quantitative evaluation of the change of progressivity during the 1980s.

The decade that followed the Reagan Administration saw many changes to the tax code, although all of much smaller magnitudes. After fulfilling its promise of “no new taxes” (only) for a year, the Bush Administration passed the Omnibus Budget Reconciliation Act (OBRA) of 1990, which increased top marginal tax rates from 28% to 31%. It also substantially increased the EITC, which combined with the higher top marginal tax rates, implied a substantial increase of the progressivity of the tax system.

Two important tax reforms were implemented during the Clinton Administration, both simultaneously aimed to reduce fiscal deficits and increase tax progressivity. The first one was the OBRA of 1993, which added two higher tax brackets with marginal tax rates of 36% and 39.6%—relative the previous top marginal tax rate of 31%. It also expanded the EITC, which made the system further more progressive. The second reform during the Clinton Administration was the Tax Payer Relief Act of 1997, which did not change statutory tax rates but included new tax credits such as the child and education credits.

Overall, the tax reforms implemented during the administrations of George H.W. Bush and Bill Clinton implied an increase in the progressivity of the tax system not only because of its increase in top marginal tax rates, but mostly because of the expansion in tax credits. Our progressivity measure γ in Figure 3 captures this increase in progressivity and also show the small magnitude of these changes from a historical perspective.

F.6 Income Taxes 2001 to 2010: Bush and Obama

Three months after his inauguration, President George W. Bush fulfilled his campaign promise of cutting taxes with the Economic Growth and Tax Relief Reconciliation Act (EGTRRA) of 2001. The act implied a decrease in marginal tax rates across the board, with the largest declines at the top bracket (39.6% to 35%) and at the bottom with the creation of a new bracket that paid a 10% rate (relative to the 15% in the next bracket). While top-income earners probably benefited the most from the EGTRRA, the change in progressivity was small from a historical perspective. The Jobs and Growth Tax Relief Reconciliation Act (JGTRA) of 2003, which decreased capital taxes and accelerated the phase-in implementation of the EGTRRA, decreased progressivity further but also did not substantially altered tax code. Interestingly, the Iraq War, which began in 2003, did not cause any substantial tax reform, and it was the first time in American history that a large military expenditure was permanently financed by increasing deficits.

The Obama Administration passed two reforms—the Tax Act of the American Recovery and Reinvestment Act (ARRA) of 2009 and the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act (TRUIRJCA) of 2010—that increased tax credits (such as the EITC) and temporarily decreased payroll taxes but did not change the structure of statutory tax rates on personal income. Actually, the American

Taxpayer Relief Act (ATRA) of 2012 made permanent the Bush tax cuts of the JGTRA of 2003, which were initially meant to expire in 2013. These small changes are capture in our measure γ of Figure 3, which shows only minor fluctuations in these years.