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

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Abstract

Historically, large changes in U.S. government spending induced fiscal efforts that were not all alike, with some using more progressive taxes than others. We develop a heterogeneous-agent New Keynesian model to analyze how the distribution of taxes across households shapes spending multipliers. The model yields empirically realistic distributions in marginal propensities to consume and labor elasticities, which result in lower responsiveness to tax changes for higher-income earners. In turn, multipliers are larger when spending is financed with higher tax progressivity—that is, when the tax burden falls more heavily on higher-income earners. This result is historically material. We estimate that, on average, tax rates increased more for top-income than for bottom-income earners after a spending shock. Thus, the typical U.S. spending shock was financed with higher tax progressivity. We further exploit the historical variation in the financing of spending to estimate progressivity-dependent multipliers, which we find consistent with the model.

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 effects of recessions—two recent examples being the European Economic Recovery Plan, proposed by the European Commission in 2008, and its U.S. 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; Ramey, 2011). Other studies, often relying on a structural VAR approach, estimate larger multipliers (Blanchard and Perotti, 2002).[1] This disparity in empirical findings has its counterpart in theoretical work. Standard versions of the neoclassical and New Keynesian models generate small 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 even smaller, or negative, when financed with distortionary taxes, as first shown in the seminal work by Baxter and King (1993).

In this debate, though—including in recent developments in heterogeneous-agent models—an important dimension has been neglected: the distribution, across households, of the fiscal burden consequent to the stimulus. This oversight is somewhat surprising in light of U.S. history. To finance large changes in spending, the United States has typically implemented substantial tax reforms, which have not been alike. In some cases—like World War I (WWI), World War II (WWII), and the Korean War—the fiscal burden was tilted toward higher-income earners, while in other cases—like the Vietnam War and the Reagan defense buildup—the burden was more evenly distributed. Furthermore, recent theoretical work, tracing back to Heathcote (2005), asserts that the cross-sectional dimension of tax policies has significant aggregate implications. Thus, how spending is financed across households is relevant both from a historical and a theoretical perspective.

In this paper, we develop a Heterogeneous Agents New Keynesian (HANK) model to analyze how the distribution of taxes shapes spending multipliers. The key feature in the model is a rich cross-sectional heterogeneity in marginal propensities to consume and labor supply elasticities, which, in line with evidence,

[1] For studies using military spending, see Barro and Redlick (2011) and Ramey and Zubairy (2018), among others. For studies using variation of a VAR approach, see Perotti (2008), Mountford and Uhlig (2009), and references therein.

[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 households exhibit high propensities to consume (Bilbiie, 2019; Auclert, Rognlie, and Straub, 2018; Hagedorn, Manovskii, and Mitman, 2019).

results in lower responsiveness to tax changes for higher-income earners. In turn, implied multipliers are larger when spending is financed with an increase in tax progressivity—that is, spending is more expansionary when the tax burden falls more heavily on higher-income earners. This result is material from a historical perspective. We estimate that, on average, tax rates increased more for top-income than for bottom-income earners after a spending shock. As such, the typical spending shock in the United States was financed with an increase in tax progressivity. Finally, we further exploit the historical variation in the financing of spending in the United States to estimate progressivity-dependent multipliers, which we find consistent with the model.

We add two components to an off-the-shelf model of heterogeneous households: an extensive labor supply decision (Chang and Kim, 2007) and heterogeneous discount factors (Carroll, Slacalek, Tokuoka, and White, 2017). In this environment, higher-income earners have exceptional labor market prospects and thus face a larger opportunity cost of exiting the labor market; consequently, they exhibit lower labor participation elasticities (*lpe*). Similarly, high discount factor households accumulate more wealth, are often further from their borrowing limits, and have lower marginal propensities to consume (*mpc*). This heterogeneity in *lpe* and *mpc* explains how the distribution of taxes shapes spending multipliers. A government will raise taxes to finance an increase in spending, and higher taxes crowd out the private sector, which limits how expansionary spending can be. Concentrating the higher taxes on the less responsive households reduces the crowding-out and, in turn, increases multipliers.

We derive a set of analytical expressions from the model that formalizes this relation between a distribution of taxes and the crowding-out on labor and consumption. We show that the labor response to a tax change depends on the average *lpe* as well as on the covariance between tax changes and households' *lpe*s. We refer to this compound response as an *aggregate effective lpe*: The effective labor crowd-out is smaller when taxes are raised on low-*lpe* households. Similarly, the consumption response to a tax change depends on the average *mpc* and on the covariance between tax changes and households' *mpc*. Additionally, the *aggregate effective lpe* induced by taxes also shapes the consumption crowd-out, as the effective labor response affects income and thus consumption. We perform a back-of-the-envelope calculation using these analytical expression and show that the distribution of taxes can have large effects on labor and consumption responses.

We then confirm this finding in our full model: The distribution of taxes has quantitatively large effects on spending multipliers. In the model, multipliers rise from 0.05 when evenly financed across households to 0.33 when financed by the top 20% of workers only. This result is obtained under empirically consistent paths for fiscal deficits and standard monetary policy assumptions but is also robust to alternative policy specifications.[3] Importantly, in line with our analytical findings, heterogeneity in both *mpc* and in *lpe* is crucial in accounting for the difference in multipliers across taxation schemes. Shifting taxes from high-*mpc* to low-*mpc* households boosts aggregate demand and thus increases multipliers (Bilbiie, 2019). Heterogeneity in *lpe* is also quantitatively important, as concentrating taxes on low-*lpe* workers reduces the crowding-out on labor supply, and eventually on consumption. As the model-implied distributions of *mpc* and *lpe* are key to this result, we carefully discuss their empirical relevance.

We then compare the model with data. We use local projections (Jorda, 2005) to estimate the effects of government spending, starting with the creation of income taxation in 1913. A long time series 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 20th century. We estimate the average response of tax rates after a spending shock: They increase for top-income earners but remain essentially constant for bottom-income earners. As such, the average shock in the United States resembles the case when spending is financed with an increase in tax progressivity in the model. Through the lens of the model, this difference in financing has large implications on multipliers, which should be kept in mind when interpreting the effects of government spending.

Finally, we exploit the historical variation in the financing of spending in the United States to estimate progressivity-dependent multipliers. We separate spending shocks financed with higher tax progressivity from those financed more evenly across households using a novel measure of tax progressivity we construct starting in 1913. Following the methodology in Ramey and Zubairy (2018) and Auerbach and Gorodnichenko (2012a), we estimate multipliers that are considerably smaller when financed more evenly across households, at about zero after three years. We see this finding as further support for the mechanism in our paper.

Our work relates to a recent line of research that has stressed the importance of households' heterogeneity in Keynesian environments for the aggregate effects of fiscal and monetary policies (Kaplan, Moll, and Violante, 2018; Gornemann, Kuester, and Nakajima, 2016).[4] The typical key element in these models is the distribution of *mpc*. For instance, Bilbiie (2019) uses a two-agent New Keynesian model to analytically show how spending multipliers depend on the distribution of *mpc* whereas Hagedorn, Manovskii, and Mitman (2019) and Auclert, Rognlie, and Straub (2018) analyze a similar mechanism in a fully fledged quantitative HANK model.

We add to this literature in two dimensions. First, in addition to heterogeneity in *mpc*, we analyze heterogeneity in *lpe*, a margin that is empirically relevant and has been explored in the public finance

[3] As we show in Section 5.4, we obtain larger multipliers when using an empirically relevant/more accommodative monetary policy, leaving the effect of the distribution of taxes on multipliers roughly unchanged.

[4] See also Auclert (2017), Bayer, Lütticke, Pham-Dao, and Tjaden (2019), Kaplan and Violante (2014), McKay and Reis (2016), Debortoli and Gali (2017), and Brinca, Holter, Krusell, and Malafry (2016), among others.

literature (Kleven and Kreiner, 2006). Interestingly, because it affects the labor response to tax changes, we show that *lpe* heterogeneity also affects the aggregate consumption response. Second, and more importantly, we analyze how the fiscal burden subsequent to the stimulus is distributed across households. Previous work considered how deficit financing affects spending multipliers, focusing on the inter-temporal allocation of taxes (Gali, Lopez-Salido, and Valles, 2007). We argue that the intra-temporal distribution of taxes is sensible from a theoretical and historical perspective and has substantial consequences for multipliers. Yet, tax distribution considerations have largely been absent in previous work on spending multipliers—notably except for Bilbiie and Straub (2004) and Monacelli and Perotti (2011).

We also add to the literature using historical events to inform macroeconomic models.[5] We briefly review the history of tax reforms in the United States since 1913, discuss how these reforms responded to major events such as wars, and analyze how these events shaped tax progressivity overall. Additionally, we construct a simple measure of tax progressivity since 1913 that accurately reflects the tax reforms we discuss. We believe this measure can be useful for quantitative work using historical events.

The rest of the paper is organized as follows. Section 2 briefly discusses the history of government spending and taxes in the United States. Section 3 introduces the model. Section 4 derives the analytical discussion, and Section 5 presents the quantitative results. Section 6 reports the empirical analysis. Section 7 concludes.

2 A Brief Review of the U.S. History of Spending and Taxes

Most large changes in spending in the United States were associated with military events and were followed by tax reforms with substantial implications on the distribution of taxes across households. We briefly review the main historical reforms in the U.S. federal income tax code following these events. A more detailed discussion can be found in Appendix D.[6]

The 16th Amendment to the U.S. 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 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

[5]Recent work in the same vein includes McGrattan and Ohanian (2010), Romer and Romer (2010), and Hall and Sargent (2019).

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

three years earlier.[7] The increase in progressivity was only temporary, and the decade that followed WWI—with Andrew Mellon as Secretary of the Treasury—observed a persistent decline in progressivity.

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.[8] However, a more drastic increase in progressivity came with the U.S. participation in WWII. While debt surged, a sequence of tax reforms increased top marginal tax rates, to reach a historical maximum range of 90% to 94% with the RA of 1945. Progressivity again decreased after WWII, although higher top marginal tax rates were temporarily reinstated to finance the Korean War.[9]

To afford the expenses of the Vietnam War, the Revenue and Expenditure Control Act of 1968 included a temporary 10% income tax surcharge on all individuals and corporations as well as a decrease in domestic spending. The next large military expense was the defense buildup during the Reagan Administration, which coincided with a decline in tax progressivity: The Economic Recovery Tax Act of 1981 and the Tax Reform Act of 1986 lowered top marginal tax rates from 70% to 28%, and while other taxes and debt increased during these years, overall progressivity declined.[10] All in all, the fiscal burden of both the Vietnam War and the Reagan defense buildup was more evenly distributed across households than in previous military events.[11]

When estimating the effects of government spending, identification heavily relies on large military events. These events were followed by tax reforms that, as discussed, were not all alike. This historical variation motivates the focus on how the distribution of taxes shapes spending multipliers. The model we present in the next section is tailored to this question.

[7] 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: In 1920, 7.3 million tax returns were filled, which amounts to roughly 30% of households (average household size of 4.3 and population of 106 million). Numbers come from Statistics of Income (SOI) tables; see Appendix B.3 for more details.

[8] See Blakey and Blakey (1935).

[9] The RA of 1951 aimed to finance 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 ended.

[10] 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 (1982) and the Deficit Reduction Act (1984). These reforms did not alter statutory rates and are unlikely to have reverted the overall decline in progressivity from the 1981 and 1986 tax reforms. See Appendix D for more details.

[11] Most of the spending shocks after the end of the Cold War were of smaller magnitude. We delegate a more systematic discussion of shocks and taxes in Appendix D.

3 Model

We develop a HANK model to study the effects of government spending. We introduce heterogeneity in discount factors and an extensive labor supply decision, which result in cross-sectional distributions of *lpe* and *mpc* in line with evidence. This rich modeling of households' labor and consumption decisions is key to understanding how multipliers depend on the distribution of taxes. The rest of the model is kept as close as possible to an off-the-shelf New Keynesian model (Galí, 2015).

We start by describing the model environment and its calibration and then discuss the model-implied distribution of *mpc* and *lpe*. Because these statistics are key to the model, we carefully discuss how they compare with previous empirical work. Section 4 derives analytical expressions showing how the distribution of taxes shapes the effects of government spending, and Section 5 quantifies the effects of government spending in this environment.

3.1 Environment

Time is discrete and indexed by $t = 0, 1, 2, \ldots$. The economy is populated by a continuum of heterogeneous households who deposit their savings with financial intermediaries and supply hours worked to labor unions. Labor unions combine households' hours into labor services, which they sell to a labor packer. Unions are under monopolistic competition and face a cost of adjusting wages as in Rotemberg (1982). Intermediate-good producers rent capital from financial intermediaries and labor from labor packers to produce output, which they sell to a final-good producer. Intermediate-good producers face the same type of pricing friction as unions. Finally, financial intermediaries invest households' savings into physical capital and government debt. We consider deterministic transition dynamics and use time t to denote the aggregate state of the economy.

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 $\pi_x(x, x')$. Households have differences in their discount factor β, which evolves stochastically following a Markov chain $\pi_\beta(\beta, \beta')$ (Krusell and Smith, 1998). Labor productivity and discount factor shocks are uninsurable: Households can only trade a one-period risk-free bond to self-insure, subject to a nonborrowing limit.

Let $V_t(a, x, \beta)$ be the maximal attainable value in period t to a household with assets a, idiosyncratic productivity x, and discount factor β:

$$
\begin{aligned}
V_t(a,x,\beta) &= \max_{c,h,a'} \left\{\log(c) - Bh + \beta\mathbb{E}\left[V_{t+1}(a',x',\beta')|x,\beta\right]\right\} \qquad (1)\\
&\text{subject to}\\
c + a' &\leq w_t^h xh + (1+r_t)a - \mathcal{T}_t(w_t^h xh, r_t a) + T_t + d_t^h(x)\\
h &\in \left\{0,\bar{h}\right\}, \qquad a' \geq 0
\end{aligned}
$$

where c and h denote consumption and hours worked, w_t^h denotes wages perceived by households, and r_t denote the real return on households' savings. Households face a distortionary tax $\mathcal{T}_t(w_t^h xh, r_t a)$—which depends on labor income $w_t^h xh$ and capital earnings $r_t a$—and receive a lump-sum transfer T_t. Finally, $d_t^h(x)$ represents the dividend payments received from firms in the economy, which we discuss in more detail below.

As commonly done in discrete choice models, we add a preference shock ϵ_h for each possible level of working hours: $h \in \left\{0,\bar{h}\right\}$ hours. The preference shock follows a Gumbel distribution with variance ϱ.[12] Let $\mathbb{h}_t^h(a,x,\beta)$ be the probability of working h hours at time t, and let $c_t^h(a,x,\beta)$ and $a_t^{h\prime}(a,x,\beta)$ denote a household's optimal policies conditional on working h hours. Finally, denote $h_t(a,x,\beta) = \sum_h h\mathbb{h}_t^h(a,x,\beta)$, $c_t(a,x,\beta) = \sum_h c_t^h(a,x,\beta)\mathbb{h}_t^h(a,x,\beta)$, and $a_t'(a,x,\beta) = \sum_h a_t^{h\prime}(a,x,\beta)\mathbb{h}_t^h(a,x,\beta)$ to the expected policies, and let $\mu_t(a,x,\beta)$ be the measure of households with state (a,x,β).

Final-Good Producers.—A competitive representative final-good producer combines a continuum of intermediate goods—indexed by $j \in [0,1]$—to produce the final good Y_t. Production technology is $Y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$, where $\epsilon > 0$ is the elasticity of substitution across intermediate inputs. Profit maximization for the final-good producers reads

$$
\max_{\{y_{jt}\}_j} \left\{P_t Y_t - \int_0^1 P_{jt} y_{jt} dj : \quad Y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}\right\} \qquad (2)
$$

where P_t and P_{jt} stand for the nominal price of the final good and the intermediate good, respectively. Optimal demand reads

$$
y_{jt}^d = \left(\frac{P_{jt}}{P_t}\right)^{-\epsilon} Y_t. \qquad (3)
$$

Intermediate-Good Producers.—The intermediate good is produced by combining effective labor n_{jt} and

[12] Rust (1997) initially proposed using a Gumbel preference shock in dynamic discrete-choice models, and Artuç, Chaudhuri, and McLaren (2010), among others, used it more recently. See Appendix A.1 for a more detailed model description.

capital k_{jt} as $y_{jt} = k_{jt}^{1-\alpha} n_{jt}^{\alpha}$. Intermediate-good producers set prices subject to a quadratic price adjustment cost. Let $J_t(P_{jt-1})$ be the maximal attainable value at time t to an intermediate-good producer that posted prices P_{jt-1} last period:

$$J_t(P_{jt-1}) = \max_{P_{jt}, y_{jt}, n_{jt}, k_{jt}} \left\{ d_{jt} + \frac{1}{1 + r_{t+1}} J_{t+1}\left(P_{jt}\right) \right\} \tag{4}$$

subject to

$$\begin{aligned} d_{jt} &= \frac{P_{jt}}{P_t} y_{jt} - w_t n_{jt} - \left(r_t^k + \delta q_t^k\right) k_{jt} - \Theta_t(P_{jt}, P_{jt-1}) - \Phi \\ y_{jt} &= \left(\frac{P_{jt}}{P_t}\right)^{-\epsilon} Y_t \\ y_{jt} &= k_{jt}^{1-\alpha} n_{jt}^{\alpha} \\ \Theta_t(P_{jt}, P_{jt-1}) &= \frac{\Theta}{2} \left(\frac{P_{jt}}{P_{jt-1}} - \bar{\Pi}\right)^2 Y_t \end{aligned}$$

where w_t is the wage paid to labor packers, r_t^k is the rental rate of capital, q_t^k is the price of capital, and Φ is a fixed operating cost. The cost of adjusting prices is $\Theta_t(\cdot)$, where $\bar{\Pi}$ is the inflation target of the monetary authority. All firms discount flows at the real rate r_t, which is justified by an arbitrage argument in this economy without aggregate uncertainty.

Intermediate-goods producers are all identical, so we focus on a symmetric equilibrium with $P_{jt} = P_t$ $\forall j, t$. Optimal decisions yield the usual New Keynesian Phillips curve:

$$\left(\Pi_t - \bar{\Pi}\right) \Pi_t + \frac{\epsilon - 1}{\Theta} = \frac{\epsilon}{\Theta} \mathcal{M}_t + \frac{1}{1 + r_{t+1}} \left(\Pi_{t+1} - \bar{\Pi}\right) \Pi_{t+1} \frac{Y_{t+1}}{Y_t} \tag{5}$$

where $\mathcal{M}_t = \left(\frac{w_t}{\alpha}\right)^{\alpha} \left(\frac{r_t^k + \delta q_t^k}{1-\alpha}\right)^{1-\alpha}$ is the marginal cost of production.

Labor Market.—We model labor market frictions by extending Erceg, Henderson, and Levin (2000) to an environment with heterogeneous households. The labor market structure mirrors the two-layers structure of the goods market, with a labor packer and a labor union, akin to the final-good producer and the intermediate-good producer. We accommodate households heterogeneity by introducing a market between unions and households, as we discuss next.

The labor packer produces a final labor bundle by combining the differentiated labor n_{kt} from each union $k \in [0, 1]$. The labor bundle is produced as

$$N_t = \left(\int_0^1 n_{kt}^{\frac{\epsilon_w - 1}{\epsilon_w}}\right)^{\frac{\epsilon_w}{\epsilon_w - 1}},$$

and optimal labor demand for each variety reads

$$n_{kt}^d = \left(\frac{W_{kt}}{W_t}\right)^{-\epsilon_w} N_t \tag{6}$$

where W_{kt} is the nominal wage paid to union k and $W_t = w_t P_t$ is the wage paid by intermediate-goods producers in nominal terms.

Labor unions are under monopolistic competition and set wages subject to a quadratic adjustment cost. They hire households labor in a competitive market at wage rate w_t^h and use it to produce their union-specific labor with a one-to-one technology. Let $J_t^w(W_{kt-1})$ be the maximal attainable value at time t to a labor union that posted wages W_{kt-1} last period:

$$J_t^w(W_{kt-1}) = \max_{W_{kt}, n_{kt}} \left\{ d_{kt}^w + \frac{1}{1+r_{t+1}} J_{t+1}^w\left(W_{jt}\right) \right\} \tag{7}$$

subject to

$$d_{kt}^w = \left(\frac{W_{kt}}{P_t} - w_t^h\right) n_{kt} - \Theta_t^w(W_{kt}, W_{kt-1}) - \Phi^w$$

$$n_{kt} = \left(\frac{W_{kt}}{W_t}\right)^{-\epsilon_w} N_t$$

$$\Theta_t^w(W_{kt}, W_{kt-1}) = \frac{\Theta^w}{2}\left(\frac{W_{kt}}{W_{kt-1}} - \bar{\Pi}\right)^2 N_t$$

where n_{kt} is the total efficient hours demanded from households.

As with intermediate-goods producers, we focus on a symmetric equilibrium where all unions post the same wages $W_{kt} = W_t \; \forall k, t$. In this case, the unions' optimal decisions yield the wage Phillips curve:

$$\left(\Pi_t^w - \bar{\Pi}\right) \Pi_t^w + \frac{\epsilon^w - 1}{\Theta^w} w_t = \frac{\epsilon^w}{\Theta^w} w_t^h + \frac{1}{1+r_{t+1}} \left(\Pi_{t+1}^w - \bar{\Pi}\right) \Pi_{t+1}^w \frac{N_{t+1}}{N_t} \tag{8}$$

where $\Pi_t^w = W_t/W_{t-1}$ is wage inflation. Note that marginal costs are given by households' wages w_t^h, and marginal revenues are given by wages charged by unions to labor packers w_t.

In absence of households' heterogeneity, most models with wage stickiness assume that labor unions maximize the utility of the representative agent.[13] With household heterogeneity, there is no unique nor obvious way to introduce wage stickiness. We overcome this difficulty by introducing a frictionless market between unions and households.

An advantage of our set-up is that labor market outcomes reflect, both, firms' labor demand as well

[13] This is the assumption in Erceg, Henderson, and Levin (2000) and is followed by most of the DSGE literature—see, for instance, Smets and Wouters (2007) and Del Negro, Giannoni, and Schorfheide (2015).

as the *distribution* of individual labor supply decisions.[14] Indeed, as unions can only adjust the wage they charge w_t at a cost, households' wage w_t^h must be high enough so that labor supply meets the demand by labor packers/intermediate-good producers. At the same time, as long as wages are not fully rigid, there is also an active labor supply margin where unions adjust wages to maximize profits. Thus, our modeling assumption allows to keep, both, demand-driven labor market dynamics jointly with a labor supply that aggregates the distribution of individual labor supply elasticities, a key object in our analysis. Note that, in absence of heterogeneity, our formulation retrieves the usual wage Phillips curve found in the dynamic stochastic general equilibrium (DSGE) literature.[15]

Capital Producer.—A competitive representative capital-good producer transforms the final consumption good into capital goods subject to a quadratic-adjustment cost function. Producing Δ_t^k new units of capital requires a total investment of $I_t = \Delta_t^k + \frac{\phi^k}{2}\left(\frac{\Delta_t^k}{K_t} - \delta\right)^2 K_t$, where K_t is the total amount of capital in the economy. Profit maximization for the capital producer reads

$$d_t^k = \max_{\Delta_t^k} \left\{ q_t^k \Delta_t^k - \left[\Delta_t^k + \frac{\phi^k}{2}\left(\frac{\Delta_t^k}{K_t} - \delta\right)^2 K_t \right] \right\}. \tag{9}$$

The capital producer optimal decision implies a relation between the price of capital and investment as

$$q_t^k = 1 + \phi^k \left(\frac{\Delta_t^k}{K_t} - \delta\right). \tag{10}$$

Financial Intermediaries.—Financial intermediaries raise deposits from households and invest in the two financial assets in this economy: physical capital and government debt. Let $F_t(A_t^F, K_t^F, D_t^F)$ be the maximal attainable value at time t to a financial intermediary who started this period with households' deposits A_t^F, capital holdings K_t^F, and government debt holdings D_t^F:

$$F_t(A_t^F, K_t^F, D_t^F) = \max_{A_{t+1}^F, K_{t+1}^F, D_{t+1}^F} \left\{ d_t^F + \frac{1}{1+r_{t+1}} F_{t+1}(A_{t+1}^F, K_{t+1}^F, D_{t+1}^F) \right\} \tag{11}$$

subject to

$$d_t^F + q_t^k K_{t+1}^F + D_{t+1}^F + (1+r_t)A_t^F = A_{t+1}^F + \left(q_t^k + r_t^k\right) K_t^F + (1+r_t^g) D_t^F$$

[14] An alternative is to assume that the union chooses a unique level of hours for all households to maximize their average utility. See, for instance, Auclert, Rognlie, and Straub (2018) and Hagedorn, Manovskii, and Mitman (2019).

[15] A linear approximation of equation (8) reads $\hat{\pi}_t^w = \frac{1}{1+r}\hat{\pi}_{t+1}^w - \lambda_w \hat{\mu}_t^w$, where $\hat{\mu}_t^w = \hat{w}_t - \hat{w}_t^h$, and w_t^h would equalize the marginal rate of substitution between labor and consumption in a representative household model. This expression is exactly the wage Philips curve in equation (T1.5) in Erceg, Henderson, and Levin (2000). Note as well that, with linear technology in labor, the wage and price rigidity formulations would be analogous.

where r_t^g is the return on government debt. The financial intermediary's optimal decisions yields non-arbitrage conditions among assets' returns

$$1 + r_t = \frac{q_t^k + r_t^k}{q_{t-1}^k} \tag{12}$$

$$r_t = r_t^g \tag{13}$$

Thus, a financial intermediary is indifferent among any asset holdings—K_{t+1}^F and D_{t+1}^F—as long as equations (12)-(13) hold. Furthermore, as there is no friction on the financing side, the liability structure of the financial intermediary is not determined. That is, the value of a financial intermediary $F_t(\cdot)$ is independent of whether an investment is financed with deposits ($A_{t+1}^F > 0$), with equity issuance ($d_t^F < 0$), or with any combination in between.[16] In turn, we assume that financial intermediaries finance their investments entirely with households deposits: $A_{t+1}^F = q_t^k K_{t+1}^F + D_{t+1}^F$. With perfect foresight, this assumption implies $d_t^F = 0$, which mitigates the effects of dividends distribution in the economy.[17]

Fiscal Authority.—The government's budget constraint is given by

$$G_t + (1 + r_t^g) D_t + T_t = D_{t+1} + \int \mathcal{T}_t(w_t x h, r_t a) d\mu_t(a, x, \beta) \tag{14}$$

where D_t is the government's debt. As we discuss in detail below, the tax function $\mathcal{T}_t(\cdot)$ will incorporate a progressive component on labor income.

Monetary Authority.—Monetary policy is fully described by a Taylor rule that sets the short-term nominal interest rate as

$$\ln\left(\frac{1 + i_{t+1}}{1 + \bar{i}}\right) = \phi_\Pi \ln\left(\frac{\Pi_t}{\bar{\Pi}}\right), \tag{15}$$

where $\phi_\Pi > 1$ and $\bar{i}$ is the steady state of the nominal interest rate. Given inflation and the nominal interest rate, the real return r_t is determined by the Fisher equation as

$$1 + r_t = \frac{1 + i_t}{\Pi_t} \tag{16}$$

[16] This property is a Modigliani-Miller type of result: The marginal discounted cost of a deposit equals one, same as the cost of issuing a negative unit of dividends. Thus, the liability structure is not determined. See Appendix A.1 for a more detailed discussion of the financial intermediaries problem.

[17] This intermediaries' financing assumption implies the same equilibrium sequences as an alternative economy, where households make the portfolio decision directly but the borrowing limit applies to the value of the portfolio and not to each asset separately.

We assume that the returns on government bonds and household deposits are determined in nominal terms. Expressing returns in real or nominal terms is irrelevant in an economy with perfect foresight, but real returns do adjust upon arrival of an unexpected shock.

3.2 Equilibrium

We discuss market clearing for labor, assets, and goods markets.

The labor market between households and unions must clear, as well as between labor packers and intermediate-good producers—that is,

$$L_t = \int_0^1 n_{kt} dk, \text{ and } N_t = \int_0^1 n_{jt} dj, \tag{17}$$

where $L_t \equiv \int x h_t(a, x, \beta) d\mu_t(a, x, \beta)$ is households' effective labor supply, $\int_0^1 n_{kt} dk$ is the unions' total labor demand, N_t is labor bundle produced by labor packers, and $\int_0^1 n_{jt} dj$ is the labor demand by intermediate-goods producers. In a symmetric equilibrium we have $N_t = L_t$.

Market clearing in the assets markets requires that (1) capital demand by intermediate-good producers equates the financial intermediaries' capital holding, (2) government's debt equates the financial intermediaries' government debt holding, and (3) households' savings equates the financial intermediaries' deposits—that is,

$$K_t^F = \int k_{jt} dj, \ D_t = D_t^F, \text{ and } A_t^F = \int a d\mu_t(a, x, \beta). \tag{18}$$

Market clearing in capital further requires that capital producers supply new capital Δ_t^k consistent with capital accumulation by financial intermediaries:

$$\Delta_t^k = K_{t+1}^F - (1 - \delta) K_t^F. \tag{19}$$

Market clearing in the goods market reads

$$Y_t = G_t + C_t + I_t + \Theta_t + \Theta_t^w + \Phi + \Phi^w, \tag{20}$$

where $C_t \equiv \int c_t(a, x, \beta) d\mu_t(a, x, \beta)$ is the consumption of all households, Θ_t is the price adjustment costs by intermediate-goods producers, and Θ_t^w is wage adjustment costs by unions.

Finally, firms' dividends are distributed across all households: $\int d_t^h(x) d\mu_t(a, x, \beta) = \int d_{jt} + \int d_{kt}^w + d_t^k + d_t^F$.

Let $\mathbb{A}$ be the space for assets a, $\mathbb{X}$ be the space for productivities x, and $\mathbb{B}$ be the space for discount factors β. Define the state space $\mathbb{S} = \mathbb{A} \times \mathbb{X} \times \mathbb{B}$, with typical element $\boldsymbol{s} \in \mathbb{S}$, and let $\mathcal{S}$ be the Borel σ-algebra induced by $\mathbb{S}$. A formal equilibrium definition for the economy is provided next.

Definition 1 *Given sequences for government policies $\{G_t, T_t, D_t, \mathcal{T}_t(\cdot)\}_t$, an equilibrium in this economy is given by: sequences of prices $\{r_t, r_t^k, q_t^k, w_t, w_t^h, i_t, \Pi_t\}_t$; sequences of households' values $\{V_t(\boldsymbol{s})\}_t$, policies $\{\mathbb{h}_t^h(\boldsymbol{s}), c_t^h(\boldsymbol{s}), a_t^{h\prime}(\boldsymbol{s})\}_{ht}$, and measures $\{\mu_t(\boldsymbol{s})\}_t$; intermediate-good producers' policies $\{k_{jt}, n_{jt}\}_{jt}$; unions' policies $\{n_{kt}\}_{kt}$; capital producer policies $\{\Delta_t^k\}_t$; and financial intermediaries' policies $\{A_t^F, K_t^F, D_t^F\}_t$, such that (i) households' policies solve their problem and achieve values $V_t(\boldsymbol{s})$; (ii) intermediate-goods producers' policies solve their problem; (iii) unions' policies solve their problem; (iv) the government's budget constraint is satisfied; (v) i_t and r_t satisfy equations (15)-(16); (vi) labor, assets, capital, and goods markets clear as in (17)-(20); and (vii) the measure evolves consistently with the households' policies: $\mu_{t+1}(\mathcal{S}_0) = \int Q_t(\boldsymbol{s}, \mathcal{S}_0)\, d\mu_t(\boldsymbol{s})\ \forall \mathcal{S}_0 \in \mathcal{S}$, where $Q_t(\cdot)$ is a transition function given as $Q_t(\boldsymbol{s}, \mathcal{S}_0) = \mathbb{I}(a_t'(\boldsymbol{s}) \in \mathcal{S}_0) \sum_{(x',\beta')\in\mathcal{S}_0} \pi_x(x', x)\pi_\beta(\beta, \beta')$.*

3.3 Calibration

A period in the model is a quarter. We calibrate the model in steady state and denote X—suppressing time indexes—as the steady-state value of variable X_t.

Households' Parameters.—We set the level of hours 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 $\rho_x = 0.939$.[18] We calibrate the dis-utility of working B to match a 75% employment rate, which is the average of the Current Population Survey (CPS) from 1964 to 2003.[19] We set the variance of the working preference shock to $\varrho = 0.066$ as to match an *lpe* of about 0.75 for the lowest income quintile of workers, as we discuss in more detail below.

We calibrate heterogeneity in discount factors β to match the households' wealth distribution. We assume β can take three values: $\beta \in \{\beta_{\text{low}}, \beta_{\text{mid}}, \beta_{\text{high}}\}$. We follow Krusell and Smith (1998) and assume a persistence of $\pi_\beta(\beta, \beta) = 0.995$, corresponding to an average duration of 50 years, and, conditional on switching, β can only move to an adjacent value on the grid. Additionally, we assume $\Delta\beta = \beta_{\text{high}} - \beta_{\text{mid}} = \beta_{\text{mid}} - \beta_{\text{low}}$. We set $\beta_{\text{high}} = 0.9988$ to match an annualized interest rate of $r = 3.5\%$ and $\Delta^\beta = 0.028$ to match the wealth concentration of the wealthiest 20%. As Table 2 shows, the model matches well the wealth distribution

[18] These numbers are estimated using the whole sample of Panel Study of Income Dynamics (PSID) ages 18 to 65 from 1979 to 1992.

[19] A similar participation rate is found in the PSID of 1983, the year that we use for comparison with other targets in our model.

coming from the Survey of Consumer Finances for the year 1983.[20] As noted recently in Kaplan and Violante (2021), heterogeneous discount factors can generate realistic *mpc* at the cost of an unrealistic wealth concentration. As we show below, stochastic discount factors allow for reasonable *mpc* without overstating wealth concentration.

Technology Parameters.—We set $\epsilon = 7$, which is a standard value in the literature. We set $\Theta = 200$ to match a Phillips curve slope, ϵ/Θ, of 0.035, in the midrange of estimates provided in Galí and Gertler (1999).[21] We set the fixed cost of production Φ so that intermediate producers make zero profits in steady state.

Regarding the wage Phillips curve, we assume the same stickiness as in prices: $\Theta^w = \Theta$ and $\epsilon^w = \epsilon$.[22] As with intermediate-goods producers, we set a fixed cost of production Φ^w so that unions make zero profits in steady state.

We assume a capital adjustment cost of $\phi^k = 15$ to match the elasticity of the investment-capital ratio to Tobin's q as in Eberly, Rebelo, and Vincent (2008).[23] The capital share α is set to 0.36, and the depreciation rate δ is set to 0.035.

Distribution of Profits.—Intermediate-good producers, unions, capital producers, and financial intermediaries may make profits, which are paid out as dividends. Let $d_t = \int_0^1 d_{jt}dj + \int_0^1 d^w_{kt}dk + d^k_t + d^F_t$ be the sum of dividends paid to these firms in period t. We assume these dividends are rebated to households in proportion to their labor productivity; that is, $d^h_t(x) = \bar{d}^h_t x$.[24] The value of $\bar{d}^h_t$ is pinned down such that all profits are distributed: $d_t = \bar{d}^h_t \mu_x$, where $\mu_x = \mathbb{E}[x]$ is the unconditional mean of idiosyncratic productivity x. This rule realistically implies that profits are more heavily concentrated in high-income households, which are typically wealthier. As such, it limits aggregate consequences of profit redistribution. Indeed, because $d^h_t(x)$ is a function of an exogenous process, it does not directly affects households' incentives to work, beyond wealth effects, which should be minimized for wealthier households. In Appendix A.6, we show that our results are robust to alternative profit distribution rules.

Tax Function.—We assume a tax function $\mathcal{T}(wxh, ra)$ with a flat tax on capital income τ_k, and a nonlinear tax rate $\tau_\ell(\cdot)$ on labor income wxh: $\mathcal{T}(wxh, ra) = \tau_k ra + \tau_\ell(w^h xh)w^h xh$. The capital tax rate τ_k is set to 35%, following Chen, Imrohoroglu, and Imrohoroglu (2007). This number primarily reflects two flat

[20] Wealth corresponds the net worth: total financial assets net of total debt. See Appendix B.2.1 for more details.

[21] Galí and Gertler (1999) directly estimate the Phillips curve and find a slope between 0.018 and 0.047 (see their Table 1). Estimation of full structural DSGE models often yields a lower slope, of around 0.01 (Del Negro, Giannoni, and Schorfheide, 2015, and Altig, Christiano, Eichenbaum, and Linde, 2011).

[22] Section 5.4 and Appendix A.6 contain robustness exercises with respect to the level of wage rigidity Θ^w.

[23] Similar adjustment cost values are used in Bayer, Lütticke, Pham-Dao, and Tjaden (2019) and Hagedorn, Manovskii, and Mitman (2019).

[24] Similar assumptions are made in Farhi and Werning (2020) and Ferrante and Paustian (2019).

taxes: corporate income taxes and property taxes.[25]

For the labor tax, we assume a log-linear tax on labor income y_ℓ as $\tau_\ell(y_\ell) = 1 - \lambda y_\ell^{-\gamma}$. With only two parameters, this tax function features a remarkable fit to the U.S. federal income tax system.[26] The first parameter, γ, measures the progressivity of the taxation scheme. When $\gamma = 0$, the tax rate is constant: $\tau_\ell(y_\ell) = 1 - \lambda \;\; \forall y_\ell$. When $\gamma = 1$, the tax function implies complete redistribution: After-tax labor income $(1 - \tau_\ell(y_\ell))\, y_\ell$ equals λ for any pre-tax income y_ℓ. A positive (negative) γ describes a progressive (regressive) taxation scheme. The second parameter, λ, measures the level of taxation. When $\gamma = 0$, the tax rate is flat at exactly $1 - \lambda$. Thus, an increase in $1 - \lambda$ raises tax rates for all levels of income, while an increase in γ makes tax rates higher for high-income and lower for low-income households. We set $\gamma = 0.1$, which is a value in line with estimates in the literature. The value of λ is computed so that the average labor tax rate is about 28%, a standard number in the literature.[27]

Fiscal and Monetary Authority Parameters.—We calibrate transfers T to match a transfers-to-output ratio of 8.2%, the historical average for the post-WWII period. Public debt D is set to match a debt-to-output ratio of 25% annually, so that total financial assets (public debt plus capital) is about 10 times quarterly GDP, in line with flow of funds data for 1983.[28] The spending-to-output ratio implied by the government's budget constraint amounts to about 10%, a number within the range of what is typically used in the literature.[29] Finally, we assume an inflation target of $\bar{\Pi} = 1$ and a monetary authority that responds with $\phi_\Pi = 1.5$ to inflation deviations from its target. Table 1 summarizes the parameter values.

Taxes	$\tau_k = 0.35$	$\gamma = 0.1$	$\lambda = 0.68$
Other fiscal variables	$T = 0.11$	$G = 0.13$	$D = 1.33$
Discount factors	$\beta_{\text{high}} = 0.9988$	$\Delta_\beta = 0.028$	$\pi_\beta(\beta, \beta) = 0.995$
Labor supply	$\bar{h} = 1/3$	$B = 0.61$	$\varrho = 0.066$
Income risk	$\rho_x = 0.939$	$\sigma_x = 0.287$	
Nominal rigidities	$\epsilon = \epsilon^w = 7$	$\Theta = \Theta^w = 200$	
Capital	$\phi_k = 15$	$\delta = 0.0235$	$\alpha = 0.36$
Monetary policy	$\phi_\Pi = 1.5$		

Table 1: Parameter Calibration

[25]The capital income taxed at a progressive rate—that is, as ordinary income in the federal tax code—represents only a small fraction of the fiscal revenues raised on capital income; see Joines (1981).

[26]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 the U.S. federal income tax code particularly well in recent years.

[27]See for instance Trabandt and Uhlig (2011).

[28]Total financial assets for households in 1983:Q4 were \$9,937.8 (U.S. billions), see "Balance Sheet of Households and Nonprofit Organizations" in Table Z.1 of flow of funds. Annual U.S. GDP that year was \$3794.7 U.S billions.

[29]Typical numbers go from about 6% (Brinca, Holter, Krusell, and Malafry, 2016) to 18% (Smets and Wouters, 2007).

	Share of wealth				
Wealth quintile	1	2	3	4	5
Model	0.00	0.00	0.02	0.10	0.88
Data	−0.00	0.01	0.04	0.09	0.86

Table 2: Wealth Distribution: Model and Data

Notes: Households are sorted by wealth. Source: Survey of Consumer Finances (SCF), 1983. See Appendix B.2.1 for more details.

3.4 Heterogeneity in *lpe* and *mpc*

The calibrated model generates a rich heterogeneity of *mpc* and *lpe* across households, which we next compare with data counterparts. While both margins are important, we discuss *lpe*s in more detail as it has been explored less in the literature so far.

Marginal Propensities to Consume.—Table 3 reports quarterly *mpc* out of a one-time $500 rebate, by wealth quintile. As typically found empirically, *mpc* in the model declines with wealth. The average *mpc* is 0.16, while it amounts to 0.57 in the lowest quintile. These numbers are in line with estimates elsewhere in the literature (Kaplan, Moll, and Violante, 2018; Kaplan and Violante, 2014; Misra and Surico, 2014). Empirical work sometimes reports annual numbers for *mpc* (Crawley and Kuchler, 2022; Fagereng, Holm, and Natvik, 2021), which we report in the second line of Table 3.[30] As expected, the average annual *mpc* is larger, at 0.26, and decreases with wealth at a somewhat slower rate.[31]

We also report the correlation of *mpc* with income, as progressive taxes are a function of income rather than wealth. We use the Italian Survey on Household Income and Wealth (SHIW) for data computations, which surveys household-level *mpc* (Jappelli and Pistaferri, 2020).[32] The model correlation between *mpc* and after-tax labor income is −0.12, close to the −0.10 obtained in the SHIW—for total after-tax income, the correlation is −0.17 in the model versus −0.13 in the data.[33] Overall, the model generates empirically plausible *mpc* profiles with respect to both, income and wealth.

Labor Participation Elasticities.—A large body of work has measured labor supply elasticities across different demographic and income groups.[34] 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

[30] See Table 1 in Carroll, Slacalek, Tokuoka, and White (2017).

[31] Using Danish data, Crawley and Kuchler (2022) get an (annual) *mpc* difference of 53bps between top and bottom liquid-wealth quintiles (see their Figure 2), close 60bps we obtain in our model.

[32] See Appendix B.2.2 for data details.

[33] We trim households with less than 1% probability of working for these model computation.

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

for lower-income earners (Blundell, 1995).[35] In particular, Meghir and Phillips (2010) find an *lpe* of 0.32 for prime-age males with low education levels in the United Kingdom, while the elasticity is only 0.03 for households with the highest education. Similarly, for the United States, Moffit and Wilhelm (2000) find an *lpe* of 0.2 for medium-income households and essentially zero for top-income earners.[36] 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 0.6 and 0.8 for the lowest-income deciles and an elasticity of zero for the highest-income deciles. Our model-implied elasticities are within this range, as we discuss next.[37]

Consistent with the empirical literature discussed above, we measure labor supply elasticities by regressing hours worked on after-tax hourly wages (MaCurdy, 1981; Altonji, 1986; Blundell, Duncan, and Meghir, 1998). Because most empirical estimates use annual frequency samples, we follow Chang and Kim (2006) and simulate a panel of households at a quarterly frequency and then time-aggregate to an annual frequency.[38] We then estimate the following regression:

$$\ln h_{in} = b_0 + b_1 \ln \tilde{w}_{in} - b_2 \ln c_{in} + \epsilon_{in}, \tag{21}$$

where h_{in}, $\tilde{w}_{in}$, and c_{in} correspond to hours worked, after-tax hourly wage, and consumption of household i during year n, respectively. The resulting parameter b_1 is typically referred to as the micro-Frisch labor supply elasticity, which is our *lpe* measure.

The model-implied *lpe*s decline with income, as shown in the first line of Table 4 shows. The elasticity

[35] 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 setup. 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 (Piketty and Saez, 2013). 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, conventional forms of taxable compensation (such as salary and bonuses) show little responsiveness to tax changes. In a recent review, Saez, Slemrod, and Giertz (2012) conclude: "There is no compelling evidence to date of *real* responses of upper income taxpayers to changes in tax rates" (original italics).

[36] 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 248–51). Juhn, Murphy, and Topel (2002) estimate a bottom-decile elasticity that is twice as large as the median-income elasticity using CPS data. Similar findings are provided in Aaberge, Colombino, and Strøm (1999) using Italian data.

[37] 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). 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. Diamond (1998) and Saez (2001), among others, also assume a homogenous intensive labor supply across households. Erosa, Fuster, and Kambourov (2016) also find homogenous elasticities on the intensive margin. See also Triest (1990) for an empirical evaluation of this assumption.

[38] We drop observations with zero hours worked during the year. See Appendix A.3.2 for more details.

is about 0.75 for the bottom quintile and below 0.2 for the top quintiles, averaging to 0.24 for the entire population. This distribution is in line with the empirical findings described above.

Further support of the model-implied *lpe*s comes from Erosa, Fuster, and Kambourov (2016), who estimate a rich structural life-cycle model and compute labor supply elasticities for different groups. They report an *lpe* of 1.08 after a one-time 1% increase in wages. We obtain 0.68 when performing the same exercise in our model, close to their estimates for workers aged 25 to 54. Erosa, Fuster, and Kambourov (2016) further report a twice-as-large *lpe* for non-college relative to college workers, suggesting substantial *lpe* heterogeneity across income groups.

Finally, we compute labor supply elasticities in our model out of a transitory increase in taxes, which is more directly informative of the exercises we perform in Section 4.[39] The second line in Table 4 presents an *lpe* after a labor-tax rate increase of 1%, which we denote lpe^{τ}. For each household with state s, we compute an $lpe^{\tau}(s)$ as the change in the probability of working after the tax change. For each income group, we report the average *lpe* withing the group. We assume taxes return to steady state at a rate of 0.9 for these computations, the shock persistence we use in Section 5.[40] The distribution lpe^{τ} follows the pattern of our previous *lpe* estimates: The elasticity is highest for bottom-income groups and monotonically decreases to become close to zero for top-income groups.

Overall, the model yields empirically realistic distributions for both *mpc* and *lpe*. As we show below, both dimensions of heterogeneity are quantitatively important for the effects of the distribution of taxes on spending multipliers.[41]

Wealth quintile	1	2	3	4	5
mpc quarterly	0.57	0.11	0.06	0.03	0.01
mpc annual	0.65	0.29	0.21	0.11	0.04

Table 3: Marginal Propensities to Consume

Note: Households are sorted by wealth. See text and Appendix A.3 for more details.

Income quintile	1	2	3	4	5
lpe	0.75	0.25	0.23	0.18	0.04
lpe^{τ}	0.95	0.52	0.22	0.15	0.03

Table 4: Labor Participation Elasticities

Note: Households are sorted by income. See text and Appendix A.3 for more details.

[39] We are thankful to one of our referees for suggesting this exercise.

[40] See Appendix A.3 for more details.

[41] For completeness, Appendix A.3 also reports marginal propensities to earn (*mpe*) by income quantile.

4 Analytical Results

The central argument of this paper is that the distribution of taxes across households shapes spending multipliers. In this section, we derive analytical expressions from our model that formalize how aggregate labor supply and consumption depend on the distribution of tax changes used to finance the fiscal stimulus.[42] The expressions we derive link tax changes to aggregate outcomes via the distributions of *mpc* and *lpe* across households. We then use the model-implied *mpc* and *lpe* to perform back-of-the-envelope calculations on the importance of the distribution of taxes. The results we present in this section build intuition on the quantitative findings in Section 5.

4.1 Tax effect on labor and consumption: Formulas

Consider a labor tax increase across households. Let $\tau_{\ell t}(s)$ be the labor tax rate faced t periods after the tax change by a working household with state s, and let $\tau_\ell(s)$ be its steady-state counterpart. Denote $\Delta\tau(s) = \frac{\tau_{\ell 1}(s)-\tau_\ell(s)}{\tau_\ell(s)}$ the proportional tax change the first period after the change in taxes. We derive the response of aggregate labor and consumption to this tax change.

Labor.—Let $\Delta L = \frac{L_1 - L}{L}$ be the proportional change in labor supply the first period after the tax change, which can be expressed as

$$\Delta L = -\int lpe^{\tau}(s)\ \Delta\tau(s)\ \omega^{\ell}(s)\ d\mu(s), \tag{22}$$

where $lpe^{\tau}(s)$ is the labor tax elasticity discussed in Section 3.4, and $\omega^{\ell}(s) = \frac{xh(s)}{L}$ is the share of effective labor provided by households with state s.[43] Equation (22) can be expressed as

$$\begin{aligned} \Delta L &= -\mathbb{E}^{\ell}\left[lpe^{\tau} \times \Delta\tau\right] \\ &= -\underbrace{\left\{\mathbb{E}^{\ell}\left[lpe^{\tau}\right] \times \mathbb{E}^{\ell}\left[\Delta\tau\right] + \mathbb{C}ov^{\ell}\left(lpe^{\tau}, \Delta\tau\right)\right\}}_{\text{aggregate } \textit{effective lpe}}, \end{aligned} \tag{23}$$

where $\mathbb{E}^{\ell}[\cdot]$ and $\mathbb{C}ov^{\ell}(\cdot)$ use $\omega^{\ell}(s) \times \mu(s)$ as a measure.

Equation (23) illustrates a core intuition of our results. The labor supply response to a tax change depends on the average *lpe* as well as on the distribution of tax changes across households with different *lpe*s. Thus, we think of ΔL in (23) as the aggregate *effective lpe* in the economy. If tax changes are the same for all households, $\Delta\tau(s) = \Delta\tau = \mathbb{E}^{\ell}[\Delta\tau]$, the covariance term is zero and thus $\Delta L = -\ \mathbb{E}^{\ell}[lpe^{\tau}] \times \mathbb{E}^{\ell}[\Delta\tau]$:

[42] We are deeply indebted to one of our referees who suggested the work in this section.
[43] Appendix A.4 derives all the expressions in this section.

The labor change is the average elasticity times the average tax change. Now, if tax changes are larger on low-*lpe* households, the covariance term is negative and thus $\Delta L > -\,\mathbb{E}^{\ell}\left[lpe^{\tau}\right] \times \mathbb{E}^{\ell}\left[\Delta\tau\right]$. That is, labor supply decreases by less when the tax burden is shifted toward low-*lpe* households.

Consumption.—Let $dC = C_1 - C$ be the change in consumption the first period after the change in taxes, and let $dT(s) = T_1(s) - T(s)$ be the change in taxes paid on impact—that is, $dT(s) = \tau_{\ell 1}(s)y_1^{\ell}(s) - \tau_{\ell}(s)y^{\ell}(s)$. We can express dC as

$$dC = -\underbrace{\int mpc(s)\; dT(s)d\mu(s)}_{\textit{tax burden channel}} \;-\; \underbrace{\left[\int mpc(s)\; lpe^{\tau}(s)\; \Delta\tau(s)\; \omega^{\ell}(s)d\mu(s)\right] w^h L}_{\textit{labor supply channel}}. \tag{24}$$

The first term in equation (24) measures the change in consumption due to higher taxes paid. We refer to the first term as the *tax burden channel*. The second term in equation (24) measures the effect that taxes have on labor supply and thus on income and consumption. We refer to the second term as the *labor supply channel*.

We can decompose the *tax burden channel* as

$$\begin{aligned} \textit{tax burden channel} &= -\mathbb{E}\left[mpc \times dT\right] \\ &= -\left\{\mathbb{E}\left[mpc\right] \times \mathbb{E}\left[dT\right] + \mathbb{C}ov\left(mpc, dT\right)\right\}, \end{aligned} \tag{25}$$

where $\mathbb{E}[\cdot]$ and $\mathbb{C}ov(\cdot)$ use $\mu(s)$ as a measure.

The intuition of equation (25) mirrors the one discussed for ΔL. The consumption response to a tax change depends on the average *mpc* and on the distribution of tax changes across households with different *mpc*. The covariance term shows that the consumption response is amplified when tax changes are larger for high-*mpc* households, while the response is dampened when the tax burden is shifted toward low-*mpc* households. The intuition of the *tax burden channel* relates to the recent work in Auclert, Rognlie, and Straub (2018) and Bilbiie (2019), who argue that tax incidence across households with different *mpc* can affect aggregate outcomes.

Next, we can decompose the *labor supply channel* as

$$\begin{aligned} \textit{labor supply channel} &= -\mathbb{E}^{\ell}\left[mpc \times lpe^{\tau} \times \Delta\tau\right] w^h L \\ &= -\left\{ \mathbb{E}^{\ell}\left[mpc\right] \underbrace{\left\{\mathbb{E}^{\ell}\left[lpe^{\tau}\right] \times \mathbb{E}^{\ell}\left[\Delta\tau\right] + \mathbb{C}ov^{\ell}(lpe^{\tau}, \Delta\tau)\right\}}_{\text{aggregate } \textit{effective lpe}} + \mathbb{C}ov^{\ell}\left(mpc, lpe^{\tau}\Delta\tau\right) \right\} w^h L \\ &= -\left\{\mathbb{E}^{\ell}\left[mpc\right] \times \Delta L + \mathbb{C}ov^{\ell}\left(mpc, lpe^{\tau}\ \Delta\tau\right)\right\} w^h L. \end{aligned} \tag{26}$$

Equation (26) shows how the consumption response depends on the effect that tax changes have on labor supply. The first term in equation (26) captures an average crowding-out effect given by the average *mpc* times the aggregate *effective lpe*–as measured by ΔL. A tax change that leads to a stronger crowding-out on labor supply also leads to a stronger crowding-out on consumption. Thus, because of heterogeneity in *lpe*, the distribution of tax changes alters the aggregate consumption response, regardless of heterogeneity in *mpc*. Additionally, the covariance between *mpc* and *lpe* also affects the consumption response, but its strength depends on the distribution of taxes. The more taxes are raised on low-*lpe* households, the closer to zero the covariance term is. The intuition of the *labor supply channel* relates to the recent work in Patterson (2022), which highlights that consumption responses are the compound of individual *mpc* and the exposure of individual income to aggregate shocks.

4.2 Tax effect on labor and consumption: Back-of-the-envelope calculations

We use the above-derived formulas to approximate the effect of a given distribution of tax changes on labor supply and consumption. We consider two cases of tax changes: an *all* case and a *top* case. In the *all* case, taxes increase by 1% for all households: $\Delta\tau_{all}(s) = \Delta\tau_{all} = 1\% \ \ \forall s$. In the *top* case, taxes increase for the top-income quintile only: $\Delta\tau_{top}(s) = \Delta\tau_{top} > 0$ if $s \in$ top-quintile and zero otherwise. We set $\Delta\tau_{top}$ so that the two cases generate the same amount of revenues: $\mathbb{E}\left[dT_{top}\right] = \mathbb{E}\left[dT_{all}\right]$.

Note that $\Delta\tau_{top} > \Delta\tau_{all}$, as revenues are collected on a smaller fraction of households. Yet, high-income households decrease their labor supply by less after a tax increase, as they have lower *lpe*; and their steady-state tax rates are higher in steady state, as taxes are progressive. In turn, to obtain the same amount of revenues, the average tax change across the entire distribution of households is lower in the *top* case than in the *all* case.[44] In particular, we obtain

$$\mathbb{E}^{\ell}\left[\Delta\tau_{top}\right] \approx 0.8\% < \mathbb{E}^{\ell}\left[\Delta\tau_{all}\right] = 1\%. \tag{28}$$

When evaluating the above-derived formulas, we use *lpe* and *mpc* measures out of persistent changes, which are more informative of the persistent spending shock we analyze in Section 5. In particular, as we discussed in Section 3.4, the tax-elasticity lpe^{τ} reflects a 1% increase in tax rates that returns to steady state at rate 0.9. Similarly, we use an *mpc* out of a \$500 increase in transfers that returns to steady state at the same rate. The more persistent increase in transfer yields higher but less dispersed *mpc*s, with an average *mpc* of 0.35 and a correlation with labor income of -0.04.

Labor.—We evaluate the labor response introducing $d\tau_{all}$ and $d\tau_{top}$ in equation (23).

In the *all* case, the covariance between *lpe* and $\Delta\tau$ is zero, as the tax change is the same across all households. Thus, the change in labor depends only on the aggregate *lpe* averaged over labor income, which is 0.10 in our calibration. As $\mathbb{E}^{\ell}\left[\Delta\tau_{all}\right] = 1\%$, we have $\Delta L_{all} = -0.10\%$.

In the *top* case, $\mathbb{E}^{\ell}\left[\Delta\tau_{top}\right] = 0.8\%$, so the first term of the change in labor, $\mathbb{E}^{\ell}\left[lpe^{\tau}\right] \times \mathbb{E}^{\ell}\left[\Delta\tau\right]$, is marginally closer to zero, at -0.08%. Furthermore, the covariance term becomes negative in the *top* case, as the tax change is concentrated on high-income/low-*lpe* earners. The covariance contributes to an *increase* of about $+0.07\%$ in labor, setting the overall labor supply response at $\Delta L_{top} = -0.02\%$. Thus, the response in ΔL_{top} is five times smaller than ΔL_{all}, even if both cases raise the same revenues. This difference is mostly driven by the covariance between *lpe* and tax changes.[45]

Consumption.—We evaluate the consumption response, $\Delta C \equiv dC/C$, using $d\tau_{all}$ and $d\tau_{top}$ in equations (25) and (26).

The *tax burden channel* implies a decline in consumption of -0.109% in the *all* case. When all households face the same tax rate change, the covariance between *mpc* and dT is close to zero. In contrast, in the *top* case, taxes are shifted toward high-income/lower-*mpc* households, so that the covariance between *mpc* and dT becomes more negative. In turn, the drop is 15% smaller in the *top* case than in the *all* case. The difference in consumption responses across tax schemes due to the *tax burden channel* reflects *mpc* heterogeneity.

[44]The formal relationship between $\mathbb{E}^{\ell}\left[\Delta\tau_{top}\right]$ and $\mathbb{E}^{\ell}\left[\Delta\tau_{all}\right]$ is given by the following formula, which highlights both the higher steady-state tax rates and the lower *lpe* of the top-income earners in our economy:

$$\mathbb{E}^{\ell}\left[\Delta\tau_{top}\right] = \Delta\tau_{all}\frac{\mathbb{E}^{\ell}[\tau_{\ell}(1-lpe^{\tau})]}{\mathbb{E}^{\ell}[\tau_{\ell}(1-lpe^{\tau})|s \in top]} < \mathbb{E}^{\ell}\left[\Delta\tau_{all}\right] = \Delta\tau_{all}. \tag{27}$$

[45]This differential labor response resembles the empirical findings in Zidar (2019), who reports substantial labor responses from tax cuts on bottom-income earners but mute responses from tax cuts on top-income earners.

In the *all* case, the *labor supply channel* implies a further 20% decline in consumption relative to the *tax burden channel*. In contrast, in the *top* case, consumption declines only by 5% more when including the *labor supply channel*. The larger decline in the *all* case is due to the larger aggregate *effective lpe*, as the covariance between *mpc* and *lpe* weighted by tax changes is quantitatively small. Thus, the difference in consumption responses across tax schemes due to the *labor supply channel* mostly reflects *lpe* heterogeneity.

Overall, the drop in consumption is about about 35% larger in the *all* than in the *top* case, with $\Delta C_{all} = -0.13\%$ and $\Delta C_{top} = -0.09\%$. The *tax burden channel* and the *labor supply channel* contribute roughly equally to this difference in consumption responses.

5 Quantitative Results

The previous section provided analytical insights on how the distribution of taxes affects households' behavior. In this section, we pursue quantitative experiments to assess the effect of government spending across different taxation schemes. The model implies a rich, and empirically realistic, distribution of *lpe* and *mpc* across households. It also includes standard features in New Keynesian models, which makes it useful for analyzing demand shocks. As such, our model is a suitable environment to explore how spending multipliers depend on the distribution of taxes.

5.1 Experiments

We model a fiscal stimulus as a 1% unexpected increase in government spending, which gradually returns to its steady-state value at rate $\rho_G = 0.90$. This number is in line with the average persistence for a spending shock, as we report in Section 6.[46] We assume the economy was at steady state before the spending shock and that there is perfect foresight after the shock.

Financing Scheme: Debt and Taxes.—The increase in spending is financed with a combination of debt and taxes. We follow Uhlig (2010) and model debt dynamics as

$$D_{t+1} - D = \theta(F_t - F), \tag{29}$$

where $F_t \equiv G_t + (1 + r_t^g)D_t - \tau^k r_t A_t + T$ represents fiscal deficits before labor tax revenues. The parameter θ captures the fraction of the spending shock financed through deficits. If $\theta = 0$, debt is constant and the shock is entirely financed with higher labor taxes. If θ is positive, part of the shock is financed with debt.

[46] This persistence is also close to estimates in the DSGE literature; see Christiano, Motto, and Rostagno (2014).

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. For instance, while WWII was initially heavily financed with debt, the Korean War was entirely financed with taxes. As a benchmark, we use an intermediate case where 50% of the additional spending is financed with deficits ($\theta = 0.5$). This number is in line with the average response of deficit financing to a spending shock, as we report in Section 6. We also consider alternative values for θ in Section 5.4.

The remaining fraction $(1 - \theta)$ of the additional spending is financed through labor taxes, which can be done in different manners. To increase revenues, labor taxes can increase for all workers. In this case, the progressivity parameter γ_t is kept constant, and only the level of taxes λ_t is adjusted. Alternatively, the higher labor taxes can be concentrated within high-income earners. To capture this case, we modify the tax function so that, relative to steady state, higher γ_t increases taxes at the top without decreasing them elsewhere.[47] In particular, while the steady-state tax scheme remains unchanged, labor income y_ℓ along the transition is now taxed at rate $\hat{\tau}_{\ell t}(y_\ell) = \max\{\tau_\ell(y_\ell), \tau_{\ell t}(y_\ell)\}$. As a consequence, selecting the level of tax progressivity γ_t along the transition amounts to selecting the fraction of households that face higher taxes to finance the spending shock.

We assume that γ_t responds to fluctuations in spending as

$$\gamma_t - \gamma = \phi\,(G_t - G)\,. \tag{30}$$

The parameter ϕ captures the fraction of households facing higher taxes after the spending shock. We report two cases similar to the *all* and the *top* tax schemes of Section 4: (i) constant progressivity, where taxes increase for all workers ($\phi = 0$), and (ii) higher progressivity, where only the top 20% of households face a higher tax ($\phi > 0$). In both cases, the tax-level parameter λ_t is determined every period to meet the government's budget constraint (14), given the paths for spending, debt, and tax progressivity.

Figure 1 reports average taxes per income group for both the constant and the higher progressivity cases, as well as spending and public debt. In the constant progressivity case, tax rates increase for all households. In the higher progressivity case, higher taxes are concentrated at the top 20% of workers, and thus tax responses are muted for the bottom income groups. Note that, beyond the change in statutory tax rates, effective tax rates may also vary because of endogenous changes in wages and hours worked. The response of government debt is comparable across the two taxation schemes. As we show next, the two tax schemes have very different implications for the effects of government spending.

[47] This change is sensible from a historical perspective. As discussed in Section 2, taxes often increased at different rates across households to finance large spending shocks (wars) but seldom decreased for anyone during these periods.

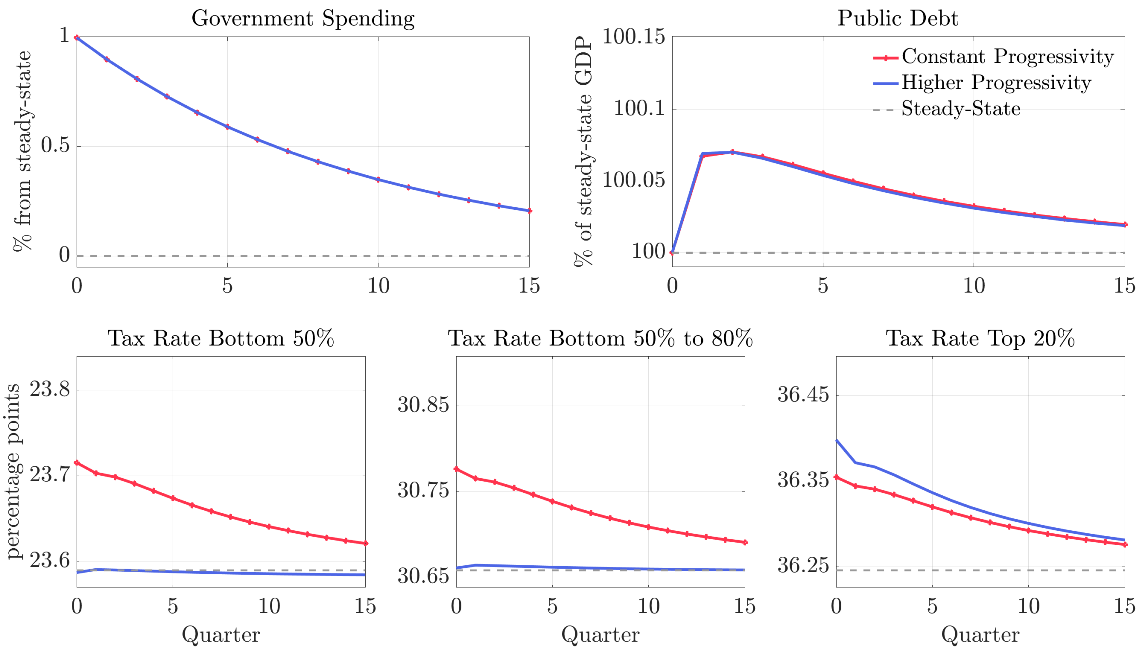

Figure 1: Spending Shock Financed with Different Paths for Progressivity: Fiscal Policy

Note: Model responses to a government spending shock financed with progressive labor taxes. Responses are computed for two paths of progressivity $\{\gamma_t\}$: constant progressivity and higher progressivity. The top-left panel depicts the impulse response of government spending. The top-right panel depicts public debt as a ratio of steady-state GDP. The three bottom panels depict the average tax rates per income group.

5.2 Spending Multipliers and Tax Progressivity

Spending is more expansionary when financed with an increase in tax progressivity. As Figure 2 shows, the increase in output and labor more than doubles when more progressive taxes are used. Similarly, while consumption declines in both cases, the contraction is substantially diminished with more progressive taxes. Hence, shifting the distribution of taxes across households shapes the aggregate effects of government spending.

As is typically done in the empirical literature (Ramey and Zubairy, 2018), we compute the spending multipliers at horizon h as $m_h = \frac{\sum_{t=0}^{h}(Y_t - Y)}{\sum_{t=0}^{h}(G_t - G)}$. Figure 3 reports multipliers at 1, 2, and 10 years after the shock—the latter of which we consider a long-run cumulative effect of the stimulus. Multipliers are larger when progressive taxes are used: about 0.36 after 10 years, relative to 0.06 with constant progressivity.[48] As we discuss next, this difference in multipliers largely reflects the direct effect of the distribution of taxes.

[48] We obtain larger multipliers when using an empirically-relevant/more accommodative monetary policy, as we discuss in Section 5.4.

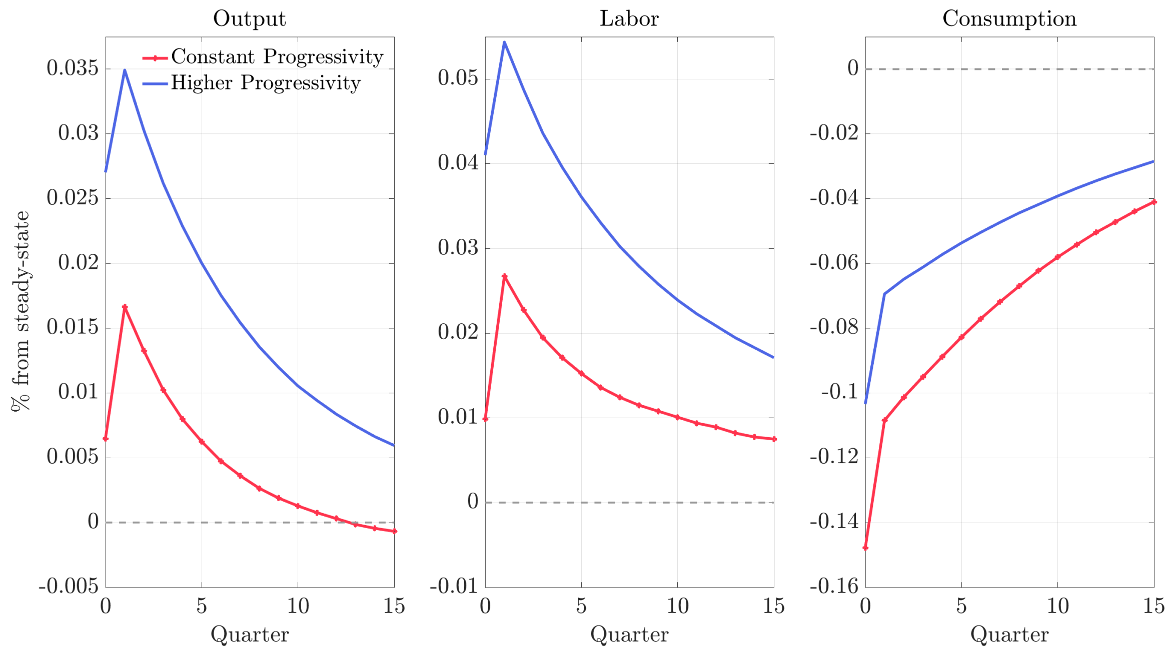

Figure 2: Model Responses to a Spending Shock Financed with Different Paths for Progressivity

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

5.3 Direct and Indirect Effects: It's All about Taxes

This striking difference in responses across the two tax schemes can be decomposed into what we refer to as a direct effect and an indirect effect. From the households' perspective, the effect of a spending shock only matters through four equilibrium sequences: taxes, wages, interest rates, and dividends. We think of households' responses to changes in taxes as the direct effect, while general equilibrium changes in prices and dividends trigger an indirect effect. To decompose direct and indirect effects, we feed taxes and prices into the households' problem separately and compute consumption and labor supply responses for each case.

In particular, given the three equilibrium price sequences $\{p_{t+j}\}_{j\geq 0} = \left\{w^h_{t+j}, r_{t+j}, d_{t+j}\right\}_{j\geq 0}$ and the labor tax sequence $\{\tau_{t+j}\}_{j\geq 0}$, we can compute the households' labor and consumption responses as $L_t\left(\{p_{t+j}, \tau_{t+j}\}_{j\geq 0}\right)$ and $C_t\left(\{p_{t+j}, \tau_{t+j}\}_{j\geq 0}\right)$. We compute the direct effect of taxes by setting prices to steady state—that is, $L_t\left(\{p, \tau_{t+j}\}_{j\geq 0}\right)$ and $C_t\left(\{p, \tau_{t+j}\}_{j\geq 0}\right)$. Analogously, we compute the indirect effect of prices by setting taxes to steady state—that is, $L_t\left(\{p_{t+j}, \tau\}_{j\geq 0}\right)$ and $C_t\left(\{p_{t+j}, \tau\}_{j\geq 0}\right)$. For each tax scheme, the left panel in Figure 4 reports the four equilibrium sequences, while the middle and right panels display the resulting decomposition for labor and consumption, respectively.

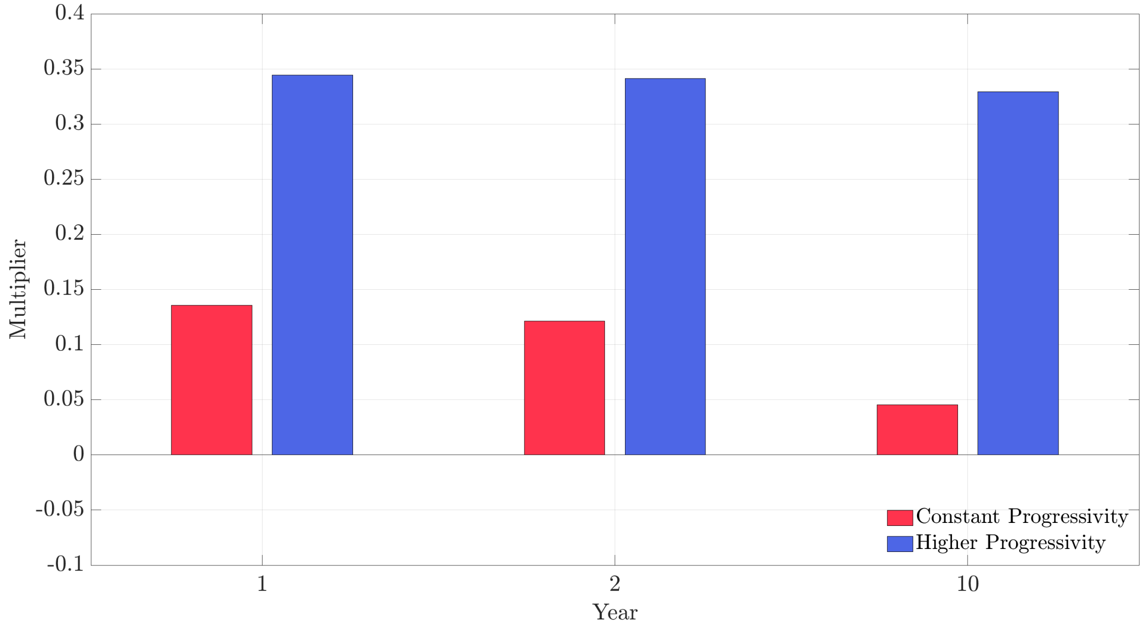

Figure 3: Cumulative Multipliers with Different Paths for Progressivity

Note: Cumulative output responses to a spending shock financed with deficits ($\theta = 0.5$) and progressive labor taxes. Multipliers are reported for two paths of progressivity $\{\gamma_t\}$: constant progressivity and higher progressivity.

Results are stark. The general equilibrium effects of a spending shock are large but mostly unaffected by the tax scheme. The sequences of wages, interest rates, and dividends are comparable across tax schemes, and, consequently, their effect on labor and consumption are also alike. As such, the indirect effects cannot explain the difference in responses under the two tax schemes.

The direct effect of taxes accounts for virtually all of the differences in responses. With constant progressivity, taxes increase for all households, including those with low income, who have larger *lpe*. Thus, labor supply declines substantially. Under the higher progressivity tax scheme, only low-*lpe* households are taxed more, and thus labor supply contracts by less. A similar rationale applies to consumption responses. When more progressive taxes are used, the tax burden is shifted toward low-*mpc* households, which mitigates the crowding-out effect of the higher taxes. As a result, both labor and consumption responses are larger.

Finally, the back-of-the-envelope calculations of Section 4.2 align well with the direct effect of taxes on labor and consumption in the quantitative model, which confirms the usefulness of the analytical formulas. We defer a detailed comparison to Appendix A.5.

The Importance of lpe *and* mpc.—What are the respective roles of *lpe* and *mpc* in explaining the

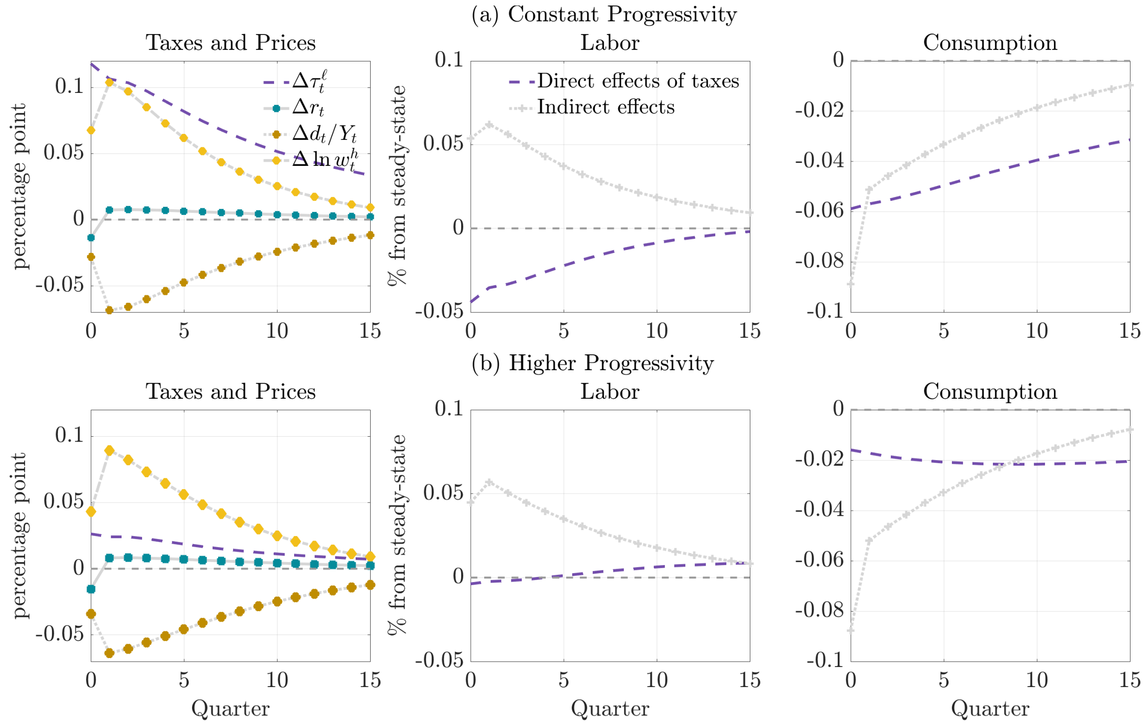

Figure 4: Direct and Indirect Effects of a Spending Shock across Progressivity Paths

Note: The top panels depict the constant-progressivity case, while the bottom ones depict the higher-progressivity case. The left column show the responses of labor taxes, interest rates, dividends-to-output, and wages after the spending shock. All variables are reported as a percentage point difference from steady state, except for wages, which are in percentage deviation. Dividends of the financial intermediaries are large on impact due to valuation effects, at −0.26% of output in the constant-progressivity case and −0.23% in the higher-progressivity case; we exclude them from the figure to ease reading. The middle and right columns plot labor and consumption responses, respectively, when feeding the labor taxes or all other sequences.

difference in responses across the two tax schemes? To complement the insights of the analytical section, we consider two alternative calibrations of the benchmark model, each one tailored to lessen the importance of *lpe* and *mpc* at a time. In particular, we consider a "flatter *lpe*" calibration and a "lower *mpc*" one. The flatter *lpe* calibration increases the variance of the working preference shock so that a household's specific conditions become less relevant for its labor supply decisions, and the distribution of *lpe* becomes flat across income groups. The lower *mpc* calibration assumes the same discount factor β for all households, which results in lower as well as uniformly distributed *mpc*.[49] In both cases, we recalibrate all remaining parameters to match the same targets we had in our benchmark calibration. Appendix A.5 contains more details on the two alternative calibrations.

[49]For the flatter *lpe* calibration, we adjust the difference in households' discount factor $\Delta\beta$ to obtain the same average *mpc*. Similarly, in the lower *mpc* calibration, we adjust the working preference shock variance to obtain the same average effective labor supply elasticity. See Appendix A.5 for details.

Figure 5 contains the difference in multipliers, labor responses, and consumption responses across taxation schemes for the benchmark calibration, the flatter *lpe* calibration, and the lower *mpc* calibration. In particular, for each calibration, the left panel plots the difference of multipliers under the higher-progressivity and the constant-progressivity case, while the middle and the right panels plot the differences in labor and consumption responses, respectively.

Flattening *lpe* and lowering *mpc* both have an important effect on the difference of multipliers across taxation schemes. Especially initially, the difference in multipliers drops more in the flatter *lpe* calibration, but the lower *mpc* calibration also has a substantial effect on the difference of multipliers. As expected, the flatter *lpe* calibration has a larger effect on the difference of labor responses across taxation schemes, whereas the lower *mpc* calibration has a larger effect on consumption. Thus, the distributions of both *lpe* and *mpc* in our benchmark calibration are crucial for the differences in responses obtained across the two tax schemes.

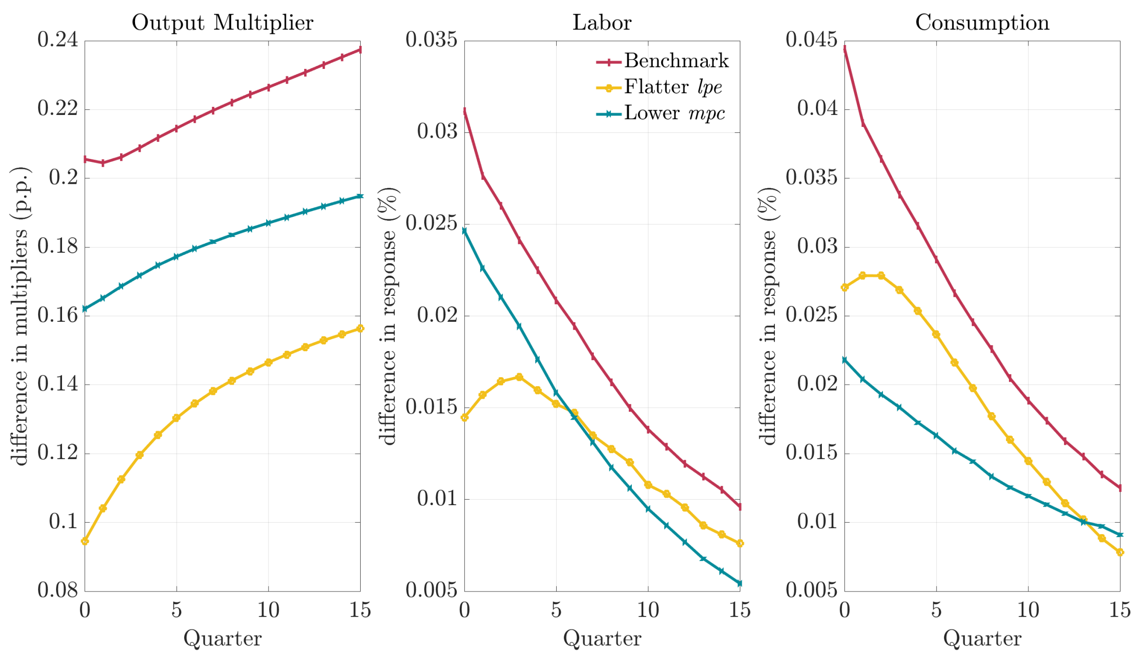

Figure 5: Difference in Multipliers across Progressivity Paths: The Role of *lpe* and *mpc*

Note: Difference in multiplier, labor responses, and consumption responses, across taxation schemes for the benchmark calibration, the "flatter *lpe*" calibration, and the "lower *mpc*" calibration. Differences are computed as the path under the higher-progressivity case minus the path under constant-progressivity case. See Appendix A.5.

5.4 Robustness

We conclude this section by conducting a series of robustness exercises. First, we explore alternative fiscal and monetary rules. Second, we compute multipliers under a flexible wage economy as well as under a neoclassical environment with no frictions. Finally, Appendix A.6 provides further robustness under alternative profit distribution rules, as well as with heterogeneity in the dis-utility of working. As we show, our results are robust to these alternative specifications.

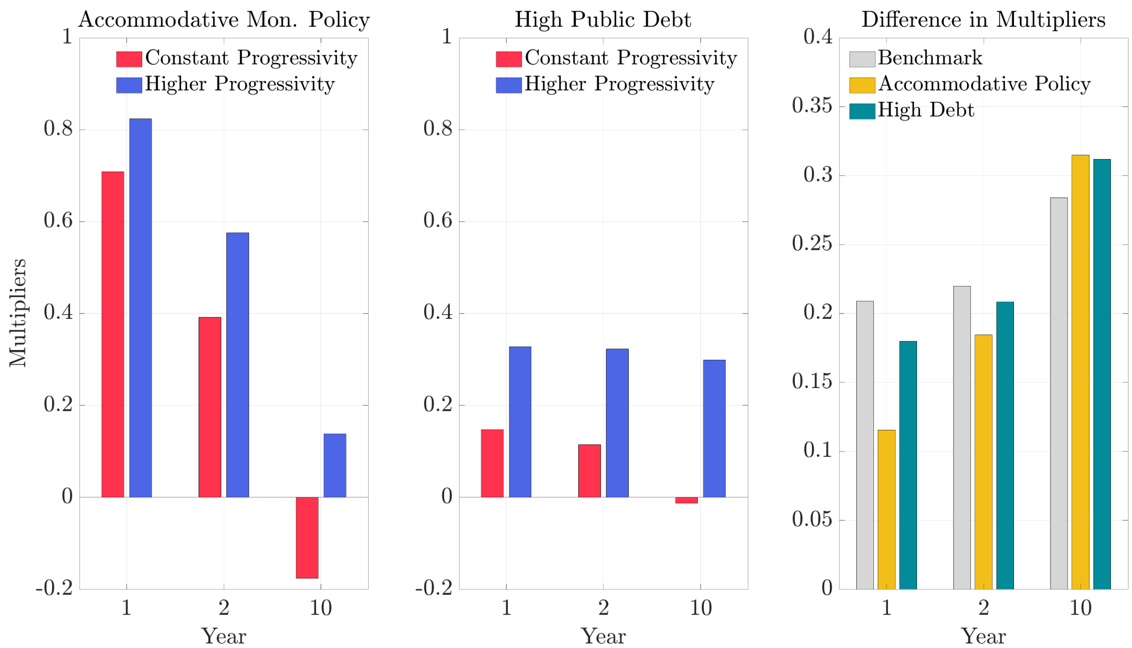

Figure 6: Robustness to Monetary Policy and Public Debt

Note: The left panel depicts cumulative multipliers for the two tax schemes—constant and higher progressivity—for the "Accommodative Monetary Policy" case. The middle panel depicts cumulative multipliers for the two tax schemes for the "High Debt" case. The right panel plots the difference in cumulative multipliers across the two tax schemes for the benchmark, the "Accommodative Monetary Policy" case and the "High Debt" case.

Monetary Policy.—Empirically, nominal interest rates barely respond to spending shocks, as pointed out in Hagedorn, Manovskii, and Mitman (2019) and as verified in Appendix C.4 for our sample. In turn, we compute multipliers under an "Accommodative Monetary Policy" where the policy rate remains constant after the spending shock.[50] Multipliers are significantly larger than under the benchmark economy with a standard Taylor rule. Impact multipliers are above one and remain well above the benchmark multipliers at

[50]We assume that the Taylor rule is reinstated after 50 years. See Hagedorn (2016) for more details on determinacy in heterogeneous agents models.

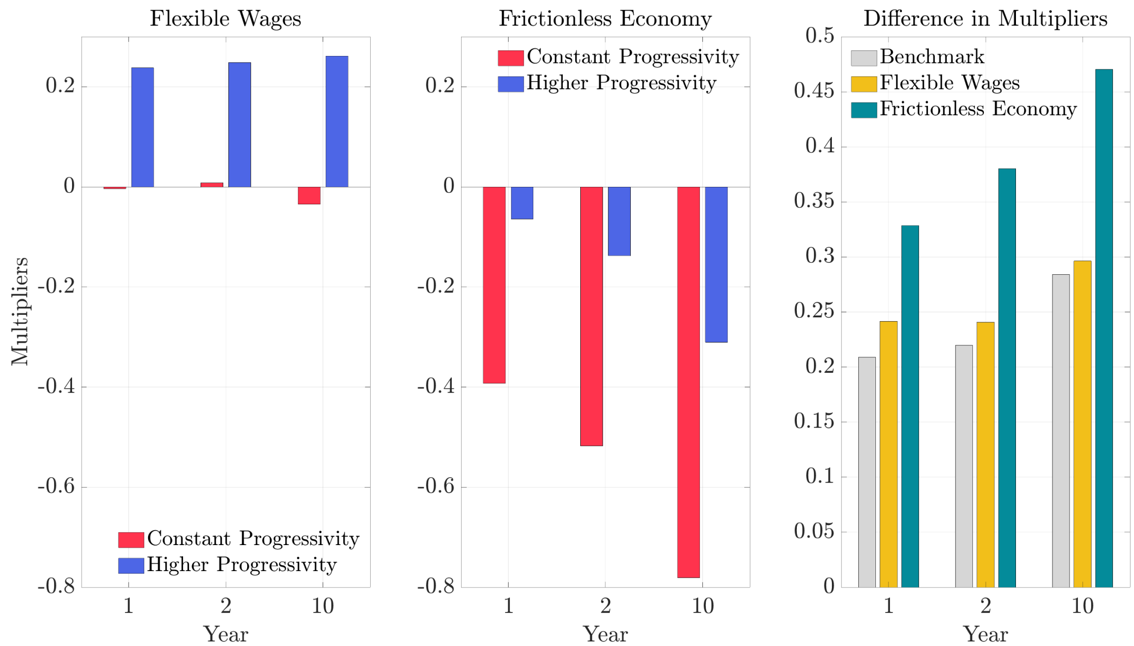

Figure 7: Robustness to Rigidities

Note: The left panel depicts cumulative multipliers for the two tax schemes—constant and higher progressivity—for the "Flexible Wage" case. The middle panel depicts cumulative multipliers for the two tax schemes for the "Frictionless Economy" case. The right panel plots the difference in cumulative multipliers across the two tax schemes for the benchmark, the "Flexible Wage" case and the "Frictionless Economy" case.

one-year and two-year horizons, as shown in the left panel of Figure 6. Yet, the difference in multipliers across the tax schemes is comparable with the benchmark, as shown in the right panel of Figure 6. Thus, while an accommodative monetary policy leads to larger multipliers, it doesn't significantly affect the difference in multipliers across taxation schemes.

Public Debt.—A larger debt issuance to finance the spending shock implies a smaller reliance on taxes and may thus limit the effect of tax progressivity on spending multipliers. To check the robustness of our results to the calibration of debt dynamics, we compute multipliers in an alternative economy with "High Debt," where $\theta = 0.75$. In that case, debt increases about twice as much as in the benchmark economy.

Larger debt issuance slightly reduces the difference in multipliers across tax schemes in the first year but has a negligible effect later on, as shown in the right panel of Figure 6. In the long run, the difference in multipliers is actually larger in the High Debt cases, as higher taxes are needed to repay the public debt. Overall, our results are robust to the degree of responsiveness in public debt: Both, the level and the difference in multipliers are only moderately affected by the degree of deficit financing.

Rigidities.—Finally, we explore the importance of rigidities in Figure 7. We compare the benchmark economy against two alternative economies: a "Flexible Wages" economy and a neoclassical "Frictionless Economy" with neither price nor investment frictions.[51] Qualitatively, the difference in multipliers across the two tax schemes is larger with fewer frictions. In the absence of price rigidities, the labor market is not demand driven, and heterogeneity in *lpe* becomes more consequential to labor responses, which reinforces the difference in multipliers across tax schemes. The levels of multipliers, however, are sensitive to frictions in the economy: Multipliers are about 15 basis points smaller with a Flexible Wages economy, and dive into negative in the Frictionless Economy. Thus, rigidities moderately dampen the differences in multipliers across tax schemes, but, as well established in the literature, they are essential to obtaining empirically reasonable levels of multipliers.[52]

Overall, multipliers are larger when financed with an increase in tax progressivity, and this result is robust to the exact dynamics of public debt or monetary policy responses.

6 Evidence

The analysis of the last two sections argues that the effects of government spending are shaped by the distribution of taxes. In this section, we provide two sets of empirical findings that substantiate this result.

First, we explore the behavior of taxes after a spending shock. We find that average tax rates (ATRs) do increase after a shock and substantially more for top-income earners. As such, the average spending shock in the United States resembles the progressive tax scheme in our model.

Second, we separate spending shocks financed with an increase in tax progressivity from the ones financed with constant or smaller progressivity and compute multipliers for each case. In line with the model, we find that multipliers are considerably smaller when spending shocks were financed with constant or smaller progressivity.

All estimations in this section use data starting in 1913, coinciding with the creation of the federal tax system in the United States. As Figure 8 shows, the largest fluctuations in spending occurred during the first half of the past century. A long time series is important to cover all large changes in spending as well as the major tax reforms.

[51] For the Flexible Wages economy, we set the cost of adjusting wages to $\Theta^w = 0$. For the Frictionless Economy, we set all price adjustment costs to zero, $\Theta = \Theta^w = 0$, as well as the cost of adjusting capital to $\phi^k = 0$.

[52] Appendix A.6 further explores how the relative contributions of heterogeneity in *lpe* and *mpc* change with the degree of wage rigidity.

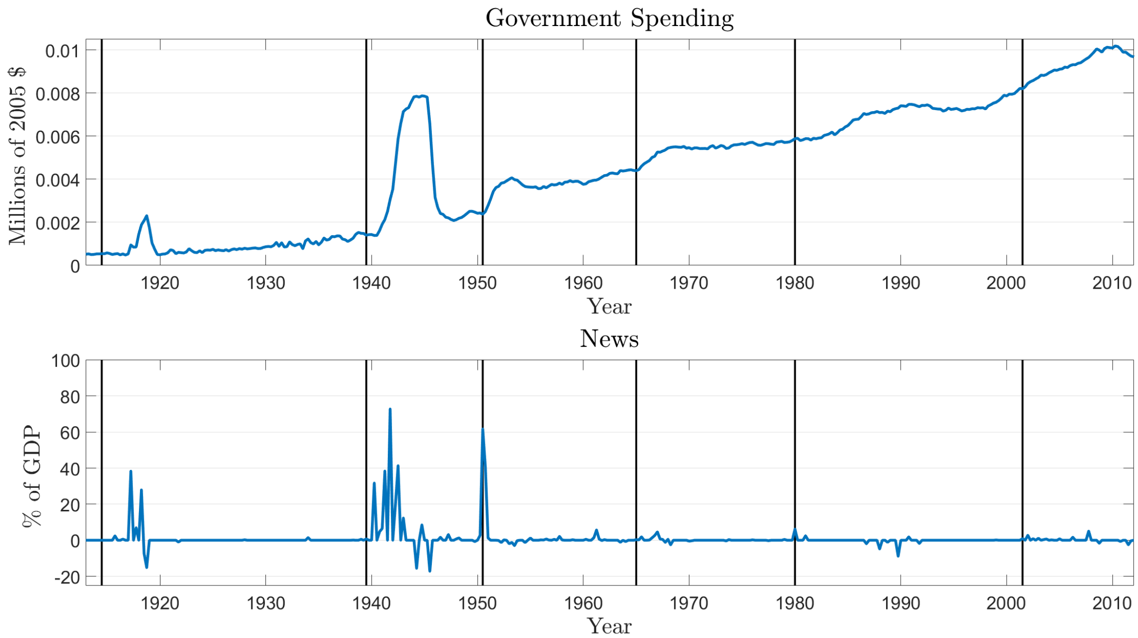

Figure 8: Defense Spending and Ramey-Zubairy Defense News

Note: "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 (World War I), 1939:Q3 (World War II), 1950:Q3 (Korean War), 1965:Q1 (Vietnam War), 1980:Q1 (Soviet Invasion of Afghanistan), and 2001:Q3 (9/11).

6.1 Multipliers and Tax Responses

We use the local projection method in Jorda (2005) to estimate responses to spending shocks, with an instrumental variable procedure as recently carried out by Ramey and Zubairy (2018). We start by estimating output effects and then move to the responses of taxes.

Spending Multipliers.—We estimate spending multipliers as follows:

$$\sum_{j=0}^{h} \Delta^j y_{t+j} = \gamma_h + \theta_h Z_t + m_h \sum_{j=0}^{h} \Delta^j g_{t+j} + \varphi trend_t + \varepsilon_{t+h} \qquad \text{for } h = 0, 1, 2, \ldots, H \tag{31}$$

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.[53] Equation (31) is estimated by a two-stage least-squares procedure, where cumulative spending growth is instrumented by an identified

[53] 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).

spending shock g_t^* to control for endogeneity.[54]

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 shock henceforth). The control Z_t includes eight lags of GDP, government spending, and the average marginal tax rate (AMTR); the trend is quartic; and the data are quarterly from 1913:Q1 through 2006:Q4.[55] We use the Newey-West correction for computing standard errors (Newey and West, 1987).

Spending induces an output expansion, with a cumulative effect of 80 cents per dollar after three years, as shown in Figure 9. This estimate is in line with common findings in the literature (Ramey, 2016), as we follow the identification and methods commonly used in the literature.[56] Next, we estimate the response of the distribution of taxes to a spending shock, a key input in our model and a novel empirical contribution.

Response of Taxes.—We estimate the dynamic response of taxes as follows:

$$\tau_{t+h} - \tau_{t-1} = \alpha_h + A_h Z_t + \beta_h \ln\left(\frac{G_{t+h}}{G_{t-1}}\right) + \phi trend_t + \epsilon_{t+h} \qquad \text{for } h = 0, 1, 2 \ldots, H \tag{32}$$

where τ_t is the ATR for a certain group of households. For each horizon h, β_h measures the change in ATRs for a 1% increase in spending over h quarters. Equation (32) is estimated by a two-stage least-squares procedure, where spending growth is instrumented by the BP and RZ shocks as before, and we use the same controls, trends, and dates. The ATR measures τ_t come from Piketty, Saez, and Zucman (2018). Figure 10 shows the response of taxes to a spending shock, evaluated at the spending path used in the model of Section 5.[57]

The estimated tax response has two remarkable features. First, ATRs do increase after a spending shock, consistent with the fact that spending shocks are financed with a mix of taxes and deficits. Second, this increase is entirely due to the response of tax rates for the top 50% of income earners. The response for the bottom 50% is essentially zero. The difference in tax rates between these two groups increases by about 4

[54] An alternative procedure to estimate the output multipliers is to project $\Delta^j y_{t+j}$ and $\Delta^j g_{t+j}$ on g_t^* separately, obtain coefficients $\beta_j^{\Delta y}$ and $\beta_j^{\Delta g}$, respectively; and, finally, compute multipliers as $m_h = \sum_{j=0}^{h} \beta_j^{\Delta y} / \sum_{j=0}^{h} \beta_j^{\Delta g}$. This alternative computation is numerically identical to the coefficient m_h obtained in equation (31). An advantage of estimating equation (31) directly is that it allows us to use more than one shock measure g_t^* as an instrument, as discussed by Ramey (2016). In addition, standard (asymptotic) inference can be used even if the instrument is a generated regressor; see Chapter 6 in Wooldridge (2010) for a further discussion.

[55] We stop our sample in 2006:Q4 to avoid using data during the Great Recession, but Appendix C shows that results are robust to using alternative time periods. We transform the annual measure of average and marginal tax rates into a quarterly one by repeating it four times. See Appendix B for data details.

[56] See Appendix C.6 for a comparison of our results with previous work.

[57] As we discuss below, the path for spending estimated from these shocks is similar to the one used in the model of Section 5.

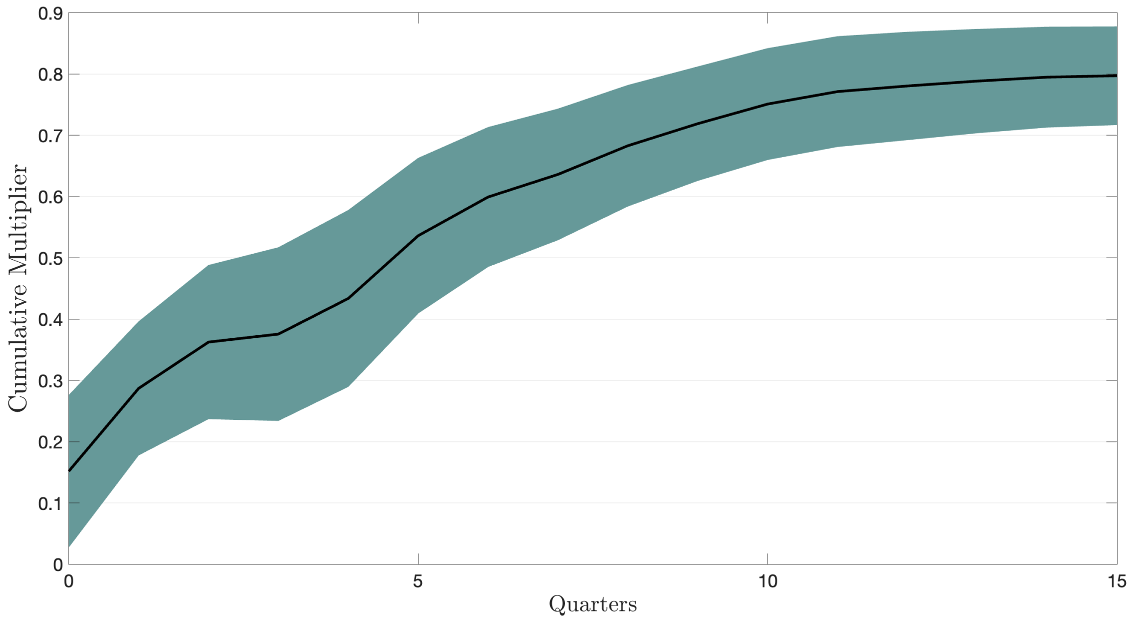

Figure 9: Cumulative Multipliers

Note: Cumulative output response to a spending shock for four years. Responses are estimated by a local projection method. The data are quarterly from 1913 to 2006. Confidence intervals are 68%.

to 5 basis points, a number comparable with the increase in the model for the progressive tax scheme.[58] As such, the average spending shock in the United States was financed with an increase of tax progressivity.

Deficits and Persistence of Spending.—We empirically verify the model calibration for the persistence of spending (ρ_G) and the response of fiscal deficits (θ). We project $\ln\left(\frac{G_{t+h}}{G_{t-1}}\right)$on $g_t^\star$ (see the left panel of Figure 11) and fit an AR(1) to the estimated response of spending to shocks.[59] While this procedure delivers a persistence of 0.92, we calibrate persistence to a slightly lower number, $\rho_G = 0.9$, to remain close to the typical estimates in the DSGE literature (Christiano, Motto, and Rostagno, 2014).

The right panel of Figure 11 plots the deficit multiplier—the increase in deficits after a $1 increase in spending—estimated using deficits to GDP as the dependent variable in equation (31). In the model, the deficit multiplier equals θ on impact, which we set at 0.5, in line with the estimate.

Taking stock, the average spending in the United States was financed with deficits and an increase in

[58]Tax data limitations before the 1960s restrict us from exploring a finer decomposition of tax rates by income quantile.

[59]For this exercise, we use the BP shock as g_t^* which measures immediate responses of spending, relative to the RZ shock, which measures news about future increases. See Appendix C.6 for a comparison of each shock effect on spending, as well as Ramey (2016) for a more detailed discussion.

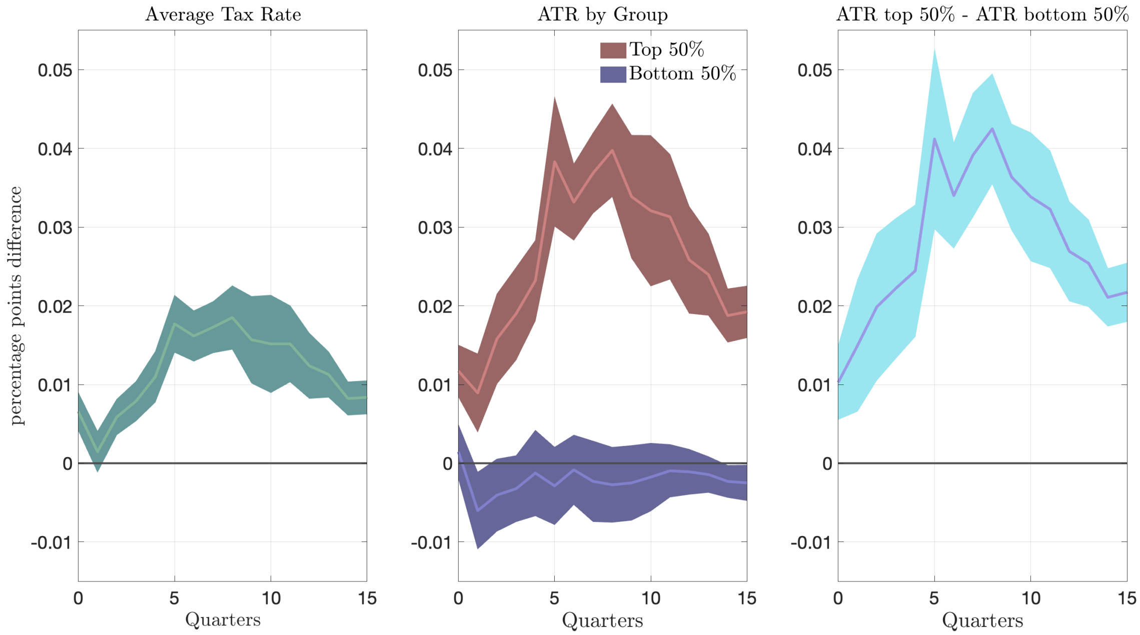

Figure 10: Average Tax Responses to a Spending Shock

Note: Average tax rates responses by income groups to a spending shock for four years. Income groups are: average response across all tax units (left panel), top 50% and bottom %50 (middle panel), and top 50% minus bottom 50% (right panel). Responses are estimated by a local projection method. The data are quarterly from 1913 to 2006. Confidence intervals are 68%.

taxes on *high-income earners*. That is, the estimated spending multiplier—which is consistent with the usual findings in the literature—should be understood *in association with* an increase in tax progressivity. The model we presented in Section 3 can rationalize this relation.

6.2 Progressivity-Dependent Multipliers

While the average tax response to a spending shock was progressive, some events—including the Vietnam War and the Reagan defense buildup—were financed more evenly across households. As such, the U.S. history of spending and taxation can be insightful to learn how the distribution of taxes shapes spending multipliers. We take advantage of these historical variations and follow a quasi-narrative approach to separate spending shocks that were financed with an increase of tax progressivity from those financed with constant or smaller progressivity.

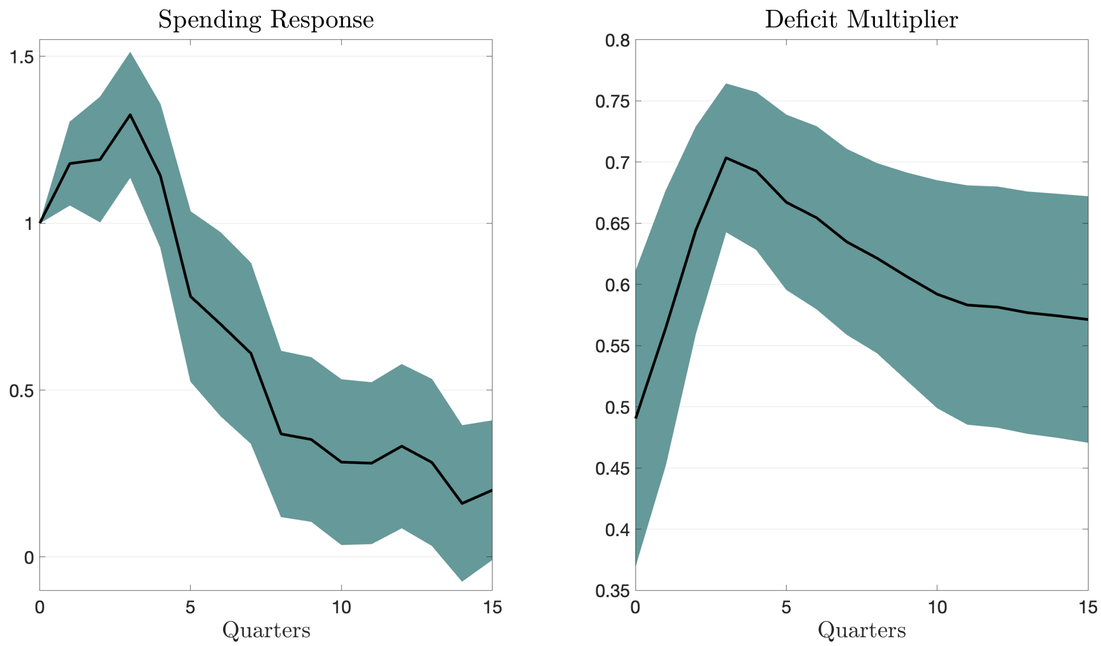

Figure 11: Persistence of Spending and Deficit Responses

Note: Responses of spending (left panel) and deficits (right panel) to a spending shocks for four years. Responses are estimated by a local projection method. The data are quarterly from 1913 to 2006. Confidence intervals are 68%.

Equation (31) can be adjusted to accommodate progressivity-dependent relations as follows:

$$\begin{aligned}\sum_{j=0}^{h} \Delta^j y_{t+j} &= \mathbb{I}\left(p_t = \mathrm{P}\right)\left\{\alpha_{P,h} + A_{P,h} Z_{t-1} + m_{P,h} \sum_{j=0}^{h} \Delta^j g_{t+j}\right\} \\ &+ \mathbb{I}\left(p_t = \mathrm{N}\right)\left\{\alpha_{N,h} + A_{N,h} Z_{t-1} + m_{N,h} \sum_{j=0}^{h} \Delta^j g_{t+j}\right\} + \phi \text{ trend}_t + \varepsilon_{t+h}\end{aligned} \tag{33}$$

where p_t is a variable that captures the progressivity of taxes used, which we discuss below, and $\mathbb{I}(\cdot)$ is an indicator function. Note that multipliers $\{m_{p,h}\}$ now depend on the tax progressivity—$p_t = P$ for spending shocks financed with an increase in tax progressivity (henceforth progressive shocks) and $p_t = N$ otherwise (non-progressive shocks). A key advantage of the local projection method, which allows us to estimate progressivity-dependent responses as the outcome of an ordinary least squares procedure.

Progressivity Selection Criterion.—Key to this approach is the selection of shocks into progressive and non-progressive. To do so, we follow a quasi-narrative approach; that is, we propose a systematic approach to categorize shocks into progressive and non-progressive and then verify that the implied classification of shocks is sensible from a historical perspective.

To estimate a measure of progressivity, we maintain the log-linear tax function used in Section 3, which—as discussed above—approximates well the U.S. federal tax code on personal income. Under this assumption, progressivity γ can easily be computed as a function of AMTR and ATR:

$$\gamma \equiv (AMTR - ATR)/(1 - ATR). \tag{34}$$

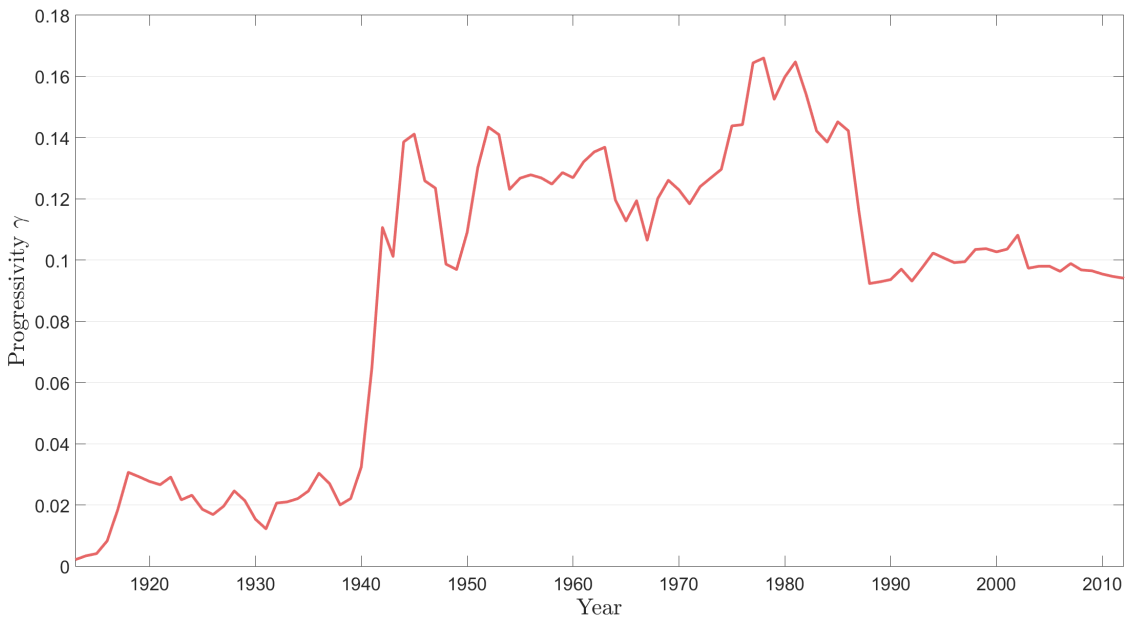

Figure 12: U.S. Federal Income Tax Progressivity

Note: Authors' computations. See Appendix B.3 for details on computations.

The computation of γ in equation (34) is exact under the assumed log-linear tax function but is also an intuitive proxy for tax progressivity. In particular, γ increases when marginal tax rates increase 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. Importantly, measures of AMTR and ATR have been constructed for the United States since 1913, and we can thus compute a measure of progressivity covering the entire period in our estimations.[60] This measure, plotted in Figure 12, captures remarkably well the historical tax

[60] We use the AMTR series constructed by Barro and Redlick (2011) and Mertens and Olea (2018) as well as IRS Statistics of Income data and the Piketty and Saez (2003) measures of income for constructing the ATR. See Appendix B.3 and Appendix B.1 for more details on the computations and data sources.

reforms since 1913, as we discuss in detail in Appendix D.

We use this measure to separate shocks into progressive or non-progressive.[61] We select a shock in quarter t as progressive if γ_t increases, on average, during the following Δ quarters: $\{p_t = P : \gamma_t^a > \gamma_{t-1}^b\}$, where $\gamma_t^a \equiv \frac{1}{\Delta_a}\sum_{j=0}^{\Delta_a}\gamma_{t+j}$ and $\gamma_{t-1}^b \equiv \frac{1}{\Delta_b}\sum_{j=1}^{\Delta_b+1}\gamma_{t-j}$. The remaining quarters are labeled non-progressive.

Note that this selection criterion is forward-looking in nature to capture whose taxes are raised subsequent to the increase in spending. Economically, it 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.[62] We select $\Delta_a = 12$ and $\Delta_b = 8$, which delivers a reasonable categorization of shocks.[63] Figure 13 shows the periods selected as progressive, together with the two measures of shocks, *BP* and *RZ*.

The selection criterion we propose is sensible from a historical perspective. WWI, WWII, and the Korean War—three wars for which the fiscal burden fell undoubtedly more on wealthier households—are categorized as progressive. The Vietnam War and the military buildup during the Reagan Administration are categorized as non-progressive, in line with the narrative discussed in Section 2. While spending shocks were smaller in the remaining years, our criterion categorizes the H. W. Bush and Clinton Administrations as progressive, a period where marginal tax rates increased at the top, and the W. Bush administration as non-progressive, when top marginal tax rates declined.[64] Thus, although a simple and uniform measure of progressivity for such a long period has clear limitations, our approach yields a historically reasonable categorization of shocks.

Multipliers and Progressivity.—The effect of government spending on output is significantly larger for shocks financed with an increase in the progressivity of taxes, as shown in Figure 14. In fact, the cumulative multiplier on output is positive only for progressive shocks: It is mildly positive on impact and steadily increases to about 0.8 after three years. For non-progressive shocks, the multiplier is initially negative and not statistically different from zero after two and three years. The p-value for the difference in multipliers across progressivity is below 5% at all horizons plotted (see Table 11).

Estimated multipliers for the progressive case are close to the average multipliers estimated in Section 6.1, because the biggest *RZ* shocks—the most important for identification—are mostly progressive. Still, the *BP* shocks are more balanced, and, as we show in Appendix C, our results hold when using each instrument

[61] Our estimate of γ includes federal income taxes but excludes payroll taxes. We exclude payroll taxes because they are exclusively used to finance Social Security benefits, which are not included in our spending measure. Appendix C.3 reports progressivity-dependent multipliers when including payroll taxes to estimate γ. As we show, our results are robust.

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

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

[64] The entire history of spending and taxation is explored in more detail in Appendix D.

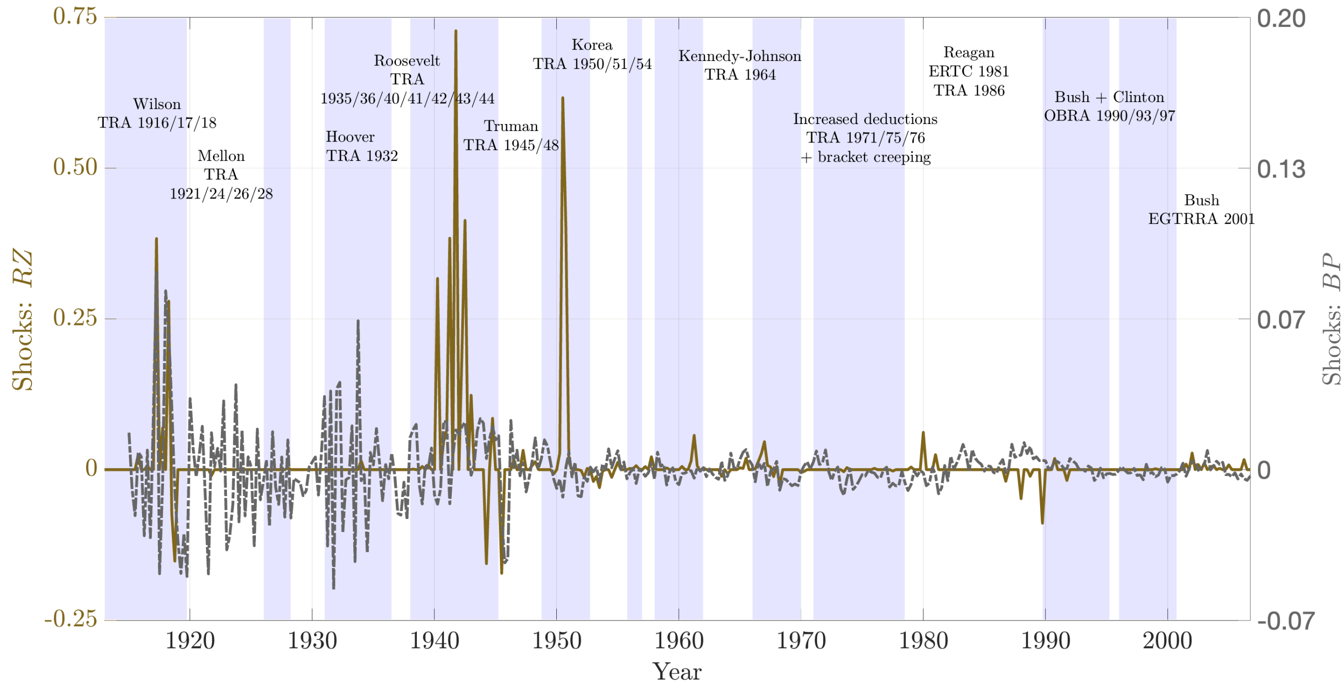

Figure 13: Spending Shocks Selection: Progressive and Non-Progressive

Note: The brown line (left scale) plots the RZ shocks as in Figure 10 (bottom panel); the black line (right scale) plots the BP shocks. Shaded areas correspond to periods of progressive shocks, $p_t = P$, and white areas depict non-progressive shocks $p_t = N$.

separately (see Table 12).

Our results are robust to several alternative controls and specifications. Recent work argued that the level of slack in the economy can affect spending multipliers (Ramey and Zubairy, 2018; Auerbach and Gorodnichenko, 2012b). We show that multipliers are larger for progressive shocks regardless of the level of slack in the economy. The recent work in Barnichon, Debortoli, and Matthes (2022) document argues that multipliers depend on the sign of the spending shock. We show that multipliers remain larger for progressive shocks when conditioning on the sign of the shock. Deficit financing could also affect the size of multipliers. We show that progressive and non-progressive spending shocks induce very similar deficit multipliers. Multipliers can be larger if monetary policy is constrained by a lower bound (Christiano, Eichenbaum, and Rebelo, 2011). We still find larger multipliers for progressive shocks when using data from 1953:Q1 to 2006:Q4, a period when monetary policy was not constrained. Appendix C contains details of these experiments as well as robustness with respect to using alternative windows Δ for the selection criterion definition, different lags and trend specifications, and different periods (starting in 1953:Q1, ending

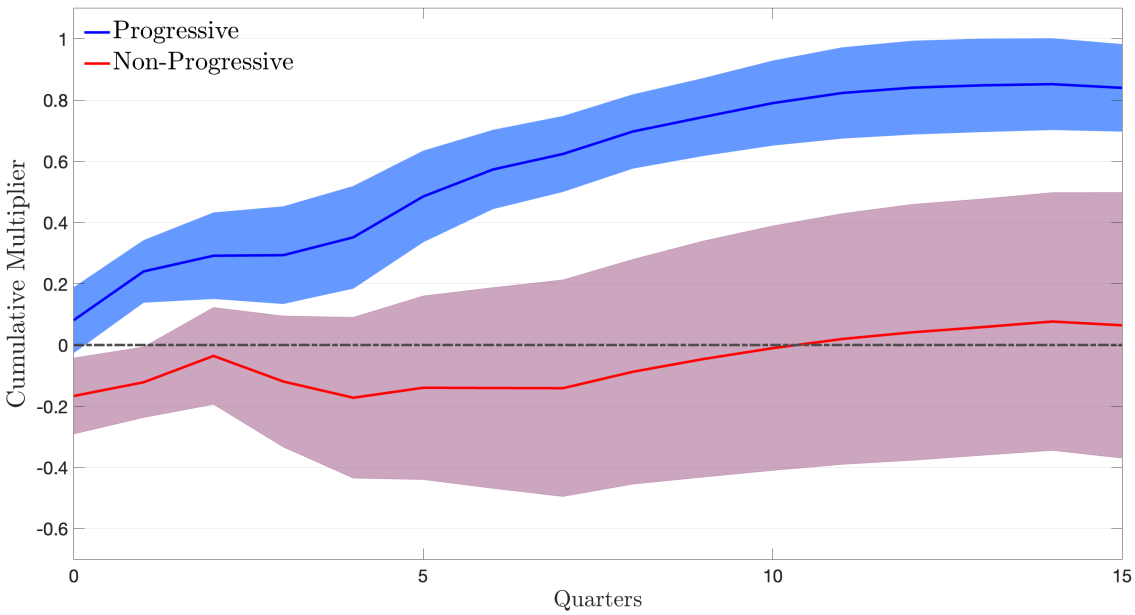

Figure 14: Progressivity-Dependent Cumulative Multipliers

Note: Cumulative output response to a spending shock for four years, progressive and non-progressive shocks. Multipliers are estimated by a local projection method. The data are quarterly from 1913 to 2006. Confidence intervals are 68%.

in 2015:Q4). Our findings are robust—spending multipliers are larger when financed with an increase in tax progressivity. We see this outcome as compelling evidence suggesting that tax progressivity shapes the effects of government spending, as implied by the model in Section 5.[65]

7 Conclusions

We developed a HANK model to analyze how the distribution of taxes shapes government spending multipliers. We introduced an extensive labor supply decision and heterogeneity in discount factors in the model, which result in cross-sectional distributions of *lpe* and *mpc* in line with evidence. The key implication of the model is a lower responsiveness to tax changes for top-income earners. In turn, spending multipliers are larger when financed with an increase in tax progressivity.

Our results are important in light of the history of the financing of spending in the United States. As we documented, the fiscal burden subsequent to a spending shock was, on average, tilted toward high-income

[65] We conducted similar exercises at the household level using TAXSIM data in a previous version of the paper. Because TAXSIM is annual and starts only in 1960, the results were noisy but qualitatively in line with predictions of the model. Results are available upon request.

earners. Furthermore, while the average tax response was progressive, there was a large historical variation across events, and some events were financed more evenly across households. These differences in financing have quantitatively large implications on multipliers through the lens of the model. This should be kept in mind when estimating and analyzing the effects of government spending.

At a more general level, our analysis indicates that the distribution of taxes should be carefully accounted for when analyzing any policy that has fiscal consequences. Monetary policy, inflation targeting, exchange rate policy, and transfer policy are all examples of policies that are not neutral for the government's budget constraint. A complete analysis of such policies should take into consideration their effects on the distribution of taxes.

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A Model Appendix

A.1 Model Details

We use this appendix to discuss in more detail the household's problem and the financial intermediary's problem.

A.1.1 Details on Household's Problem

Let $V_t^h(a,x,\beta)$ be the maximal attainable value in period t to a households who works h hours, has assets a, idiosyncratic productivity x, and discount factor β. That is, $V_t^h(a,x,\beta)$ is the value conditional on working h hours, and given as

$$\begin{aligned} V_t^h(a,x,\beta) &= \max_{c,a'} \left\{\log(c) - Bh + \beta\mathbb{E}\left[V_{t+1}(a',x',\beta')|x,\beta\right]\right\} \quad (A.1) \\ \text{subject to} & \\ c + a' &\leq w_t^h xh + (1+r_t)a - \mathcal{T}_t(w_t^h xh, r_t a) + T_t + d_t^h(x) \\ a' &\geq 0 \end{aligned}$$

Let $c_t^h(a,x,\beta)$ and $a_t^{h\prime}(a,x,\beta)$ denote a household's optimal policies conditional on working h hours, which achieve value $V_t^h(a,x,\beta)$ in equation (A.1).

Let ϵ_h be the preference shock for each level of working hours h, and collect them in the vector $\vec{\epsilon} = \{\epsilon_0, \epsilon_{\bar{h}}\}$. The value $V_t(a,x,\beta)$ is the expectation over each possible level of working hours. That is

$$V_t(a,x,\beta) = \mathbb{E}_{\vec{\epsilon}}\left[\max\left\{V_t^0(a,x,\beta)+\epsilon_0,\quad V_t^{\bar{h}}(a,x,\beta)+\epsilon_{\bar{h}}\right\}\right] \quad (A.2)$$

$$= \varrho \ln\left(\sum_{h\in\{0,\bar{h}\}} \exp\left(\frac{V_t^h(a,x,\beta)}{\varrho}\right)\right) \quad (A.3)$$

where the expectation in equation (A.2) is taken over $\vec{\epsilon}$, and the expression in equation (A.3) derives from assuming that ϵ_h follows a Gumbel distribution with variance ϱ. In turn, the probability $\mathbb{h}_t^h(a,x,\beta)$ of working h hours at time t is given as

$$\mathbb{h}_t^h(a,x,\beta) = \frac{\exp\left(\frac{V_t^h(a,x,\beta)}{\varrho}\right)}{\sum_{\tilde{h}\in\{0,\bar{h}\}}\exp\left(\frac{V_t^{\tilde{h}}(a,x,\beta)}{\varrho}\right)} \quad (A.4)$$

A.1.2 Details on Financial Intermediary's Problem

The problem of the financial intermediary reads

$$F_t(A_t^F, K_t^F, D_t^F) = \max_{A_{t+1}^F, K_{t+1}^F, D_{t+1}^F} \left\{ d_t^F + \frac{1}{1+r_{t+1}} F_{t+1}(A_{t+1}^F, K_{t+1}^F, D_{t+1}^F) \right\} \tag{A.5}$$

subject to

$$d_t^F + q_t^k K_{t+1}^F + D_{t+1}^F + (1+r_t)A_t^F = A_{t+1}^F + \left(q_t^k + r_t^k\right) K_t^F + (1+r_t^g)D_t^F.$$

First-order conditions with respect to capital and government debt read

$$(K_{t+1}^F) : 0 = -\, q_t^k + \frac{1}{1+r_{t+1}} \frac{\partial F_{t+1}(\cdot)}{\partial K_{t+1}^F} \tag{A.6}$$

$$(D_{t+1}^F) : 0 = -\, 1 + \frac{1}{1+r_{t+1}} \frac{\partial F_{t+1}(\cdot)}{\partial D_{t+1}^F}. \tag{A.7}$$

Using envelope theorem on equation (A.5) we obtain

$$\frac{\partial F_t(\cdot)}{\partial K_{t+1}^F} = q_t^k + r_t^k \tag{A.8}$$

$$\frac{\partial F_t(\cdot)}{\partial D_{t+1}^F} = 1 + r_t^g. \tag{A.9}$$

Introducing (A.8) into (A.6) and (A.9) into (A.7)

$$q_t^k = \frac{1}{1+r_{t+1}} \left(q_{t+1}^k + r_{t+1}^k\right) \tag{A.10}$$

$$1 + r_{t+1}^g = 1 + r_{t+1} \tag{A.11}$$

which are equations (12) and (13).

To see the liability structure indeterminacy, consider the value of purchasing one unit of government bond which can be financed in two possible ways: either by issuing equity or by raising deposits. Let ΔF_d and ΔF_A be the value of financing the bond with equity and deposits, respectively. The value ΔF_d is given by $\Delta F_d = -1 + \frac{1}{1+r_{t+1}} \frac{\partial F_{t+1}(\cdot)}{\partial D_{t+1}^F}$, that is, the unit cost today of raising equity today plus the discounted pay-off of having the bond next period $\frac{\partial F_{t+1}(\cdot)}{\partial D_{t+1}^F}$. Similarly, the value ΔF_A is given by $\Delta F_A = \frac{1}{1+r_{t+1}} \frac{\partial F_{t+1}(\cdot)}{\partial A_{t+1}^F} + \frac{1}{1+r_{t+1}} \frac{\partial F_{t+1}(\cdot)}{\partial D_{t+1}^F}$, that is, the financing cost $\frac{\partial F_{t+1}(\cdot)}{\partial A_{t+1}^F}$, which is only paid next period and thus discounted, plus the pay-off, which is same as before. The envelope theorem implies $\frac{\partial F_t(\cdot)}{\partial A_t^F} = -(1+r_t)$ and thus $\Delta F_d = \Delta F_A$.

A.2 Steady-State Solution and Transition Computations

A.2.1 Steady State

To solve for the steady state of the economy, we need to find the real interest rate r and the level of taxes λ. We explain next how we do this.

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

1. Guess values for the interest rate r and the tax parameter λ. Recall that $r^k = r$ and $q_k = 1$ in steady-state. Compute implied wages w from the price Phillips curve (5), and w^h from the wage Philips curve (8).

2. Solve for household policies by value function iteration. In particular, for a given guess of the value function $V(a, x, \beta)$, update the value function of working h hours in equation (A.1) as

$$\hat{V}^h(a, x, \beta) = \max_{a' \geq 0} \left\{ \log(c) - Bh + \beta \sum_{(x', \beta') \in (\vec{x}, \vec{\beta})} \pi_x(x', x) \pi_\beta(\beta', \beta) V(a', x', \beta') \right\}$$

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

where $\mathcal{T}(wxh, ra) = \tau_k ra + wxh - \lambda(wxh)^{1-\gamma}$. Then, using equation (A.3), update the value function as: $\hat{V}(a, x, \beta) = \varrho \ln \left(\sum_{h \in \{0, \bar{h}\}} \exp\left(\frac{\hat{V}^h(a, x, \beta)}{\varrho} \right) \right)$. Iterate until $\left\| \hat{V} - V \right\| < \varepsilon^V$. We use $\varepsilon^V = 1e-10$.

3. Compute the stationary measure implied by the optimal policies of step 2. In particular, for a given guess $\mu(a, x, \beta)$, compute implied measure $\hat{\mu}(a, x, \beta)$ as

$$\hat{\mu}(a_{i'}, x_{j'}, \beta_{k'}) = \sum_{i=1}^{N_a} \sum_{j=1}^{N_x} \sum_{k=1}^{N_\beta} \sum_{h \in \{0, \bar{h}\}} \mathbb{L}\left\{ a_{i'} = a^{h\prime}(a_i, x_j, \beta_k) \right\} \pi_x(x_{j'}, x_j) \pi_\beta(\beta_{k'}, \beta_k) \mathbb{h}^h(a_i, x_j, \beta_k) \mu(a_i, x_j, \beta_k)$$

where $\mathbb{L}$ computes a linear interpolation: $\mathbb{L}(a_i, a') = \mathbb{I}(a' \in (a_{i-1}, a_i]) \frac{a - a_{i-1}}{a_i - a_{i-1}}$. Iterate until $\|\hat{\mu} - \mu\| < \varepsilon^\mu$. We use $\varepsilon^\mu = 1e - 10$.

4. Compute $\hat{\lambda}$ so that, given the household policies (step 2) and the measure (step 3), the government budget constraint holds: $\hat{\lambda} = \left[\int (y_\ell(a, x, \beta) + \tau_k a)\, d\mu(a, x, \beta) - (G + rD + T) \right] / \left[\int y_\ell(a, x, \beta)^{1-\gamma} d\mu(a, x, \beta) \right]$, with $y_\ell(a, x, \beta) = wxh(a, x, \beta)$ the labor income. Similarly, compute excess demand of government

bonds: $E^A = A - (K + D)$, where $A = \int a d\mu(a, x, \beta)$ and K is given by the intermediate-good producers' first-order condition given prices and labor supplied by households $L = \int x h(a, x, \beta) d\mu(a, x, \beta)$.

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

A.2.2 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 $V_{\bar{T}}(a, x, \beta) = V(a, x, \beta)$ and that the measure at time $t = 1$ is equal to the steady-state value $\mu_1(a, x, \beta) = \mu(a, x, \beta)$. Then, given a guess for taxes and prices $\{\lambda_t, w_t^h, r_t\}_{t=1}^{\bar{T}}$ such that $\left(\lambda_{\bar{T}}, w_{\bar{T}}^h, r_{\bar{T}}\right) = \left(\lambda, w^h, r\right)$, we solve the household problem backwards and iterate on the sequence $\{\lambda_t, w_t^h, r_t\}_{t=1}^{\bar{T}}$ using a quasi-Newton algorithm to clear markets. More formally, we proceed as follows:

1. Guess sequences $\left\{r_t^k, \Pi_t, w_t^h, \lambda_t, d_t\right\}_{t=1}^{\bar{T}}$ for firms' real rates, inflation, household wages, taxes and dividends—such that $(r_{\bar{T}}^k, \Pi_{\bar{T}}, w_{\bar{T}}^h, \lambda_{\bar{T}}, d_{\bar{T}}) = (r, \Pi, w^h, \lambda, 0)$. Given the path for inflation, compute the nominal rate $\{i_t\}_{t=1}^{\bar{T}}$ using the Taylor rule in equation (15), assuming that the nominal rate is fixed at the moment of the shock. Compute the real rate $\{r_t\}_{t=1}^{\bar{T}}$ using the Fisher equation (16). Finally, compute $\{q_t^k\}_{t=1}^{\bar{T}}$ using the financial intermediaries' first-order condition (12), and $\delta_t(x)$ using the rule for profits distribution.

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

$$V_t^h(a, x, \beta) = \max_{a' \geq 0} \left\{ \log(c) - Bh + \beta \sum_{(x', \beta') \in (\vec{x}, \vec{\beta})} \pi_x(x', x) \pi_\beta(\beta', \beta) V_{t+1}(a', x', \beta') \right\}$$

$$c + a' \leq w_t x h + (1 + r_t) a - \mathcal{T}_t(w_t x h, r_t a) + T + \delta_t(x)$$

where $\mathcal{T}_t(w_t x h, r_t a) = \tau_k r_t a + w_t x h - \lambda_t (w_t x h)^{1-\gamma_t}$. We then obtain $V_t(a, x, \beta) = \varrho \ln\left(\sum_{h \in \{0, \bar{h}\}} \exp\left(\frac{\hat{V}_t^h(a, x, \beta)}{\varrho}\right)\right)$ and iterate backwards. As terminal condition, use $V_{\bar{T}}(a, x, \beta) = V(a, x, \beta)$.

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

compute $t+1$ measure as

$$\mu_{t+1}(a_{i'}, x_{j'}, \beta_{k'}) = \sum_{i=1}^{N_a}\sum_{k=1}^{N_\beta}\sum_{k=1}^{N_\beta}\sum_{h\in\{0,\bar{h}\}} \mathbb{L}\{a_{i'} = a'_t(a_i, x_j, \beta_k)\}\pi_x(x_{j'}, x_j)\pi_\beta(\beta_{k'}, \beta_k)\mathbb{h}_t^h(a_i, x_j, \beta_k)\mu_t(a_i, x_j, \beta_k)$$

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

4. Compute market clearing errors:

- $E_t^r = r_t^k - \hat{r}_t^k$, where $\hat{r}_t^k$ is computed using the intermediate-good producers' first-order condition, with labor and capital computed from the households' policies $L_t = \int xh_t(a, x, \beta)d\mu_t(a, x, \beta)$ and $K_t = (A_t - D_t)/q_{t-1}^k$, with $A_t = \int a d\mu_t(a, x, \beta)$ and D_t given by equation (29); and the marginal cost $\mathcal{M}_t$ being computed from the Philips curve (5);
- $E_t^q = q_t^k - \hat{q}_t^k$, where $\hat{q}_t^k$ is computed using the capital good producers' first-oder condition (10) and capital is computed from the households' policies;
- $E_t^w = w_t^h - \hat{w}_t^h$ where $\hat{w}_t^h$ is computed using the wage Philips curve (8), with w_t given by the intermediate-good producers' first-order condition;
- $E_t^G = G_t + (1 + r_t)D_t + T_t - D_{t+1} - \int \mathcal{T}_t(w_t xh, r_t a)d\mu_t(a, x, \beta)$ the error in government budget constraint;
- and $E_t^d = d_t - \hat{d}_t$, where $\hat{d}_t$ is obtained from adding up realized profits from intermediate-good producers, capital good producers, labor unions and financial intermediaries at guessed prices.

Let $E_t = \left(E_t^r, E_t^q, E_t^w, E_t^G, E_t^d\right)'$ collect all errors. Let $\mathcal{E}(\mathcal{X})$ collect the $5\bar{T} \times 1$ errors for all periods along the transition, where $\mathcal{X} = \left\{r_t^k, \Pi_t, w_t^h, \lambda_t,\right\}_{t=1}^{\bar{T}}$. An equilibrium can be written as

$$\mathcal{E}(\mathcal{X}) = 0 \tag{A.12}$$

We solve for $\mathcal{X}$ in equation (A.12) using a quasi-Newton method.

When computing the fixed nominal rate case, the algorithm is modified as follows. We guess the same five sequences $\left\{r_t^k, \Pi_t, w_t^h, \lambda_t, d_t\right\}_{t=1}^{\bar{T}}$ for firms' real rates, inflation, household wages, taxes and dividends. Given the path for inflation and the fixed nominal rate for 50 years we use the Fisher equation (16) to compute the real rate. The rest of the algorithm is as above. We additionally check that inflation is back to steady state after 50 years, which we find to be the case.

A.3 *mpc* and *lpe* computations

A.3.1 *mpc* computations

We compute the quarterly *mpc* in Table 3 using the steady-state consumption policies. The only caveat is the effect that transfers have on the probability of working. In particular, let $s = (a, x, \beta)$ denote the state of the household and Δ be the transfer (e.g.: \$500 dollars). With a slight abuse of notation, denote $s + \Delta = (a + \Delta, x\beta)$ as the state with an additional Δ of wealth. We compute *mpc* for each state s as

$$mpc(s) = \frac{\sum_h \left[\mathbb{h}^h(s+\Delta)c_t^h(s+\Delta) - \mathbb{h}^h(s)c_t^h(s)\right]}{\Delta} \tag{A.13}$$

where $\mathbb{h}^h(s)$ is the probability of working h hours, and $c_t^h(s)$ is the consumption conditional on working h hours. That is, we integrate over the working preference shock when computing *mpc*.

The annual *mpc* in Table 3 is similar to the quarterly one, but it requires following individuals over time. In particular, let $\Gamma_j(\tilde{s}, s)$ be to probability that a household with state s reaches state $\tilde{s}$ in j periods. Then, we compute the annual *mpc* as

$$mpc^{\text{annual}}(s) = \sum_{j=0}^{3} \frac{\sum_h \left[\mathbb{h}^h(\tilde{s}+\Delta_j)c_t^h(\tilde{s}+\Delta_j)\Gamma_j(\tilde{s}+\Delta_j, s+\Delta) - \mathbb{h}^h(\tilde{s})c_t^h(\tilde{s})\Gamma_j(\tilde{s}, s)\right]}{\Delta} \tag{A.14}$$

where $\Delta_j = \Delta$ for $j = 1$ and zero otherwise—and note that $\Gamma_0(\tilde{s}, s) = 1$ if $\tilde{(s)} = s$ and zero otherwise. Thus, the annual *mpc* takes into account the effect that a transfer Δ has on the probability of reaching state $\tilde{s}$.

A.3.2 *lpe* computations

To compute *lpe*, we follow the method of Chang and Kim (2006). Using steady-state policies, we simulate a panel of 50,000 households for 1120 periods. We drop the first 1000 periods and aggregate the last 120 periods to build a 30 years annual frequency panel containing yearly means of: hours, wages, total income, and consumption, for each household. Each year, we drop all observations with zero hours worked during the entire year. Then, we sort households into quintiles each period by their income that period, and finally run equation (21). To avoid a sample selection bias, we use the labor-income households would have if working when sorting them into quintiles.

We compute the tax elasticity lpe^τ out of a persistent increase in labor taxes. In particular, let $\tau_\ell(y_\ell) = 1 - \lambda y_{ell}^{-\gamma}$ be the steady-state tax rate for an income level y_ℓ. We temporarily increase labor tax rates by Δ_t so that, t periods after the increase, tax rates are $\tau_{\ell,t}(y_\ell) = (1 + \Delta_t)\tau_\ell(y_\ell)$. We set $\Delta_t = \rho^\Delta \Delta_{t-1}$, with

$\Delta_1 = 1\%$ for the first period and $\rho^{\Delta} = 0.9$. We perform the exercise in partial equilibrium where all prices are kept constant. Let $\mathbb{h}_t^{\bar{h}}(s)$ be the probability that a household with state s works $\bar{h} > 0$ hours t periods after the tax increase. We compute $lpe_t^{\tau}(s)$ for household s as the change in the probability of working: $lpe_t^{\tau}(s) = \frac{\mathbb{h}_t^{\bar{h}}(s) - \mathbb{h}^{\bar{h}}(s)}{\mathbb{h}^{\bar{h}}(s)}$. We then average $lpe_t^{\tau}(s)$ by income groups and report the elasticity for the first period, $t = 1$.

A.3.3 Marginal Propensities to Earn

For completeness, we also report marginal propensities to earn (*mpe*) along the income distribution. We compute *mpe* out of a one-time unexpected windfall in the model. While it depends on the size of the windfall, the model-implied aggregate *mpe* is somewhat larger than empirical estimates (Imbens, Rubin, and Sacerdote, 2001, Golosov, Graber, Mogstad, and Novgorodsky, 2021)—as typically found in the literature (Auclert, Bardóczy, and Rognlie, 2023).

In particular, we replicate the experiment in Golosov, Graber, Mogstad, and Novgorodsky (2021) (GGMN) in our model. Starting from the steady-state distribution, we increase each household's assets by the size of the windfall. We compute average labor earnings of households for the next 20 quarters using non-stochastic simulation (Young, 2010)—as we did for annual *mpc*s in equation (A.14). As control group, we also simulate a panel of households not experiencing a wealth shock. We compute *mpe* as the difference between the average annual after-tax labor earnings of the two groups, relative to the windfall. Following GGMN, we report *mpe* for three windfall sizes: a small windfall, at \$165,000; a medium windfall, at \$650,000; and a large windfall, at \$2,000,000.[66] We obtain *mpe*s equal to: 0.06, 0.05, 0.03, for small, medium and large windfall sizes, respectively; compared to 0.06, 0.03 and 0.01 estimated in GGMN. Table 5 also reports the model-implied distribution of *mpe* by income quartile.

	Data	Model	Q1	Q2	Q3	Q4
Small-windfall *mpe*	0.06	0.06	0.04	0.08	0.07	0.04
Medium-windfall *mpe*	0.03	0.05	0.03	0.06	0.06	0.05
Large-windfall *mpe*	0.01	0.03	0.02	0.03	0.04	0.04

Table 5: Marginal Propensities to Earn

Note: 'Data' reports *mpe* as estimated in GGMN, Figure 3.5; 'Model' reports the aggregate annual *mpe* in the model, averaged over 5 years; 'Q1' to 'Q4' report *mpe* by income quartile in the model. We report *mpe* for three windfall sizes.

[66] GGMN group prizes in three bins: from \$30,000 to \$300,000; from \$300,000 to \$1,000,000; and above \$1,000,000.

A.4 Analytical Results: Derivations

This appendix provides the derivation of the analytical expressions presented in Section 4.

Labor.—For any variable z, let $z_t(s)$ denote the value of that variable t periods after the tax change for a household with state s, and let $z(s)$ be its steady-state counterpart. Recall that $\Delta\tau(s) = \frac{\tau_{\ell 1}(s)-\tau_{\ell}(s)}{\tau_{\ell}(s)}$ the proportional tax change the first period after the change in taxes. One can express $\Delta L = \frac{L_1 - L}{L}$ as

$$
\begin{aligned}
\Delta L &= \frac{1}{L}\int x(s)(h_1(s)-h(s))d\mu(s) \\
&= \int \frac{x(s)h(s)}{L}\,\frac{(h_1(s)-h(s))/h(s)}{(\tau_{\ell 1}(s)-\tau_{\ell}(s))/\tau_{\ell}(s)}\,\frac{\tau_{\ell 1}(s)-\tau_{\ell}(s)}{\tau_{\ell}(s)}d\mu(s) \\
&= -\int \frac{x(s)h(s)}{L}\; lpe^{\tau}(s)\;\Delta\tau(s)d\mu(s) \\
&= -\int lpe^{\tau}(s)\;\Delta\tau(s)\;\omega^{\ell}(s)d\mu(s)
\end{aligned}
$$

where, as specified above, $lpe^{\tau}(s) = \frac{(h_t(s)-h(s))/h(s)}{(\tau_{\ell 1}(s)-\tau_{\ell}(s))/\tau_{\ell}(s)}$ and $\omega^{\ell}(s) = \frac{x(s)h(s)}{L}$. This recovers equation (22). Note that

$$
\int \omega^{\ell}(s)d\mu(s) = \int \frac{x(s)h(s)}{L}d\mu(s) = 1
$$

so $dp(s) \equiv \omega^{\ell}(s)d\mu(s)$ is a well-defined measure. Thus, one can rewrite (22) as

$$
\Delta L = -\int lpe^{\tau}(s)\;\Delta\tau(s)\;dp(s)
$$

and (23) follows from the definition of covariance.

Consumption.—To derive the equation for consumption, let us first note that a change in after-tax labor income $\tilde{y}_1(s) - \tilde{y}(s)$ can be decomposed as

$$
\begin{aligned}
\tilde{y}_1(s) - \tilde{y}(s) &= (1-\tau_{\ell 1}(s))w^h x(s)h_1(s) - (1-\tau_{\ell}(s))w^h x(s)h(s) \\
&= w^h x(s)\left(h_1(s)-h(s)\right) - \left[\tau_{\ell 1}(s)w^h x(s)h_1(s) - \tau_{\ell}(s)w^h x(s)h(s)\right] \\
&= w^h x(s)\left(h_1(s)-h(s)\right) - \left[T_1(s) - T(s)\right]
\end{aligned}
$$

where $T_1(s) = \tau_{\ell 1}(s) w^h x(s) h_1(s)$ is total tax paid by a household with state s the first period after the change in taxes. Thus, a change in consumption $dC = C_1 - C$ can be expressed as

$$\begin{aligned} dC &= \int (c_1(s) - c(s)) d\mu(s) = \int \frac{c_1(s) - c(s)}{\tilde{y}_1(s) - \tilde{y}(s)} (\tilde{y}_1(s) - \tilde{y}(s)) d\mu(s) \\ &= \int mpc(s) \left\{ w^h x(s) \left(h_1(s) - h(s) \right) - \left[T_1(s) - T(s) \right] \right\} d\mu(s) \\ &= - \int mpc(s) dT(s) d\mu(s) + \int mpc(s)\ w^h x(s)\ \left(h_1(s) - h(s) \right) d\mu(s) \\ &= \underbrace{- \int mpc(s) dT(s) d\mu(s)}_{tax\ burden\ channel} \ \underbrace{+ \left[\int mpc(s)\ lpe^{\tau}(s)\ \Delta\tau(s) \omega^{\ell}(s) d\mu(s) \right] w^h L}_{labor\ supply\ channel} \end{aligned}$$

where $mpc(s) = \frac{c_1(s) - c(s)}{\tilde{y}_1(s) - \tilde{y}(s)}$, and $dT(s) = T_1(s) - T(s)$. This recovers equation (24). Equation (25) follows from covariance definition. Finally, note that we can use the same measure $dp(s)$ defined above to obtain

$$labor\ supply\ channel = \left[\int mpc(s)\ lpe^{\tau}(s)\ \Delta\tau(s) dp(s) \right] w^h L$$

and using again the definition of covariance delivers equation (26).

Back-of-the-envelope computations.—We derive next the formal relationship between $\mathbb{E}^{\ell}\left[\Delta\tau_{top}\right]$ and $\mathbb{E}^{\ell}\left[\Delta\tau_{all}\right]$ such that the two tax experiments generate the same revenues, taking into account behavioral responses. For any distribution of taxes $\{\Delta\tau(s)\}$, labor income of household s under the new policy is

$$\begin{aligned} y_1(s) = w^h x(s) h_1(s) &= w^h x(s) \left[\frac{\left(h_1(s) - h(s) \right) / h(s)}{\left(\tau_{\ell 1}(s) - \tau_{\ell}(s) \right) / \tau_{\ell}(s)} \frac{\tau_{\ell 1}(s) - \tau_{\ell}(s)}{\tau_{\ell}(s)} + 1 \right] h(s) \\ &= y(s) \left[1 - lpe^{\tau}(s) \Delta\tau(s) \right]. \end{aligned}$$

Therefore, fiscal revenues in the first period after the tax change equate

$$\begin{aligned} R_1 &= \int \tau_{\ell 1}(s) y_1(s) d\mu(s) = \int (1 + \Delta\tau(s)) \tau_{\ell}(s) y_1(s) d\mu(s) \\ &= \int (1 + \Delta\tau(s)) \left[1 - lpe^{\tau}(s) \Delta\tau(s) \right] \tau_{\ell}(s) y(s) d\mu(s) \\ &\approx R + \int \Delta\tau(s) \left(1 - lpe^{\tau}(s) \right) \tau_{\ell}(s) y(s) d\mu(s) \\ &\approx R + \left[\int \Delta\tau(s) \tau_{\ell}(s) \left(1 - lpe^{\tau}(s) \right) \omega^{\ell}(s) d\mu(s) \right] w^h L, \end{aligned}$$

where $R = \int \tau_{\ell}(s) y(s) d\mu(s)$ are the fiscal revenues in steady state and we approximated to the square of tax changes as zero: $\left(\Delta\tau(s) \right)^2 \approx 0$.

In the *all* experiment, all households face the same change in tax $\Delta\tau_{all}$. Thus, we obtain

$$\begin{aligned} R_1^{all} &\approx R + \Delta\tau_{all}\left[\int \tau_\ell(s)\,(1 - lpe^\tau(s))\omega^\ell(s)d\mu(s)\right] w^h L \\ &\approx R + \mathbb{E}^\ell\left[\Delta\tau_{all}\right]\mathbb{E}^\ell\left[\tau_\ell(1 - lpe^\tau)\right] w^h L. \end{aligned}$$

where we used that $\mathbb{E}^\ell\left[\Delta\tau_{all}\right] = \Delta\tau_{all}$, since taxes change the same for all s in the *all* case.

Similar computations for the *top* experiment deliver

$$\begin{aligned} R_1^{top} &\approx R + \left[\Delta\tau_{top}\int_{s\in top} \tau_\ell(s)\,(1 - lpe^\tau(s))\omega^\ell(s)d\mu(s)\right] w^h L \\ &\approx R + \Delta\tau_{top}\left[\int_{s\in top} \omega^\ell(s)d\mu(s)\right]\mathbb{E}^\ell\left[\tau_\ell(1 - lpe^\tau)|s \in top\right] w^h L \\ &\approx R + \mathbb{E}^\ell\left[\Delta\tau_{top}\right]\mathbb{E}^\ell\left[\tau_\ell(1 - lpe^\tau)|s \in top\right] w^h L. \end{aligned}$$

where we used that $\mathbb{E}^\ell\left[\Delta\tau_{all}\right] = \int_{s\notin top} 0\ \ \omega^\ell(s)d\mu(s) + \int_{s\in top}\Delta\tau_{top}\ \ \omega^\ell(s)d\mu(s) = \Delta\tau_{top}\int_{s\in top}\omega^\ell(s)d\mu(s)$.

Finally, imposing $R_1^{all} = R_1^{top}$ delivers equation (27).

A.5 Quantitative Analysis

A.5.1 Direct effect of taxes: comparing quantitative and analytical results

The direct effect of taxes on labor in Figure 4 aligns well with the magnitudes obtained from the analytical expressions in Section 4.2. Tax rates increase by 0.44% on average in the constant progressivity case, compared to 1% in the *all* case. Consistently, the labor response is -0.037% in the constant-progressivity case, close to the -0.044% ($= 0.44 \times \Delta L_{all}$) implied by the the *all* case. Similarly, the labor decline in the *top* case is about five times smaller than in the *all* case, thus implying a response of -0.008% ($= -0.044\%/5$), close to the -0.003% we obtain for the higher-progressivity case.

The consumption response is -0.056% in the constant progressivity case, in line with the -0.057%($= 0.44 \times \Delta C_{all}$) implied by the *all* case. However, the consumption decline in the higher progressivity case is even more muted than predicted by the *top* case. This discrepancy traces back to *mpc* computations, which we treated as a primitive in the analytical section but are rather policy dependent. In particular, the analytical section uses an *mpc* out a persistent rebate for all households, which is sensible for the constant progressivity case when all households face higher taxes. Yet, in the higher progressivity case, a household faces higher taxes only if they are at the top-20% of earners, a condition that may change over time. This effectively lowers the persistence of the tax increase, thus leading to a lower *mpc* and a smaller crowding-out of taxes on consumption. This underlines the usefulness of the quantitative evaluation we do in Section 5.2, in complement to analytical expressions.

A.5.2 "Flatter *lpe*" and "Lower *mpc*" economies

Section 5.3 reports multipliers in two alternative economies, each one tailored to lessen the importance of *lpe* and *mpc* at a time. We describe their calibration next.

Calibration of the "Flatter lpe" Economy.—We increase the variance of the working preference shock to $\varrho = 0.33$ to match a flat profile of *lpe*. We recalibrate the distance in discount factors to $\Delta_\beta = 0.039$ to match an aggregate *mpc* comparable to the benchmark calibration, at 0.15. Finally, we recalibrate labor disutility B as well as public spending G, transfers T and debt D, to match the same targets as in the benchmark calibration. Table 6 reports calibration parameters, while Table 7 shows the distributions of *mpc* and *lpe*.[67]

Calibration of the "Lower mpc" Economy.—This calibration removes heterogeneity in discount factors: $\Delta_\beta = 0$. We recalibrate the variance of the working preference shock to $\varrho = 0.048$ to match the same average aggregate *lpe*, and recalibrate all other parameters to match the usual targets. Note that the aggregate *mpc* falls to 0.03 in this calibration; flattening the *mpc* profile without lowering the aggregate *mpc* cannot be achieved without an abnormally low discount factor, which would imply a counterfactually high interest rate. Tables 8 and 9 report calibration and distributions of *mpc* and *lpe*, respectively.

Fiscal parameters	T	G	D	λ
	0.10	0.13	1.27	0.68
Preference parameters	ϱ	Δ_β	β_h	B
	0.33	0.039	0.999	0.42

Table 6: "Flatter *lpe*": Calibration

Wealth quintile	1	2	3	4	5
mpc quarterly	0.30	0.23	0.14	0.05	0.01
Income quintile	1	2	3	4	5
lpe^τ	0.10	0.12	0.12	0.12	0.09

Table 7: "Flatter *lpe*": *mpc* and *lpe*

Fiscal parameters	T	G	D	λ
	0.11	0.14	1.37	0.68
Preference parameters	ϱ	Δ_β	β_h	B
	0.048	0	0.992	0.42

Table 8: "Lower *mpc*": Calibration

Wealth quintile	1	2	3	4	5
mpc quarterly	0.09	0.02	0.01	0.01	0.01
Income quintile	1	2	3	4	5
lpe^τ	1.02	0.73	0.18	0.02	0.01

Table 9: "Lower *mpc*": *mpc* and *lpe*

[67] See Appendix A.3 for more details on *mpc* and *lpe* computations.

A.6 Robustness Analysis

A.6.1 Heterogeneous dis-utility of labor B

The model predicts a decline in hours worked as a function of wealth, which is a counterfactual (Ferraro and Valaitis, 2020). In this appendix, we present a variation of our model to generate a more empirically realistic distribution of hours with wealth. As we show, our results are robust: multipliers are larger when financed with higher-progressivity.

We assume that the dis-utility of labor B is lower for households with the highest discount factor β_{high}. Thus, as β is stochastic, so it's B. We refer to this as the "(β, B) Model". This alternative model generates wealthy households with low dis-utility of working, so that hours worked across the wealth distribution becomes more in line with data. In particular, we assume that households with the highest β have a labor dis-utility that is half the value for the remaining population. Importantly, we recalibrate the preference shock variance, ϱ, and the difference in discount factors, Δ_β, to generate the same average *lpe* and *mpc* across households as in the benchmark model. We also recalibrate all other parameters to same targets we have in the benchmark calibration.

Figure 15 compares the "(β, B) Model" calibration with the benchmark model. The "'(β, B) Model" has a flatter distribution of hours worked across wealth groups, with wealthy households working more than in the benchmark. The distribution of assets and, more importantly, *lpe* and *mpc* are very similar in "(β, B) Model" and the benchmark calibrations.

Figure 16 shows that, in the "(β, B) Model", multipliers are also larger when financed with higher tax progressivity. Because the distributions of *lpe* and *mpc* are comparable to the benchmark, the difference in multipliers across taxation schemes are comparable to the benchmark. If at all, the multiplier under the higher-progressivity case becomes somewhat larger in the "(β, B) Model", as the high-income/low-*lpe* households represent a larger share of total hours worked in the alternative model.

A.6.2 Alternative profit distribution rules

The benchmark calibration assume that profits are redistributed to households in proportion to their labor productivity; that is, $d_t^h(x) = \bar{d}_t^h x$. This rule has two advantages: first, the rule only depends on an exogenous process, so that profits only alter households' behaviors through wealth effects; second, the rule concentrates profits on wealthier households, so that the wealth effects associated with profits are minimized.

However, in HANK models, the modeling of profit redistribution may not be innocuous. To quantify to which extent our rule for profit distribution matters to the multipliers, we consider two alternative economies,

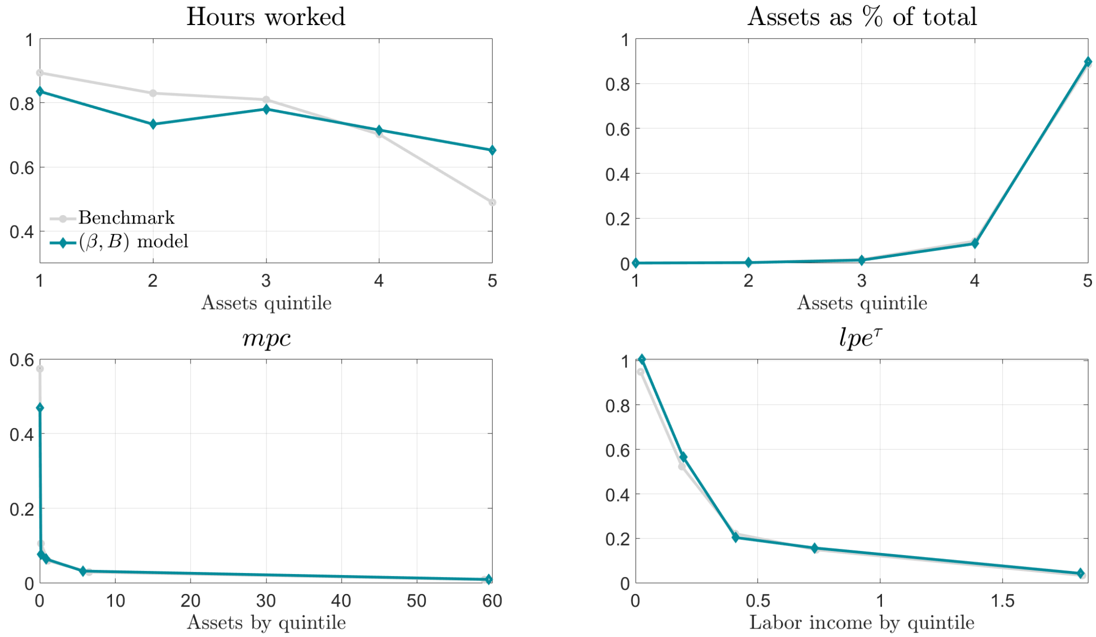

Figure 15: Calibration of the "(β, B) Model"

Note: The two top panels depict average hours and asset shares, respectively, by asset quintile. The bottom left panel plots *mpc* by asset quintile. The bottom right panel plots lpe^{τ} by labor income quintile. All four panels report both the benchmark and the "(β, B) Model" calibration.

with a "Less Concentrated" and a "More Concentrated" distribution of profits. Formally, we assume that profits are redistributed as a function of a polynomial of labor productivity, $d_t^h(x) = \bar{d}_t^h x^{\omega}$, with $\omega = 0.5$ for the Less Concentrated case and $\omega = 2$ for the More Concentrated case.

Figure 17 depicts multipliers in both economies under constant and higher progressivity. Both the level of multipliers and the difference in multipliers across tax schemes are comparable to the benchmark. The difference in multipliers is a bit larger when profits are less concentrated, but overall, our results are robust to the exact concentration of profits in the economy.

A.6.3 Relative roles of *lpe* and *mpc* under different levels of wage rigidities

In this appendix, we discuss how the degree of wage rigidity (Θ^w) alters the relative contributions of *lpe* and *mpc* to the differences in multipliers across tax schemes. We show that the relative *lpe* contribution, while mitigated with more rigid wages, remains substantial for a reasonable range of Θ^w.

The baseline calibration features a slope of the wage Philips curve equal to $\varepsilon^w/\Theta^w = 0.035$. We compute multipliers under two alternative cases: "Flexible Wages", with $\Theta^w = 0$; and "More Rigid Wages", with

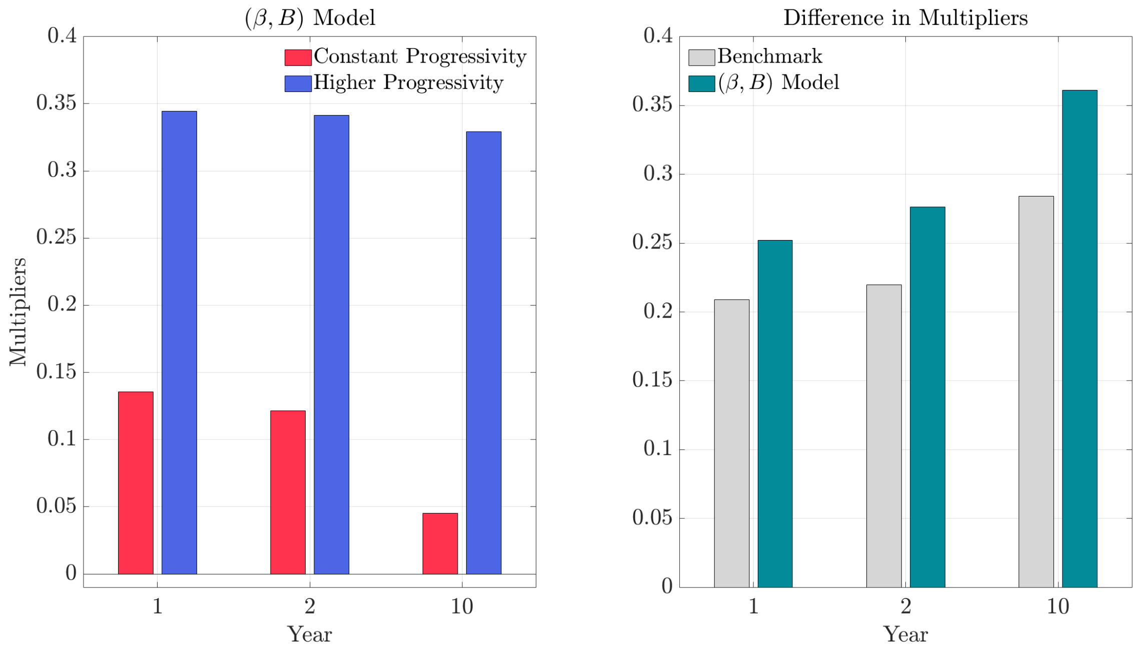

Figure 16: Robustness to Heterogeneous Dis-utility of Labor

Note: The left panel depicts cumulative multipliers for the tax schemes—constant and higher progressivity—for the "(β, B) Model" calibration. The right panel plots the difference in cumulative multipliers across the two tax schemes for the benchmark and for the "(β, B) Model" calibration.

$\Theta^w = 600$. The latter implies a slope of the wage Philipps curve equal to 0.01, a number towards the lower end of values recently estimated in Fitzgerald, Jones, Kulish, and Nicolini (2022).[68] For each level of wage rigidity, Figure 18 reports the difference in multipliers across tax schemes for three calibrations used in Section 5.3: the benchmark calibration; the "Flatter *lpe*" calibration, which isolates the role of *mpc* heterogeneity; and the "Lower *mpc*" calibration, which isolates the role of *lpe* heterogeneity. More details on the counterfactual calibrations can be found in Appendix A.5.2.

In line with results in Figure 7, the difference in multipliers across tax schemes tends to fall with more rigid wages. Still, the difference in multipliers amounts to 20 p.p. after four years in the "More Rigid Wages" case, compared to 24 p.p. in the baseline, and 25 p.p. in the "Flexible Wages" case. This decline in the difference of multipliers follows from *lpe*. When isolating the role of *lpe* heterogeneity, the difference in multipliers falls as wage rigidity raises, as the "Lower *mpc*" calibration shows. The role of *mpc* is less sensitive

[68] Del Negro and Schorfheide (2008) suggests that the macro time series typically used for DSGE estimation are not informative enough to precisely measure the degree of nominal wage and price rigidity. Fitzgerald, Jones, Kulish, and Nicolini (2022) overcomes this issue by using regional data and find higher–and more robust–estimates of the slope of the wage Phillips curve. Similar estimates of the slope are found in Sbordone (2018). There is still an ongoing debate on estimates of Phillips curve slopes (Hazell, Herreño, Nakamura, and Steinsson, 2022).

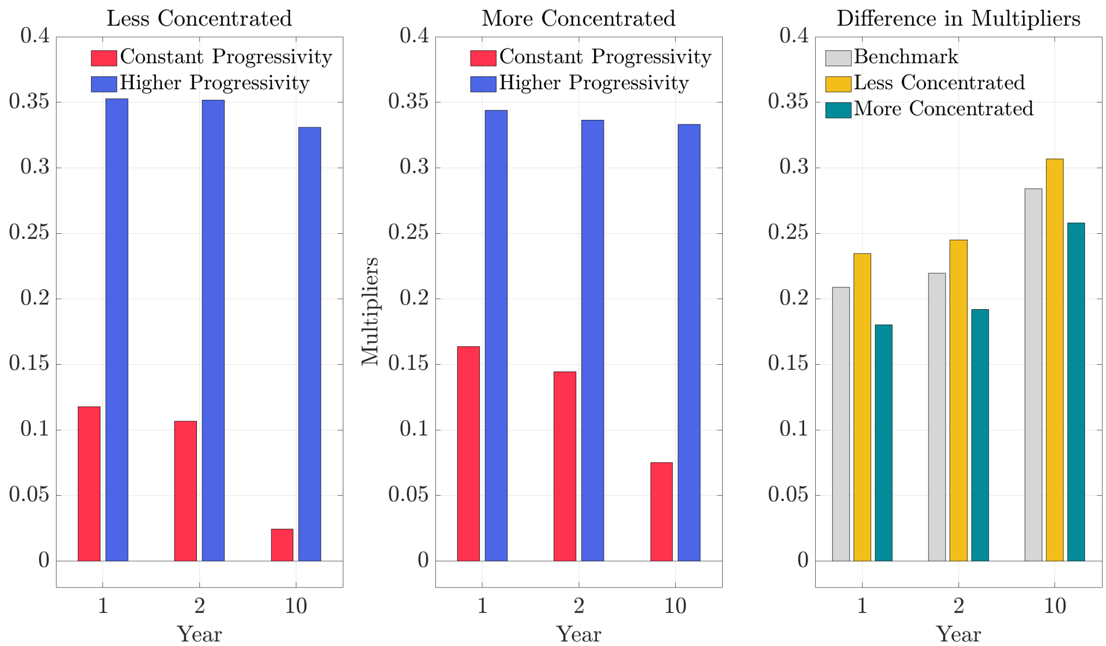

Figure 17: Robustness to Profit Redistribution

Note: The left and middle panels depict cumulative multipliers for the two tax schemes—constant and higher progressivity—for the "Less Concentrated" and the "More Concentrated" case, respectively. The right panel plots the difference in cumulative multipliers across the two tax schemes for the benchmark, the "Less Concentrated" case and the "More Concentrated" case.

to wage rigidity, as the "Flatter *lpe*" calibration shows. Intuitively, as wages become more rigid, labor is more demand-driven and thus the labor supply margin becomes less relevant for the multiplier. However, as the right panel of Figure 18 shows, the relative contribution of *lpe* to differences in multipliers remains substantial for a reasonable range of wage rigidity values.

B Data Sources and Definitions

B.1 Macro Variables

We use the measure of Ramey and Zubairy (2018) for military news (data: quarterly, 1913 to 2012). Quarterly measures for GDP, GDP deflator, government spending, unemployment, population, 3-month T-bill, and fiscal deficits from 1913 to 2015 are also borrowed from Ramey and Zubairy (2018). Marginal and average tax rates are discussed in Appendix B.3.1.

The estimates of Appendix C.7 additionally use data on investment, hours, and wages. We borrow investment and hours data from Ramey (2011), who constructs quarterly variables for 1939 to 2008. We use

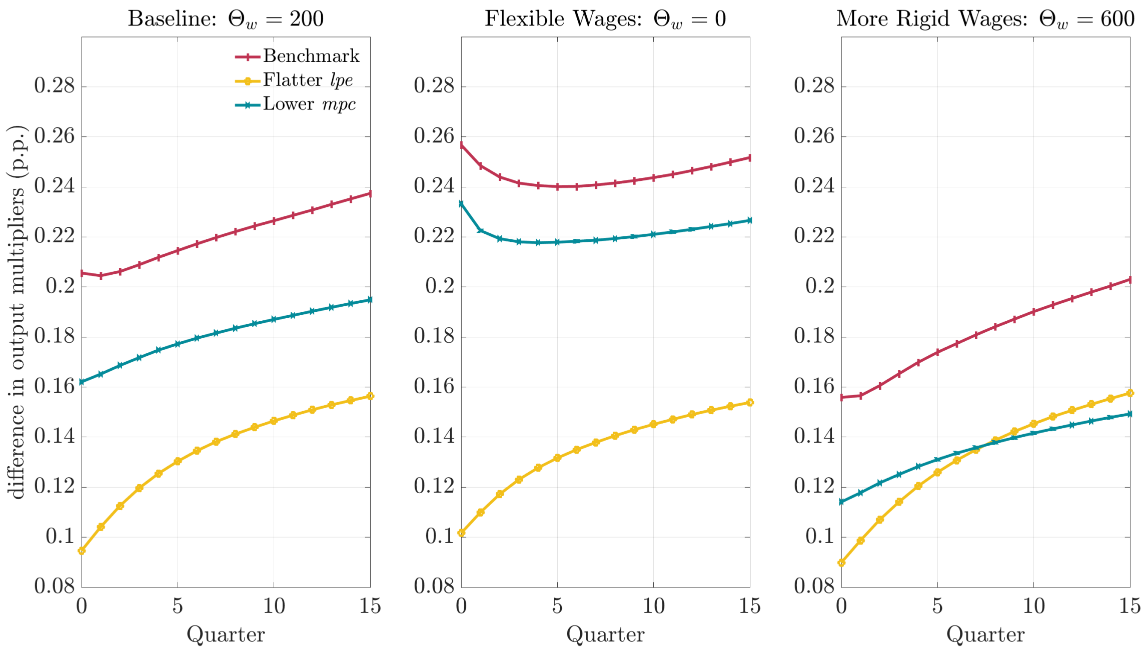

Figure 18: The Role of *lpe* and *mpc* across Wage Rigidity Levels

Note: Each panel plots difference in multipliers across tax schemes for three calibrations: the benchmark, the "Flatter *lpe*", and the "Lower *mpc*". The left, middle, and right panels report the baseline ($\Theta^w = 200$), "Flexible Wages" ($\Theta^w = 0$), and "More Rigid Wages" ($\Theta^w = 600$), respectively.

total fixed private investment and civilian non-farm hours.[69] We use non-farm real hourly compensation (data, quarterly 1947 to 2012) as comparable wage measures do not exist for longer periods.

B.2 Micro Data

B.2.1 Wealth distribution: Survey of Consumer Finances

We compute households wealth distribution from the Survey of Consumer Finances for year 1983. Wealth corresponds total financial assets net of total debt. Total financial assets include: paper assets (variable B3303), gross home value (B3708), gross value of other properties (B3801), and value of vehicles (B3902). Total debt includes: total real estate Debt (B3318), and total consumer debt (B3319). We use the weights provided by the survey (B3016).

[69]Investment data comes from *National Income, 154 Edition, A Supplement to the Survey of Current Business* for 1939-1946, and from Bureau of Economic Analysis for 1947-2008. Hours data comes from Kendrick et al. (1961) for 1939-1947 and from Current Population Survey for 1948-2008. See Appendix I in Ramey (2011) for more details.

B.2.2 *mpc* and Income: Italian Survey of Household Income and Wealth

We use last two waves (years 2010 and 2016) of the Italian Survey of Household Income and Wealth (SHIW). We compute after-tax labor income as: payroll income (variable YL) + pensions and net transfers (YT) + net self-employment income (YM). Total after-tax income is: after-tax labor income + income from real-estate (YCA) + income from financial assets (YCF).

B.3 Tax Data

B.3.1 Progressivity Construction

We build a novel time series to measure the progressivity [P] of the income tax since 1913, using measures of average tax rate [ATR] and average marginal tax rate [AMTR]. Our benchmark measure focuses on federal income taxes. In particular, 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).[70] 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, 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

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

correlation to our measure of progressivity of 0.79 in levels and 0.80 in growth rate on overlapping periods.

We also use as a robustness a measure for progressivity including payroll taxes. To do so, we use the estimates of marginal rates including social security taxes, as provided by Barro and Redlick (2011) and Mertens and Olea (2018) at the link specified above; and we augment the Total Tax Liability with Employer and Employee Contributions for Government Insurance (Source: NIPA, Table 3.6, Contributions for Government Social Insurance; we focus on lines 4 and 22 to be consistent with our measures of marginal rates).[71] Table 10 reports the two measures of progressivity.

Year	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
P[fed]	0.002	0.003	0.024	0.008	0.018	0.031	0.029	0.028	0.027	0.029	0.022	0.023	0.019	0.017	0.020
P[ss]	0.002	0.003	0.024	0.008	0.018	0.031	0.029	0.028	0.027	0.029	0.022	0.023	0.019	0.017	0.020
Year	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942
P[fed]	0.025	0.021	0.015	0.012	0.021	0.021	0.022	0.025	0.030	0.026	0.018	0.021	0.032	0.064	0.109
P[ss]	0.025	0.021	0.015	0.012	0.021	0.021	0.022	0.025	0.030	0.027	0.020	0.022	0.032	0.065	0.111
Year	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
P[fed]	0.099	0.136	0.139	0.125	0.120	0.095	0.096	0.103	0.126	0.137	0.134	0.114	0.119	0.119	0.116
P[ss]	0.101	0.139	0.141	0.126	0.123	0.099	0.097	0.109	0.130	0.143	0.141	0.123	0.127	0.129	0.127
Year	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
P[fed]	0.114	0.117	0.112	0.117	0.119	0.118	0.010	0.093	0.102	0.085	0.104	0.105	0.010	0.093	0.102
P[ss]	0.125	0.129	0.127	0.132	0.135	0.137	0.120	0.113	0.119	0.106	0.120	0.126	0.123	0.118	0.124
Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
P[fed]	0.106	0.114	0.127	0.128	0.149	0.150	0.149	0.160	0.167	0.155	0.145	0.142	0.149	0.153	0.112
P[ss]	0.127	0.130	0.144	0.144	0.164	0.166	0.152	0.160	0.165	0.154	0.142	0.138	0.145	0.142	0.116
Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
P[fed]	0.085	0.087	0.087	0.089	0.085	0.092	0.102	0.099	0.098	0.103	0.109	0.110	0.108	0.104	0.107
P[ss]	0.092	0.093	0.094	0.097	0.093	0.098	0.102	0.101	0.099	0.099	0.103	0.104	0.103	0.104	0.108
Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012					
P [fed]	0.099	0.102	0.104	0.103	0.106	0.098	0.095	0.095	0.094	0.096					
P [ss]	0.097	0.0980	0.098	0.096	0.099	0.097	0.096	0.095	0.095	0.094					

Table 10: Income Tax Progressivity since 1913.

Note: Progressivity measures from 1913 to 2012. P[fed] reports federal income tax progressivity, while P[ss] also includes social security taxes. Source: authors' computations.

Finally, we extend our benchmark progressivity measure [P] until 2015, the latest available year for spending shocks, using estimates of marginal tax rates for years 2013, 2014, and 2015 provided by Bayer, Born, and Luetticke (2020) at this link.

B.3.2 Tax Rates Distribution

Average tax rates for different groups used in Figure 10 come from Piketty, Saez, and Zucman (2018) (data: Table TG1).

[71]Note that it is also possible to use NIPA to build a measure of Total Tax Liability for federal taxes, but one should be careful with the exact timing of tax revenues. In particular, one can reconstruct Total Tax Liabilities of year y from Table 3.4, Personal Current Tax Receipts, as withheld taxes (line 4) of year y plus Declarations and settlements less Refunds (lines 5 and 6) of year $y+1$. However, this data is available only after 1946. After 1946, the NIPA measure is very close to the SOI measure described above; prior to 1946, the SOI data is the only available source.

C Local Projection Method: Robustness

We use this appendix to discuss robustness of our empirical results. First, we show that our progressivity-dependent multipliers are robust to changing controls, time periods, and other specifications. We also show that our results are robust to conditioning on the state of the economy (slack vs expansion) as well as the sign of the shock, two elements that can affect multipliers. Second, we show that the behavior of deficits is similar across progressive and non-progressive shocks. Third, we show that including social security taxes in the progressivity measure does not alter the estimated progressivity-dependent multipliers. Fourth, we argue that difference in progressive/non-progressive multipliers is not induced by the response of monetary policy to a spending shock. Fifth, we argue that there is no systematic state-level response in taxes that could alter the interpretation of our results. Additionally, we compare our results to Ramey and Zubairy (2018), whose methodology we borrow, and argue that our results align with theirs. The last section in this appendix concludes by showing impulse response functions of several variables to progressive and non-progressive spending shocks.

C.1 Multipliers: Specification Robustness

The benchmark estimation is as follows: spending is instrumented by two shocks, RZ and BP; the control Z_t includes eight lags of $\log GDP_t$, $\log G_t$, 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 11 and 12 present numerous robustness checks. Table 11 documents multipliers by expansion/slack states, as well as for positive/negative shocks, and under different sets of controls: without the marginal tax rate, with the average tax rate, with fiscal deficit, and with T-bill. Table 12 explores robustness to the instrument we use, the time period, the lags, the trend, and the definition of the selection criterion.[72] The results hold in almost all cases, though when using only the BP shock the difference is statistically significant only from 1953 onwards. Multipliers are imprecisely estimated when using only the RZ shocks from 1953 onwards, a finding that might be explained by the limited amount of RZ shocks after 1953.

Multipliers and State of the Economy.—We check that our progressivity measure is not correlated with the slack/expansion state of the economy, which could affect multipliers (Ramey and Zubairy, 2018; Auerbach and Gorodnichenko, 2012b). In particular, the probability (measured as a frequency rate) of a progressive state given economic conditions is always around 50%. We find that $\mathbb{P}(p_t = \text{progressive} | z_t = \text{slack}) = 0.53$ and $\mathbb{P}(p_t = \text{progressive} | z_t = \text{expansion}) = 0.45$—with unconditional probability at $\mathbb{P}(z_t = \text{slack}) =$

[72] We recompute the BP shock when changing controls or time periods, as to maintain the BP shock orthogonal to the set of controls in the sample used.

0.48. Thus, it does not seem that our progressivity-dependent multipliers are picking up a correlation with the cycle of the economy. Additionally, while estimates are less precise when slicing the data further, multipliers remain larger after a progressive shock even when conditioning on the state of the economy, as Table 11 shows.

Multipliers and Sign of Shocks.—The recent work in Barnichon, Debortoli, and Matthes (2022) documents an interesting asymmetry, with larger multipliers following a negative spending shock. As we argue below, our results do not seem to be biased by a systematic relation between negative/positive shocks and progressive/non-progressive shocks. In particular, the RZ shocks, which are important for identification, are mostly positive and tend to be more progressive. Yet, we find larger multipliers after progressive shocks. More generally, Figure 19 plots distribution of the RZ and BP shocks conditional on progressive and non-progressive episodes. The RZ shock has more large positive realizations in the progressive episode than in the non-progressive episode, while the BP shocks are more balanced across positive/negative and progressive/non-progressive shocks. Thus, there doesn't seem to be a correlation between progressive and negative shocks. Additionally, as Table 11 shows, multipliers are larger after a progressive shock even when conditioning on the sign of the shock.

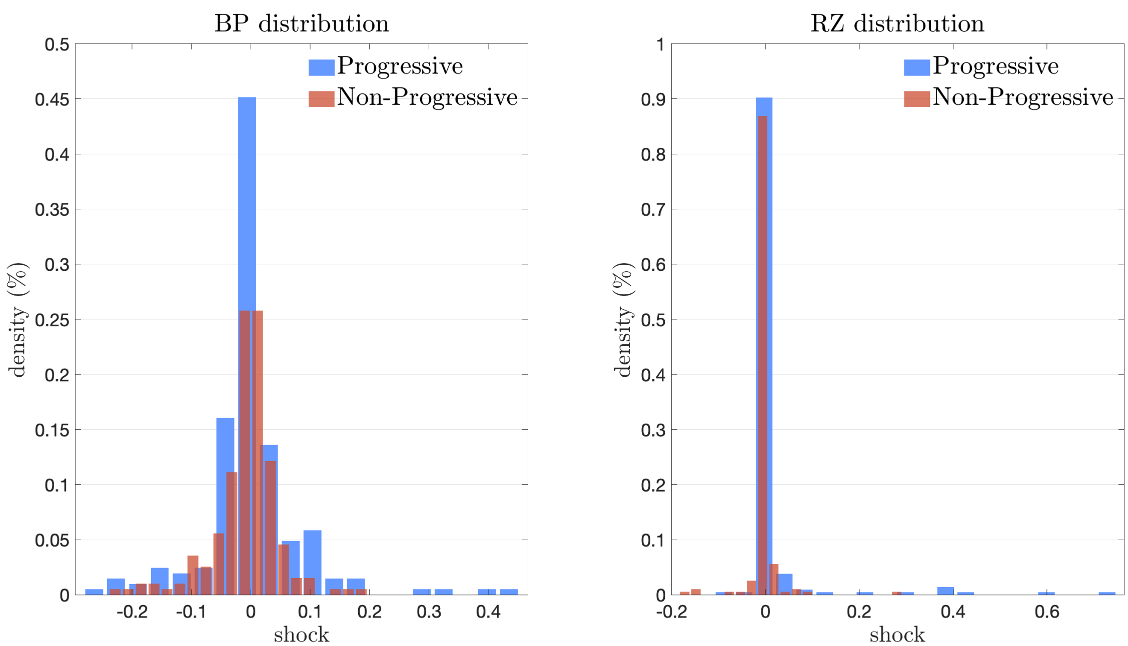

Figure 19: Size Distribution of BP and RZ Spending Shocks

Note: Distribution of shocks by sign: BP shocks (left panel) and RZ shocks (right panel); data: quarterly 1913 to 2006.

	Progressive			Non-Progressive			p-values		
	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y
Benchmark	0.35	0.70	0.84	-0.17	-0.09	0.04	0.05	0.01	0.02
	(0.17)	(0.12)	(0.15)	(0.26)	(0.36)	(0.41)			
Expansions & slack									
- expansion states	0.48	0.77	0.95	-0.62	-0.18	0.03	0.00	0.00	0.09
	(0.13)	(0.15)	(0.20)	(0.25)	(0.43)	(0.67)			
- slack states	0.51	0.72	0.94	3.30	-4.60	-4.50	0.02	0.14	0.09
	(0.23)	(0.26)	(0.20)	(1.15)	(3.57)	(3.17)			
Sign									
- positive shocks	-0.47	-0.21	0.21	-2.16	-1.56	-1.28	0.10	0.09	0.14
	(0.41)	(0.41)	(0.35)	(1.28)	(1.10)	(1.29)			
- negative shocks	1.63	1.13	1.33	-0.98	-1.30	-1.15	0.00	0.00	0.00
	(0.52)	(0.23)	(0.28)	(0.32)	(0.59)	(0.73)			
Controls									
- no MTR	0.42	0.64	0.74	0.16	0.26	0.38	0.16	0.08	0.09
	(0.12)	(0.06)	(0.07)	(0.19)	(0.23)	(0.21)			
- with ATR	0.32	0.70	0.86	-0.05	-0.01	0.21	0.26	0.03	0.02
	(0.16)	(0.11)	(0.14)	(0.27)	(0.33)	(0.32)			
- with deficit	0.29	0.63	0.75	0.04	-0.39	-0.72	0.56	0.10	0.04
	(0.18)	(0.15)	(0.16)	(0.42)	(0.69)	(0.78)			
- with T-bill*	0.56	0.76	0.93	-0.09	0.12	0.51	0.02	0.01	0.07
	(0.09)	(0.16)	(0.20)	(0.28)	(0.26)	(0.35)			

Table 11: Local Projection Methods: Robustness.

Note: This table shows robustness of the results with respect to the sample we use, the instruments, the number of lags, the trend structure, and the window to define the selection criterion. The $\star$ indicates that the sample starts in 1920:Q1. The last three columns report p-values testing for difference between progressive and non-progressive coefficients.

	Progressive			Non-Progressive			p-values		
	1-y	2-y	3-y	1-y	2-y	3-y	1-y	2-y	3-y
Period									
- 1953:Q1-2006:Q4	2.23	2.68	2.67	-0.09	0.43	1.08	0.02	0.00	0.00
	(0.71)	(0.59)	(0.45)	(0.50)	(0.44)	(0.48)			
- 1913:Q1-2015:Q4	0.36	0.72	0.87	0.10	0.13	0.29	0.28	0.02	0.02
	(0.16)	(0.11)	(0.13)	(0.20)	(0.28)	(0.30)			
Shocks									
- *BP* only	0.30	0.76	1.00	-0.17	-0.30	0.10	0.36	0.27	0.44
	(0.18)	(0.17)	(0.24)	(0.47)	(0.90)	(1.06)			
- *BP* only*	2.38	3.57	3.35	-0.24	0.23	0.87	0.00	0.00	0.00
	(0.72)	(0.80)	(0.65)	(0.51)	(0.46)	(0.51)			
- *RZ* only	0.67	0.68	0.80	0.17	-0.03	-0.06	0.06	0.04	0.04
	(0.16)	(0.15)	(0.18)	(0.33)	(0.45)	(0.53)			
- *RZ* only*	-5.57	-2.27	13.88	-4.73	-3.19	26.13	0.90	0.87	0.91
	(9.99)	(5.04)	(119.96)	(16.37)	(10.68)	(234.31)			
Specification									
- lag = 4	0.39	0.70	0.84	0.13	0.17	0.27	0.12	0.03	0.03
	(0.11)	(0.07)	(0.11)	(0.15)	(0.23)	(0.25)			
- lag = 2	0.41	0.69	0.79	0.20	0.20	0.22	0.23	0.05	0.03
	(0.10)	(0.05)	(0.08)	(0.14)	(0.23)	(0.25)			
Windows									
- $\Delta_a = 8$	0.23	0.61	0.80	0.07	0.29	0.53	0.45	0.07	0.15
	(0.18)	(0.14)	(0.15)	(0.19)	(0.25)	(0.25)			
- $\Delta_a = 16$	0.44	0.74	0.87	0.07	0.17	0.14	0.22	0.07	0.05
	(0.23)	(0.14)	(0.12)	(0.26)	(0.36)	(0.43)			
- $\Delta_b = 4$	0.40	0.61	0.75	0.35	0.37	0.40	0.76	0.23	0.19
	(0.15)	(0.11)	(0.13)	(0.17)	(0.22)	(0.30)			
- $\Delta_b = 12$	0.29	0.64	0.83	-0.07	-0.03	0.13	0.08	0.00	0.00
	(0.18)	(0.14)	(0.16)	(0.19)	(0.30)	(0.35)			

Table 12: Local Projection Methods: Robustness.

Note: This table shows robustness of the results with respect to the expansion/slack state, and several controls. The $\star$ indicates that the sample starts in 1953:Q1. The last three columns report p-values testing for difference between progressive and non-progressive coefficients.

C.2 Deficit Financing and Progressivity

We compute the response of fiscal deficits after both a progressive and a non-progressive spending shock. To do so, we re-estimate equation (33) using deficits as a dependent variable. In particular, we estimate the following:

$$\begin{aligned} \sum_{j=0}^{h} \Delta^j d_{t+j} &= \mathbb{I}(p_t = \mathrm{P}) \left\{ \alpha_{P,h} + A_{P,h} Z_{t-1} + m^d_{P,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} \\ &+ \mathbb{I}(p_t = \mathrm{N}) \left\{ \alpha_{N,h} + A_{N,h} Z_{t-1} + m^d_{N,h} \sum_{j=0}^{h} \Delta^j g_{t+j} \right\} + \phi \; trend_t + \varepsilon_{t+h} \end{aligned} \tag{C.1}$$

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 $m^b_{p,h}$ is the cumulative *deficit* multiplier: it measures the accumulated increase in deficits after a \$1 increase in spending. The specification of equation (C.1) is the same as in equation (33) (controls, lags, and instruments) and only the dependent variable changes.

The response of fiscal deficits is very similar across progressive and non-progressive spending shocks, as Figure 20 shows. If at all, deficits increase slightly more with non-progressive shocks. For progressive shocks, deficits cover around 50% of the stimulus initially, which increase up to 80% after a year before decreasing. For non-progressive shocks, deficits initially cover 75% of spending and reach around 90% after a year before declining.

C.3 Multipliers: Including Social Security Taxes

Our progressivity measure is based on federal income taxes, and it does not include social security taxes. In this section, we show that results are robust to including social security in our progressivity measure.

Figure 21 shows the progressivity measure γ for two cases: using (1) based on federal income taxes (benchmark), and (2) based on federal income taxes and social security taxes. Historically, social security taxes have largely been implemented as a flat tax rates subject to a cap on annual contributions. This cap makes the social security taxes somewhat regressive. Consistently, for most of our sample, the progressivity measure including social security is slightly lower than in our benchmark. However, both progressivity measure track each other closely, and the timing of most significant changes in progressivity coincides for both measures.

We re-estimate the progressivity-dependent multipliers of equation (33) using the progressivity measure which includes social security taxes. In particular, the definition of progressive and non-progressive shocks

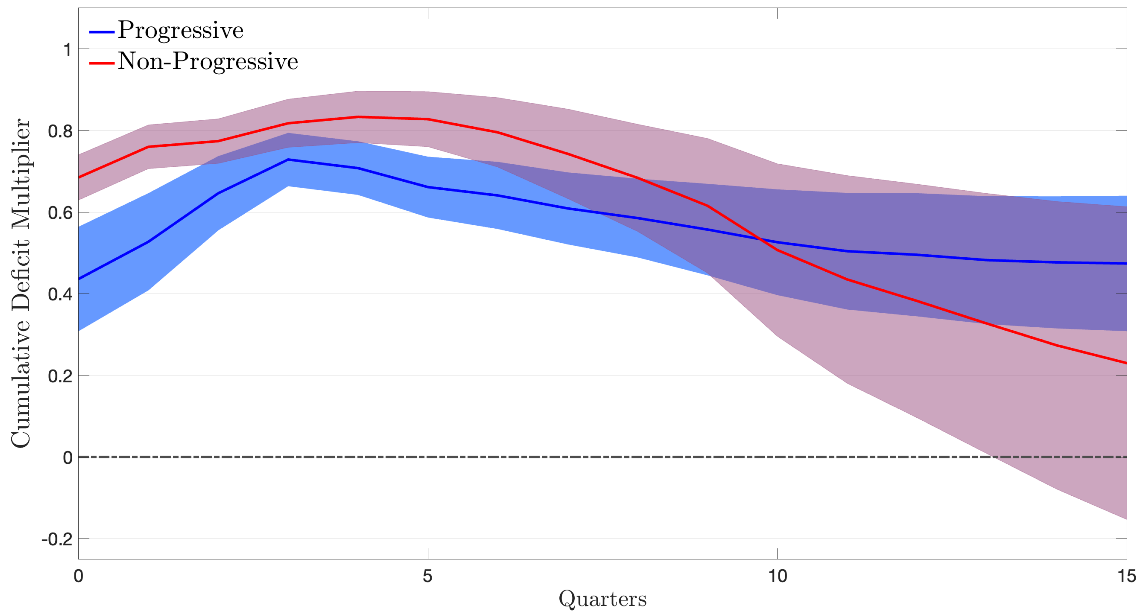

Figure 20: Progressivity-Dependent Deficit Multipliers

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

is now based on the progressivity measure using social security taxes.

The effect of government spending on output remains significantly larger for shocks financed with an increase in the progressivity of taxes, as Figure 22 shows. The multipliers we estimate are comparable to those estimated in our benchmark.

C.4 Monetary policy response to spending shocks

We report the average and progressivity-dependent response of monetary policy to spending shocks. As we argue, monetary policy was typically not very responsive to spending shocks. Importantly, we do not find any evidence that monetary policy was more accommodating after progressive shocks.

We estimate the response of the 3-months Treasury Bill (TB3) to government spending changes, using the same procedure as in the paper: a two-stage least square estimate, using the *BP* and *RZ* shocks as instruments.[73] We estimate responses for our entire sample (1920:Q1 to 2006:Q4), as well as for the post

[73] We use the TB3, instead of the fed-fund rates, because TB3 data is available for a longer period, starting 1920:Q1. However, both rates remarkably track each other: the quarterly correlation is 0.99 for the overlapping period. We estimate the TB3 response using equation (C.3), see Appendix C.7 for a more detailed discussion.

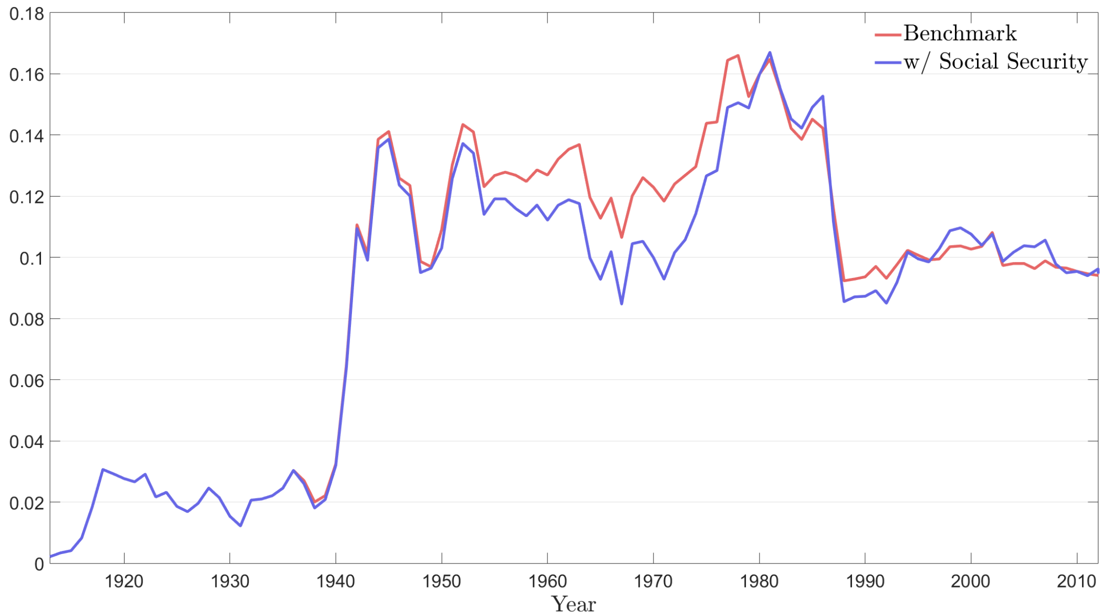

Figure 21: Measures of Federal Tax Progressivity

Note: Authors' computations. See Appendix B.3 for details on computations.

Treasury-Fed Accord period (1951:Q1 to 2006:Q4), and for the post-80s period (1980:Q1 to 2006:Q4). These two sub-samples are relevant because, while they exclude some of the larger shocks in the first half of the century, they are potentially associated with a less accommodative monetary policy: the Treasury-Fed Accord led the FED to start acting more independently from the Treasury, while 1980 corresponds to the first year of Paul Volcker as the Chair of the FED. Figure 23 shows the average TB3 estimated response to a spending shock for the three time periods, and Figure 24 shows the progressivity-dependent response for the two first periods (the last sub-sample is too short to estimate progressivity-dependent responses).

Three features are interesting from the average response, in Figure 23. First, on the entire sample, the TB3 response to a spending shock is essentially zero, and the 68% confidence intervals contain zero for most horizons. This is in line with the estimates reported in Hagedorn, Manovskii, and Mitman (2019). Second, the TB3 response is roughly ten times larger in the post Fed-Treasury Accord sample, although still not statistically different from zero. Third, there is no evidence of a systematic tightening of monetary policy to a spending shock after 1980 neither. If at all, the monetary policy actually became more accommodative, perhaps suggesting that the large shocks of the early 1980s, which we categorize as non-progressive, were not expansionary.

Two results are worth mentioning of the progressivity-dependent TB3 responses in Figure 24. First,

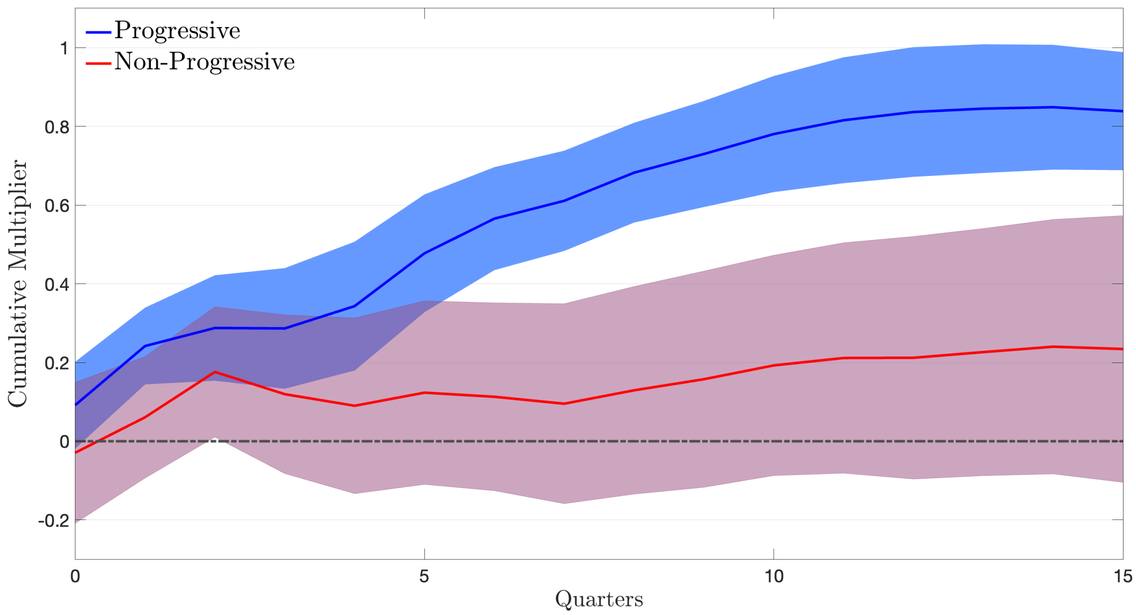

Figure 22: Progressivity-Dependent Cumulative Multipliers (Including Social Security Taxes)

Note: Cumulative output response to a spending shock for four years, progressive and non-progressive shocks. Multipliers are estimated by local projection method; data: quarterly 1913 to 2006; confidence intervals: 68%.

for the entire sample, the TB3 response after a progressive shocks is not statistically different from the response after a non-progressive shock. The p-value for the difference in TB3 response across progressive/non-progressive shocks is 20% for the first quarter, and then always above 70% for all other horizons. Second, responses are larger for the post Fed-Treasury Accord sample, and less accommodating after progressive shocks. The less accommodating response can be understood as the systematic component of monetary policy, as we showed that progressive shocks lead to a larger output expansion.

We find these results as compelling evidence that monetary policy does not drive the difference in spending multipliers we report in the empirical section of the paper.

C.5 State level responses to spending shocks

We investigate a potentially systematic state-level tax response to a spending shocks. We find no such a systematic response. In particular, we use a panel version of equation (32) to estimate the average state-level

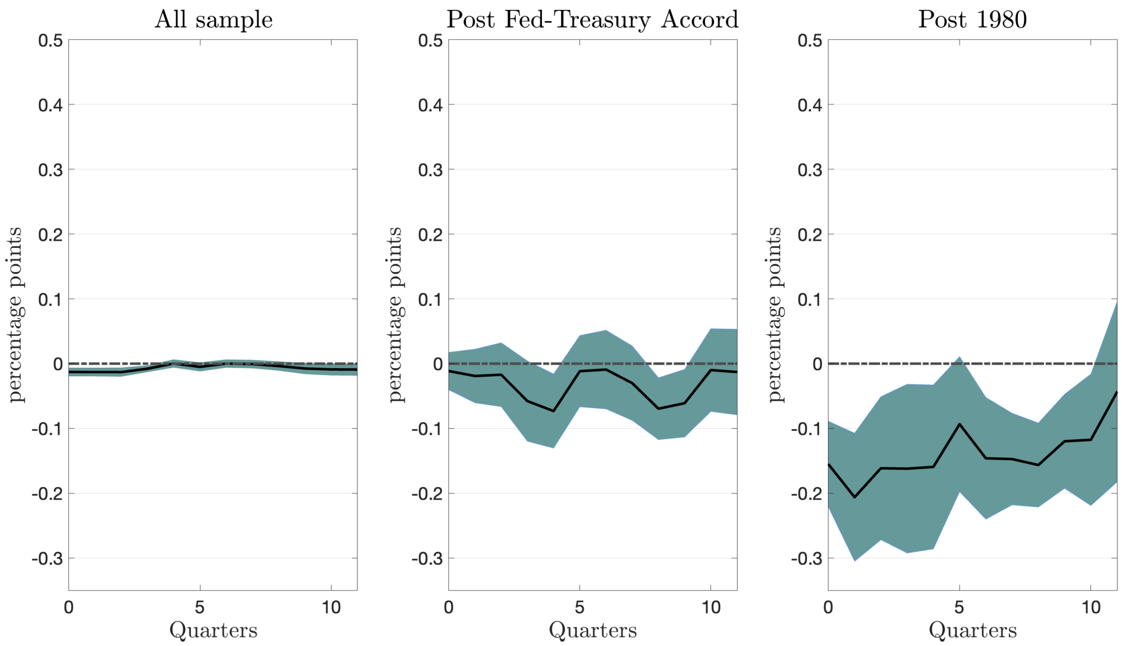

Figure 23: TB3 Average Response to a Spending Shock

Note: TB3 response to a spending shock. Responses are estimated by local projection method; data: quarterly 1920 to 2006 (left panel), 1951 to 2006 (center panel), and 1980-2006 (right panel); confidence intervals: 68%.

tax response using income tax rates across states. That is, we estimate

$$\tau_{i,t+h} - \tau_{i,t-1} = \alpha_{i,h} + A_h Z_{i,t} + \beta_h \ln\left(\frac{G_{t+h}}{G_{t-1}}\right) + \phi_i trend_t + \epsilon_{i,t+h} \qquad \text{for } h = 0, 1, 2 \ldots, H \tag{C.2}$$

where i stands for state. Thus, we allow for state-specific fixed effects and trends, and β_h captures the average state-level tax response to a (federal) spending shock.

We construct state-level tax rates, $\tau_{i,t}$, using NIPA "Personal Current Taxes" table in "Annual Personal Income and Employment by State" (Table SAINC50). The table includes state level personal income and state tax revenues. We compute state-level tax rate $\tau_{i,t}$ as the ratio of state level taxes to state level personal income.[74] Data is annual from 1948 to 2015, and we transform it into quarterly by repeating it four times. Controls $Z_{i,t}$ contain lags of state level income and and tax revenues, in addition of the aggregate controls we used in our benchmark.

As shown in Figure 25, the state level response is essentially zero for all horizons, and much smaller than

[74] We obtained almost identical results when using state-level personal income tax revenues, instead of state-level tax revenues.

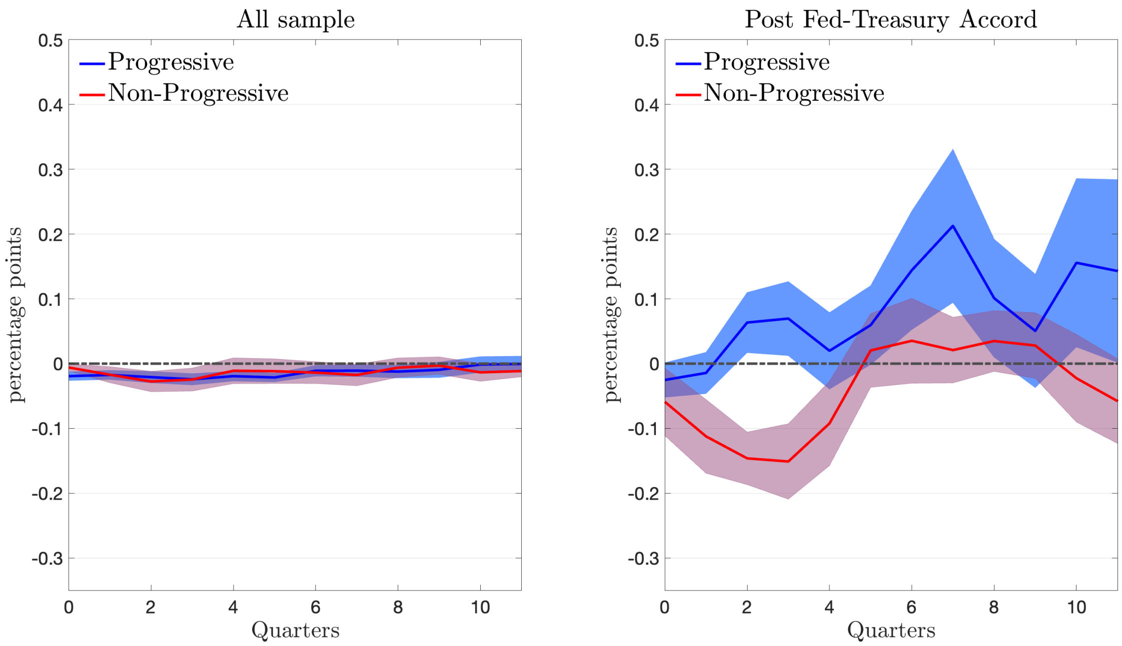

Figure 24: TB3 Progressivity-Dependent Response to a Spending Shock

Note: TB3 response to a spending shock, progressive and non-progressive shocks. Responses are estimated by local projection method; data: quarterly 1920 to 2006 (left panel), and 1951 to 2006 (right panel); confidence intervals: 68%.

the federal income tax response. These results are in line with Liu and Williams (2019), who argue that state level taxation doesn't seem to affect the results of federal tax shocks. Based on this discussion, we think there is not a strong state-level response in taxes to a spending shock that could significantly alter the interpretation our results.[75]

C.6 Comparison with Ramey and Zubairy (2018)

We compare the multipliers we obtain for the linear case (Figure 9) to the multipliers presented in Ramey and Zubairy (2018), whose methodology we follow. Our multiplier estimates are align with theirs, with small differences in levels that we investigate next.

There are three main differences between our set-up and the one used in Ramey and Zubairy (2018): (1) we use a different time period, (2) we include average marginal tax rates as controls while they do not, and (3) we directly use a polynomial time trend in our regressions, while they de-trend by a potential GDP

[75] A recent paper by Fleck, Heathcote, Storesletten, and Violante (2021) argues that the progressivity of state taxes correlates fairly well with the "political color" of the state, suggesting strong persistence in state progressivity as well.

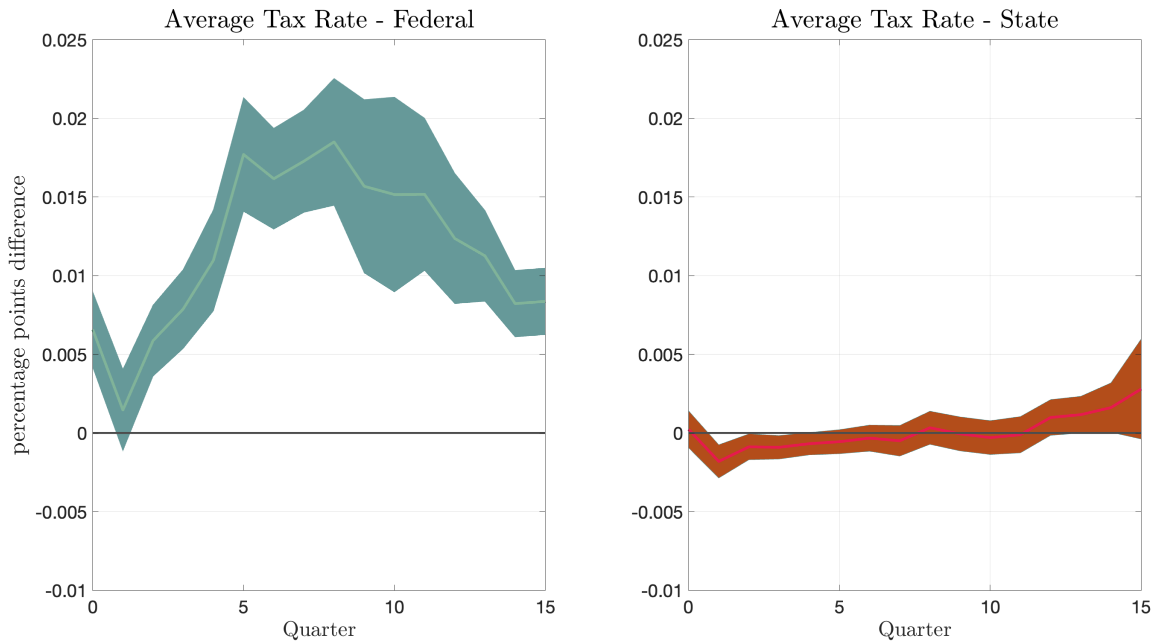

Figure 25: Tax Response to a Spending Shock: Federal Taxes and State Taxes

Note: Tax response for federal taxes (left) and average state level response (right). Responses are estimated by local projection method; data: quarterly 1948 to 2006; confidence intervals: 68%.

measure obtained out of a polynomial time-trend fitted on actual GDP.[76] Figure 26 shows how each of these differences affect estimated multipliers.

First, we use years from 1913 to 2006, while the benchmark analysis in Ramey and Zubairy (2018) goes from 1889 to 2012. We start in 1913 with the creation of the federal income tax system and end in 2006 to avoid using the GFC years, but we show robustness of results when using data up to 2015 (see Table 12). When using our time period, their multipliers increase by 10 basis points (from the crosses line to dots line). Adding taxes as a control seems a very natural implication from our paper, which accounts for another 5 basis points difference in multipliers (black line to pink line). The remaining difference is accounted by the GDP normalization (pink line to dots line).[77] Overall, our estimates are a little larger, and the time profile is as theirs.

For completeness, Figure 27 below shows the response of spending and output to the two shocks we use

[76] Additionally, we use eight lags of variables while they use only four, but this makes a very minor difference, as shown in Appendix C.1.

[77] The NBER working paper version of Ramey and Zubairy (2018) had the same GDP normalization we use. The normalization by potential GDP came in their published version. Our results are robust to normalizing by potential GDP.

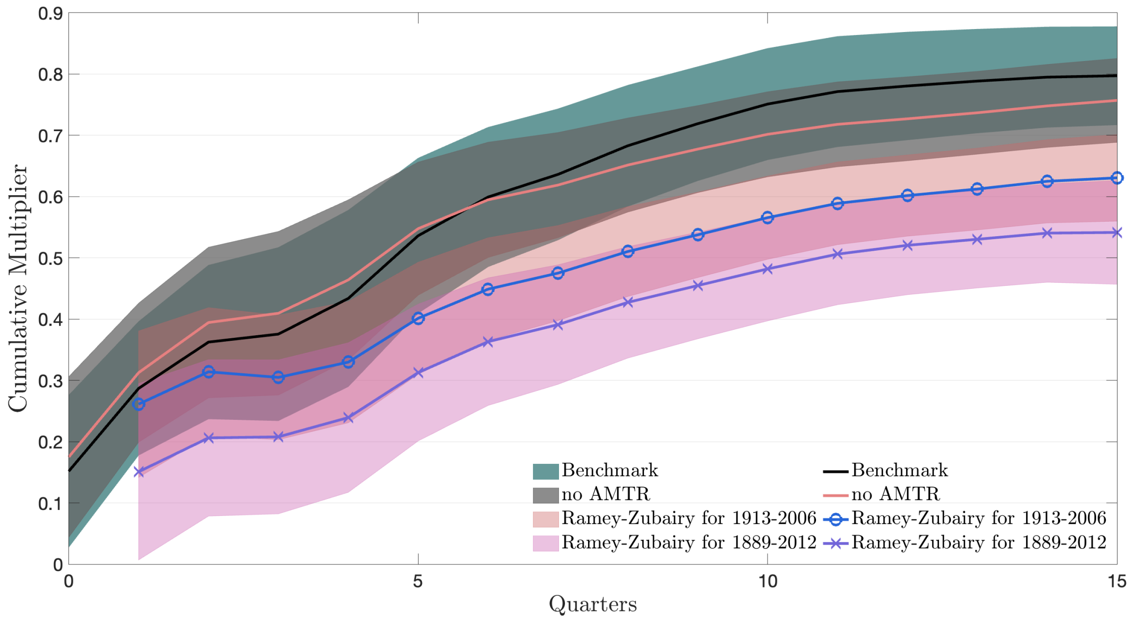

Figure 26: Cumulative Multipliers: Comparison with Ramey and Zubairy (2018)

Note: Cumulative output response to a spending shock under different specifications. Responses are estimated by local projection method; confidence intervals: 68%. The solid black line plots our benchmark estimate. The solid pink line removes marginal tax rates from the set of controls. The dots line additionally normalizes variables by last quarter potential GDP, rather than by last quarter actual GDP. The cross line additionally extends the time period and recover the benchmark estimates of Ramey and Zubairy (2018). We used the codes posted by Ramey and Zubairy (2018), which do not save the impact multiplier, so we plot their multipliers starting from horizon $h = 1$ as they do in their paper.

in the paper: the Blanchard and Perotti (2002) shock and the Ramey and Zubairy (2018) shock. We use $\Delta^h y_{t+h} = \frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}}$ for output and $\Delta^h g_{t+h} = \frac{G_{t+h} - G_{t-1}}{Y_{t-1}}$ for spending, as used in regression (31) and in Ramey and Zubairy (2018). Spending and output both present a hump-shaped response, as found in Ramey (2016) for a wide variety of identified spending shocks. Modulo the time sample and control differences discussed above, and a normalization of the size of the shock, our results are comparable to what Ramey and Zubairy (2018) present in Figure 5 (RZ shock) and Appendix Figure 2 (BP shock).

C.7 Progressivity-Dependent Impulse Response Functions

We compute impulse response functions (*irf*) of several variables after progressive and non-progressive spending shocks. We compute responses of government policies—spending, monetary policy, and fiscal deficits—as well as responses of other macroeconomic variables—investment, wages, and hours worked. As we discuss, the behavior of these variables after a progressive/non-progressive shock aligns well with the implications of

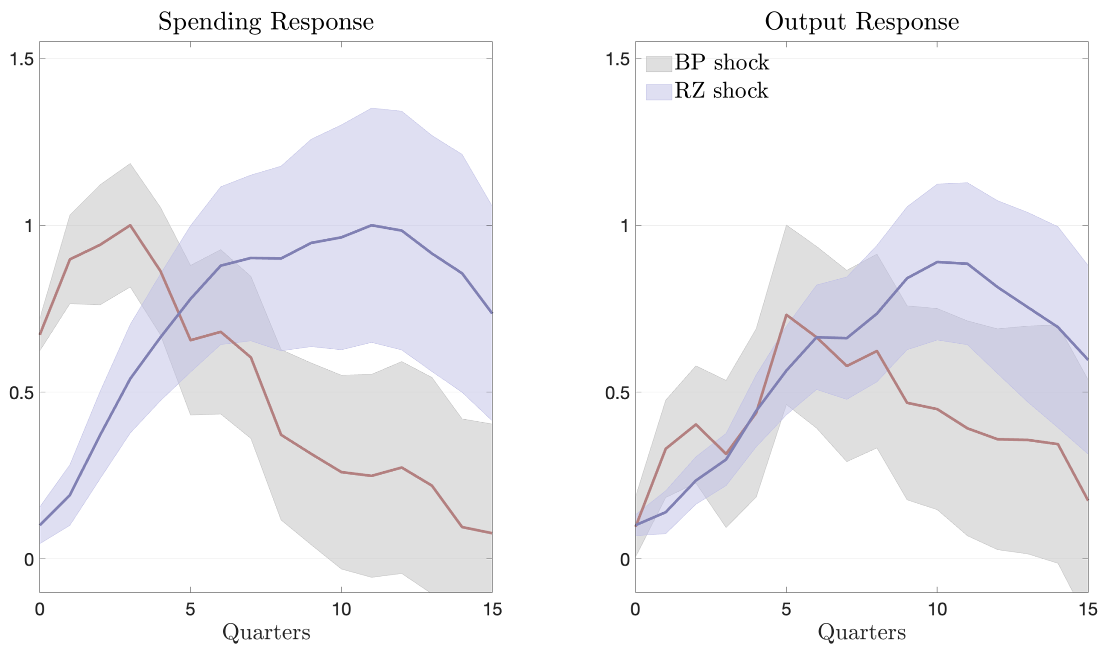

Figure 27: Impulse Response to BP and RZ Shocks

Note: Spending and output responses to a spending shock. Responses are estimated by local projection method; data: quarterly 1913 to 2006; confidence intervals: 68%.

our model in Section 5.

We estimate progressivity-dependent *irf* using local projections, as follows:

$$\begin{aligned} x_{t+h} - x_{t-1} = &\, \mathbb{I}\left(p_t = P\right)\left\{\alpha_{P,h} + A_{P,h} Z_{t-1} + \beta_{P,h} \Delta g_t\right\} \\ &+ \mathbb{I}\left(p_t = N\right)\left\{\alpha_{N,h} + A_{N,h} Z_{t-1} + \beta_{N,h} \Delta g_t\right\} + \phi \text{ trend}_t + \varepsilon_{t+h} \end{aligned} \tag{C.3}$$

where x_t is the outcome variable of interest, and $\Delta g_t = \frac{G_t - G_{t-1}}{Y_{t-1}}$ is the adjusted-by-GDP increase in government spending. Equation (C.3) is an adjusted version of the regression (34) in the paper, which allows us to estimate an *irf* instead of a cumulative multiplier. That is, the sequences $\{\beta_{P,h}\}$ and $\{\beta_{N,h}\}$ are a progressivity-dependent *irf* estimates, measuring the h-period response of x_t after an increase in spending. We use the same estimation procedure as before: a two-stage least square estimate, using the *BP* and *RZ* shocks as instruments for Δg_t. The controls and trends are as specified before, including lags of x_t to control for potential serial correlation in outcome variables. Figure 28 reports the response of spending, the 3-months Treasury Bill (TB3), fiscal deficit, and investment, while Figure 29 reports the response of wages and hours worked.[78]

The *irf* on Figure 28 exhibit no strong differences after progressive vs non-progressive shocks. Spending has a hump-shaped response after a progressive shock, which makes the response somewhat more persistent than after a non-progressive shock. Monetary policy, as captured by the TB3, seems to be accommodative after progressive/non-progressive shocks, with essentially no economically meaningful response after an increase in spending.[79] Deficits response essentially mirror spending, which explains why we find similar deficit multipliers across progressive/non-progressive shocks (see Figure 20). The response for deficits shows why, beyond *irf*, it can be instructive to compute multipliers—that is, to normalize variables by the path of spending—as done elsewhere in this paper.[80] Finally, investment declines a bit more after a progressive shock, but differences are not statistically significant for most horizons.

The response of hours and wages on Figure 29 provide strong support for the findings in this paper. In the model, wage responses are similar across taxation schemes, albeit slightly larger for the non-progressive case (Figure 4). In the data, wages also increase slightly more after a non-progressive shock. Yet, despite the lower increase in wages, hours increase substantially more after a progressive shock, both in model and data. That is, empirically, the distribution of taxes substantially affects labor responses after a spending shock, supporting the main result of this paper.

D 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 these changes remarkably well. Importantly, we argue that virtually all changes to the tax code are the result of political events and emergencies, predominantly wars.

D.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.[81] The Revenue Act of 1913 determined personal income tax brackets for the first

[78] See Appendix B.1 for data details.

[79] As discussed in Appendix C.4, TB3 responses are small and similar across progressive/non-progressive shocks when using other time periods. Additionally, we also found the inflation response to be quantitatively small, after both progressive and non-progressive shocks, in line with recent findings in Jørgensen and Ravn (2022).

[80] See Zeev, Ramey, and Zubairy (2023) for a recent discussion.

[81] 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

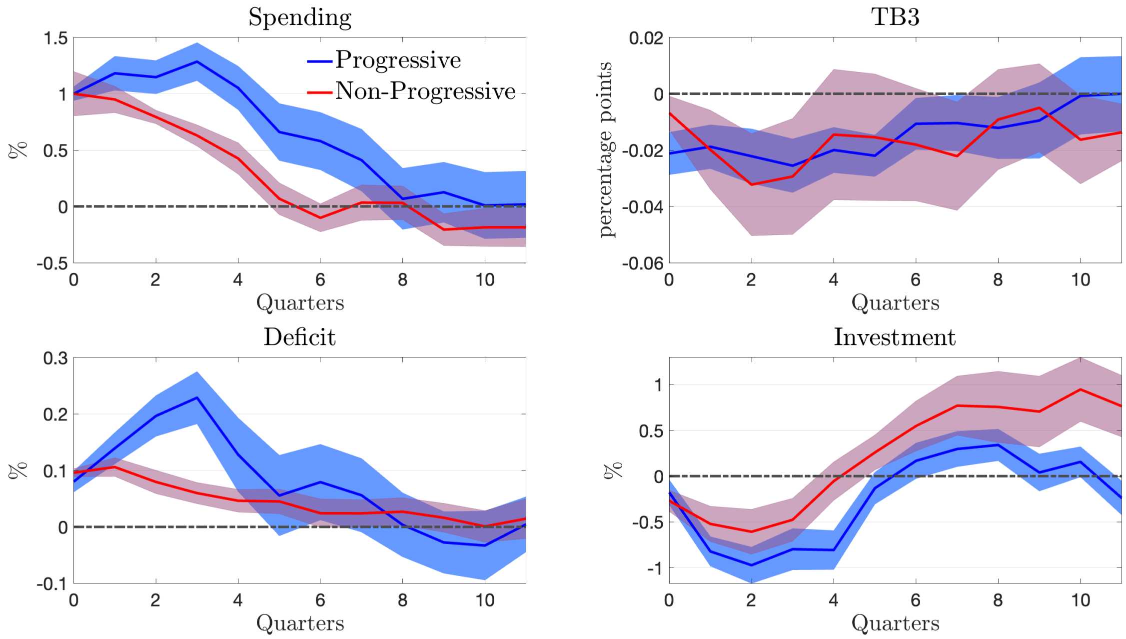

Figure 28: Progressivity-Dependent *irf*: Spending, TB3, Deficit, and Investment.

Note: Impulse response functions after a spending shock. Responses are estimated by local projection method; data: quarterly 1913 to 2006 (spending and deficit), 1920 to 2006 (TB3), and 1939 to 2006 (investment); confidence intervals: 68%.

time, with a modest but progressive structure: the lowest marginal tax rate was 1% for income below $20,000 and increased steadily, reaching a 7% marginal rate for income above $500,000. The tax was progressive because of its structure and because only wealthier households actually paid.

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 than they were three years before. Although tax rates also increased at the bottom, including a temporary 4% tax for income over $4,000 for 1919 and 1920, the Revenue Act of 1918 included exemptions that dampened the effect for lower-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 filed in 1920, which amounts to roughly 30% of households (average household size of 4.3 and population of 106 million).

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).

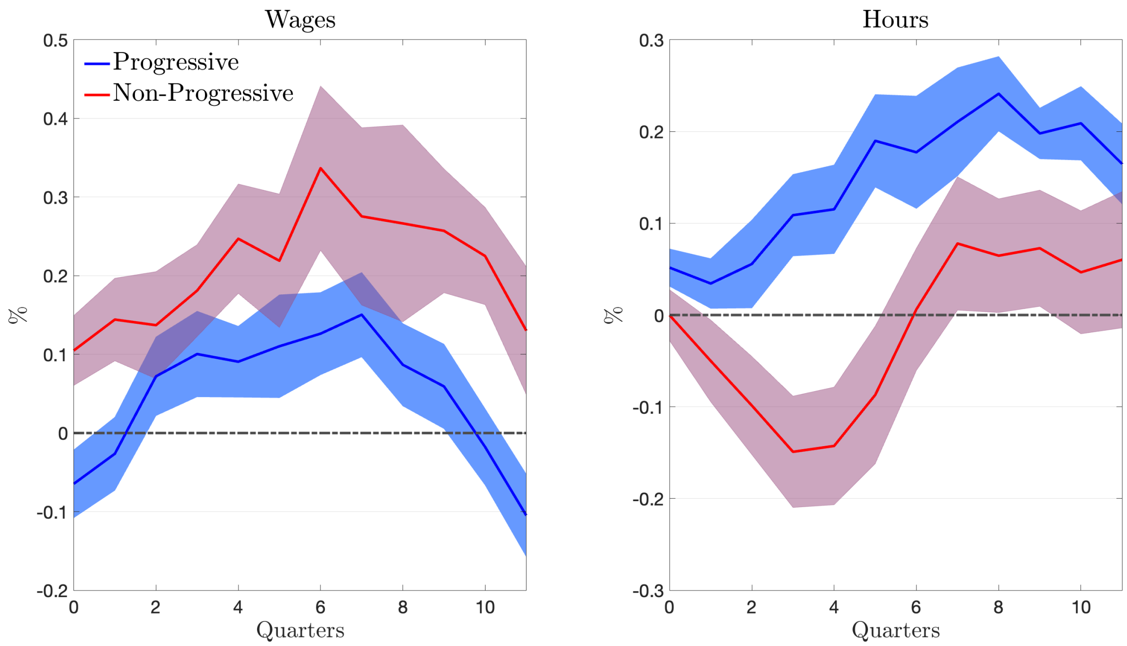

Figure 29: Progressivity-dependent *irf*: Wages and Hours Worked

Note: Impulse response functions after a spending shock. Responses are estimated by local projection method; data: quarterly 1947 to 2006 (wages), and 1939 to 2006 (hours); confidence intervals: 68%.

The decade that followed WWI observed a decrease in 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.[82] 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 12 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.

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

D.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.[83] The acts of 1934 and 1936 kept top marginal tax rates fixed but increased tax rates 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.[84]

Again, our progressivity measure γ in Figure 12 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.

D.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 to the tax code during the 25 years that followed WWII, especially when compared to the inter-war 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*.

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

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

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 was effectively 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 temporarily increased corporate taxes. By the end of the Korean War, some of these measure were reverted with the 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, particularly at the top, pushing down top marginal tax rates to a 60% to 70% range from the previous 80% to 91% range. Further tax cuts were probably prevented because of the increased participation of the United States in the Vietnam War.[85] 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*.[86]

Again, our progressivity measure γ in Figure 12 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.

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

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

D.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 were 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 large fiscal deficits. The Reagan Administration responded by increasing taxes other than personal income statutory taxes. 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 (an 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.[87] Third, it notably expanded the Earned Income Tax Credit (EITC), which effectively moved many low-income households into negative tax rates.

The overall effect of the Reagan "tax cuts" on 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 of 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 Administration.[88]

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

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

Our progressivity measure γ in Figure 12 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 are only comparable in size to the ones implemented during the Roosevelt Administration.

D.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*

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" 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 in 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 even 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 12 captures this increase in progressivity and also show the small magnitude of these changes from a historical perspective.

D.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 alter the 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 captured in our measure γ of Figure 12, which shows only minor fluctuations in these years.