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The Nonlinear Effects of Fiscal Policy

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Abstract

We argue that the fiscal multiplier of government purchases is increasing in the size of the spending shock: more expansionary government spending shocks generate larger multipliers and more contractionary shocks generate smaller multipliers. We empirically document this pattern across time, countries, and modes of financing. We propose a neoclassical mechanism that hinges on the relationship between fiscal shocks, their form of financing, and the response of labor supply across the wealth distribution. An incomplete markets model predicts that the aggregate labor supply elasticity is increasing in the spending shock, and this holds regardless of whether shocks are deficit- or balanced-budget financed. We show that this mechanism survives the introduction of nominal price rigidities and find evidence for it using micro-data for the US.

Keywords: Fiscal Multipliers, Nonlinearity, Asymmetry, Heterogeneous Agents
JEL Classification: E21, E62, H50

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1. Introduction

During the 2008-2009 financial crisis, many OECD countries adopted expansionary fiscal policies to stimulate economic activity. These fiscal expansions were often followed by austerity measures aimed at reducing the size of the resulting high levels of government debt (referred to as fiscal consolidations). This era of fiscal activism inspired the economic literature to revive the classical debate on the size of the fiscal multiplier and its determinants, such as the state of the economy, income and wealth inequality, demog-

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raphy, tax progressivity, and the stage of development, among others.[2] More recently, the COVID-19 crisis has forced many countries into unprecedented budget deficits; concerns about debt sustainability are likely to spur consolidation programs of different sizes and forms of financing after the crisis.

Most of the literature on fiscal policy, however, treats the fiscal multiplier as one number: small and large shocks are assumed to have the same relative effects on output. In this paper, we argue that fiscal multipliers from government spending shocks depend on the size of the shock. Specifically, large negative shocks yield smaller multipliers, while large positive shocks yield larger multipliers. We first present empirical evidence of this pattern and then show that it can be generated by a standard calibrated neoclassical model with incomplete markets and heterogeneous agents. The key mechanism, which hinges on the differential response of labor supply across the wealth distribution, is robust to assumptions about the form of financing and survives the introduction of nominal rigidities in the context of a Heterogeneous Agents New Keynesian (HANK) model.

Applying the data and methodology from two well known empirical studies (Alesina et al. 1 and Ramey and Zubairy 33), we find evidence of the size dependence of fiscal multipliers across different time periods, countries, and modes of financing. In our first empirical exercise we adapt the methodology and data of Alesina et al. [1], who use annual data on exogenous fiscal consolidation shocks (defined as policies aimed at reducing government debt) identified via a narrative approach, across 15 OECD countries over the 1981-2014 period. We find the multiplier to be significantly — both quantitatively and statistically — larger for smaller fiscal consolidation shocks, with the effect being stronger for unanticipated than for anticipated shocks. We also find the results to be similar across both spending- and tax-based fiscal consolidations.

[2] See for example Auerbach and Gorodnichenko [7], Ramey and Zubairy [33], Brinca et al. [14], Brinca et al. [13], Hagedorn et al. [21], Krueger et al. [28], Basso and Rachedi [9], Ferriere and Navarro [18], Ilzetzki et al. [25], and Faria-e-Castro [17].

In the second empirical exercise we borrow the data and methodology from Ramey and Zubairy [33], who use quarterly data for the US economy going back to 1889 and an identification scheme for government spending shocks that follows the identification assumptions of Blanchard and Perotti [12]. Using the projection method of Jordà [26], we find evidence that the fiscal multiplier depends on the size of the shock. This corroborates the finding that the multipliers of larger consolidations are smaller than those of smaller negative fiscal shocks.

We then show that these empirical findings can be rationalized in the context of a standard, neoclassical, heterogeneous agents model with incomplete markets, similar to Brinca et al. [14] but with an infinite time horizon. The model is calibrated to match key features of the US economy, such as the income and wealth distributions, hours worked, and taxes. In our model, agents face uninunsurable labor income risk that induces precautionary savings behavior. The equilibrium features a positive mass of agents who are borrowing constrained: as is well known, the elasticity of intertemporal substitution (EIS) is increasing in wealth, with constrained agents having the lowest EIS.[3] Thus the labor supply elasticity of constrained and low-wealth agents is higher and their work hours are more responsive to contemporaneous changes in income. On the opposite, the hours worked of constrained and low-wealth agents are less responsive to future income shocks. This model feature, combined with shifts of the wealth distribution, is prevalent in driving the nonlinear effects of fiscal policy, and we show that the mechanism survives the introduction of nominal price rigidities.

We study how the economy responds to different types of government spending shocks: permanent or temporary, deficit-financed or balanced-budget financed. A decrease in government spending that leads to a reduction in government debt generates a positive future income effect, as capital crowds out government debt and increases

[3]See Domeij and Floden [16] for the relationship between wealth and EIS of labor and Vissing-Jørgensen [38] for the relationship between wealth and the EIS of consumption.

real wages. This positive shock to future income induces agents to reduce savings today, raising the mass of agents at or close to the borrowing constraint. Since wealthier agents react more to shocks to future income, their labor supply falls by relatively more in response to this government spending shock. Combining these two forces delivers our result: larger debt consolidations (i.e., larger negative shocks to government spending) lead to a larger increase in the mass of constrained agents, and these are the agents whose labor supply responds less to the shock. Therefore, larger fiscal consolidations elicit a relatively smaller aggregate labor supply response, which results in a smaller fiscal multiplier. For increases in government spending financed by debt, the opposite is true: larger positive shocks induce larger labor supply responses and thus larger fiscal multipliers. We show that this mechanism holds for deficit-financed reductions in government spending, regardless of whether they are permanent or temporary.

We also show that balanced-budget government spending shocks result in the same pattern of sign and size dependence thanks to this mechanism. Consider the case of a fiscal contraction that is accompanied by a contemporary increase in transfers so that public debt is held constant: the contemporary positive income effect elicits a much larger labor supply response by constrained and low-wealth agents. This positive income effect increases agents' wealth and pushes some of them away from the borrowing limit. This rightward shift in the wealth distribution decreases the aggregate labor supply response, as agents further away from the constraint respond less than those at the constraint, resulting in a smaller response of output and a smaller fiscal multiplier. The larger the change in the transfer, the larger the shift in the wealth distribution and the larger the reduction in the aggregate labor supply elasticity and the fiscal multiplier. The opposite is true for fiscal expansions contemporaneously financed by a decrease in lumpsum transfers: the negative income effect decreases agents' wealth and shifts the wealth distribution to the left, where agents have a stronger labor supply response, leading to a larger multiplier, the larger the size of the government spending shock.

We then show that our key mechanism, which relies on the differential response of labor supply across the wealth distribution and movements of the distribution, survives the introduction of nominal rigidities. We repeat the same experiments in a state-of-the-art HANK model as in Auclert et al. [6], and find that nominal rigidities not only increase the level of the multiplier, but also its sensitivity to the size of the shock. The results and mechanism hold for both deficit-financed and balanced-budget fiscal experiments. We show that a version of the HANK model where the central bank reacts less to changes in inflation from its target is able to reproduce the level and range of multipliers that we estimate in the data.

We conclude the paper by empirically testing the validity of our labor supply channel in the micro-data. Using data from the Panel Study of Income Dynamics (PSID), we assess how the labor supply response to government spending shocks depends on wealth and how this relationship depends on the financing of the shock. We establish that for spending shocks that are financed through contemporary taxes/transfers, the labor supply response is strongest for poorer agents, while the response is stronger for wealthier agents when spending shocks are deficit-financed.

Our work is closely related to that of Krueger et al. [28], Athreya et al. [4], Ferriere and Navarro [18], Auclert et al. [5], Andres et al. [3], Basso and Rachedi [9], Hagedorn et al. [21], Brinca et al. [14], Brinca et al. [13] and Heathcote [22] who also study the effects of fiscal policy in the context of incomplete markets models with heterogeneous agents. Our focus, however, is not on the state dependence of multipliers or on how different policies produce different multipliers, but rather on how the same type of policy — government spending — can generate fiscal multipliers that are size-dependent, regardless of the manner in which it is financed. Also related is the work of Cantore et al. [15], who study how the effects of monetary policy interact with the labor supply of the left tail of the income distribution via a neoclassical mechanism that is based on wealth effects. Our study is complementary in theirs and focuses on a similar mechanism for fiscal policy.

The rest of the paper is organized as follows: Section 2 presents empirical evidence on size- and sign-dependent fiscal multipliers. Section 3 introduces the heterogeneous agents neoclassical model, and Section 4 describes our calibration strategy. Section 5 presents the results from the quantitative model. Section 6 introduces nominal price rigidities in the neoclassical model and shows that the driving force of the nonlinear effects of fiscal policy remains the same. Section 7 empirically tests and validates the mechanism combining micro data from the PSID with data on government spending and debt. Section 8 concludes.

2. Empirical Evidence

In this section, we use two different empirical methodologies and datasets to document that larger fiscal shocks generate relatively larger effects on output, i.e. larger fiscal multipliers. We begin by presenting evidence from fiscal consolidation programs in 15 OECD countries, using the dataset from Alesina et al. [1]. Second, we employ the methodology from Ramey and Zubairy [33], who study fiscal multipliers using historical data for the US.

2.1. Fiscal Consolidation Episodes

Using the dataset of Alesina et al. [1], we show that larger fiscal consolidations (reductions of government debt) generate smaller fiscal multipliers. We show that this pattern is more evident for unanticipated fiscal shocks and applies both to revenue-based and spending-based fiscal consolidations.

The annual dataset of fiscal consolidation episodes includes 15 OECD countries and ranges from 1981 to 2014.[4] Alesina et al. [1] expand the original dataset of Pescatori

[4]The dataset includes Australia, Austria, Belgium, Canada, Denmark, Spain, Finland, France, Japan, the United Kingdom, the US, Ireland, Italy, Portugal, and Sweden. As we only have data for Germany starting in 1991, we drop it from the baseline analysis. We then test and confirm that the results hold when including Germany, with the sample ranging from 1991 to 2014.

et al. [31] with exogenous fiscal consolidation episodes, known as IMF shocks. Pescatori et al. [31] use the narrative approach of Romer and Romer [34] to identify exogenous fiscal consolidations, i.e. consolidations driven uniquely by the desire to reduce budget deficits. The use of the narrative approach filters out all policy actions driven by the business cycle, ensuring that the identified consolidations are independent from the current state of the economy.

Besides expanding the dataset of Pescatori et al. [31], Alesina et al. [1] use the methodological innovation introduced by Alesina et al. [2], who point out that a fiscal adjustment is a multi-year plan rather than an isolated change and consequently results in both unexpected policies and policies that are known in advance. Ignoring the link between both expected and unexpected policies may yield biased results.

Alesina et al. [1] define a fiscal consolidation as deviations of public expenditure relative to their level (in % of GDP) if no policy had been adopted plus expected revenue changes stemming from tax code revisions. Moreover, fiscal consolidations that were not implemented are not included in the dataset, and so all considered fiscal consolidation episodes are assumed to be fully credible.

To formally investigate the nonlinear impact of consolidation shocks on GDP, we use the local projection method of Jordà [26] to estimate the following specification at different horizons h, to test for the existence of nonlinear effects of the consolidation shocks:

$$\Delta y_{i,t+h} = \beta_1 e_{i,t} + \beta_2 (e_{i,t})^2 + \alpha_i + X_{t-1} + \gamma_t + \epsilon_{it} \tag{1}$$

where $\Delta y_{i,t+h}$ and $e_{i,t}$ are the output growth rate and the fiscal consolidation shock in % of GDP, respectively, in country i and year t. X_{t-1} is a vector of lagged control variables, including output growth rate and the fiscal consolidation shocks. α_i and γ_t are country- and time-level fixed effects, respectively. We include the squared term of the fiscal consolidation shocks $(e_{i,t})^2$ to capture the nonlinear effects of fiscal shocks. To account for simultaneous cross-country correlations of the residuals, we estimate equation (1) using

	h		
Variable	0	1	2
β_1	-0.503***	-1.174***	-0.412**
	(0.154)	(0.203)	(0.161)
β_2	0.094**	0.217***	0.082
	(0.046)	(0.058)	(0.053)
Observations	495	480	465
Number of countries	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1: Nonlinear effects of fiscal consolidation shocks at different horizons h.

the generalized least-squares method and controlling for heteroskedasticity. To control for the effects of outliers, we winsorize output variations at the 5th and 95th percentiles.

The coefficients reported in Table 1 capture the negative effect of consolidation shocks on output, with β_1 being negative and statistically significant. β_2 is positive and significant, which illustrates the nonlinear effect of consolidation shocks on output: larger consolidations generate relatively smaller effects on output, i.e., smaller fiscal multipliers.[5] Not only is β_2 statistically significant but is also economically meaningful. Going from a marginal to a 1.5% of GDP consolidation decreases the multiplier on impact by 28%, as can be seen in Table 2. Moreover, the nonlinear effects are persistent, and are still present one year after the shock.

Table A.12 in Appendix A.1 compares the non-linear effects of both unanticipated and anticipated shocks. The main driver of the non-linear effects are the unanticipated shocks, with the quadratic term not being significant for anticipated shocks.

[5]Notice the fiscal multiplier is given by $\beta_1 + \beta_2 \times e_{it}$. If β_2 was zero, the multiplier would be constant and equal to β_1.

	h		
	0	1	2
Multiplier 0%	0.503	1.174	0.412
Multiplier -0.5%	0.456**	1.066***	0.371
Multiplier -1.5%	0.362**	0.849***	0.289

Table 2: Fiscal consolidation multipliers for different shocks at different horizons h. Stars indicate the p-value of a t-test for the statistical difference of the multipliers of the different sized shocks relative to the the 0% multiplier: *** p<0.01, ** p<0.05, * p<0.1.

2.1.1. *Financing Instrument*

We also test if it matters whether consolidations are consumption-, transfer- or tax-based. Tables A.13-A.15 in the appendix report the average consolidation shocks during transfer, consumption and tax based consolidations.[6] We have in total 211 consolidation episodes, with 63 being classified as transfer, 71 as consumption and 77 as tax based consolidations.

Using the three different consolidation types, we estimate the following specification:

$$\Delta y_{i,t+h} = \beta_1^G e_{i,t}^G + \beta_2^G (e_{i,t}^G)^2 + \beta_1^g e_{i,t}^g + \beta_2^g (e_{i,t}^g)^2 + \beta_1^t e_{i,t}^t + \beta_2^t (e_{i,t}^t)^2 + X_{t-1} + \alpha_i + \gamma_t + \epsilon_{it}$$

where $e_{i,t}^G$, $e_{i,t}^g$ and $e_{i,t}^t$ are the consumption, transfer, and tax-based consolidation shocks. The coefficients are reported in Table 3 and establish that the quadratic terms for both consumption and tax based (unanticipated) consolidations – β_2 and β_6, respectively – are positive and statistically significant on impact, and persist over the next two years. Moreover, both coefficients are economically meaningful on impact. Going from a marginal to a 1.5% of GDP consolidation decreases the multiplier for G and t consolidations by 59% and 44%, respectively, as reported in Table A.11 in Appendix A.1

Table A.16 in Appendix A.1 shows that our results are robust to the inclusion of

[6] We follow the Alesina et al. [1] consolidation classification. A consolidation is classified as a tax, transfer, or consumption consolidation depending on the largest component out of the three for the horizon of the consolidation plan.

	h		
Variable	0	1	2
β_1^G	-1.011***	-2.009***	-0.613**
	(0.274)	(0.297)	(0.290)
β_2^G	0.401***	0.573***	0.201**
	(0.093)	(0.097)	(0.098)
β_1^g	0.250	-0.494*	-0.011
	(0.255)	(0.267)	(0.190)
β_2^g	0.020	0.121*	-0.041
	(0.063)	(0.065)	(0.061)
β_1^t	-0.975***	-1.915***	-1.504***
	(0.317)	(0.331)	(0.287)
β_2^t	0.286**	0.337***	0.390***
	(0.122)	(0.126)	(0.115)
Observations	495	480	465
Number of countries	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Non-linear effects of fiscal unanticipated consumption, transfers and taxed based consolidation shocks, including controls.

previously announced consolidation-plans implemented at time t. Finally, Tables A.17 to A.18 show that our results are robust to (i) including Germany and (ii) restricting the sample to the 1991-2014 period.

2.2. *US Historical Data*

We continue to investigate the relationship between the fiscal multiplier and the size of the underlying fiscal shock by employing the methodology and the historical dataset constructed by Ramey and Zubairy [33], which contains quarterly time series for the US economy ranging from 1951 to 2015.[7] The dataset includes real GDP, the GDP deflator, government purchases, federal government receipts, population, unemployment rates, interest rates, and defense news. Quarterly US historical data provides us with a long

[7] We focus on the post-1951 period to ensure that our results are not driven by three major wars: WWI, WWII and the Korean War.

enough time series to compare the multipliers across fiscal shocks of different sizes, as well as many periods of expansion and recession, and different regimes for fiscal and monetary policy.

To identify exogenous government spending shocks, Ramey and Zubairy [33] use two different approaches: (i) a defense news series proposed by Ramey [32], which consists of exogenous variations in government spending linked to political and military events that are identified using a narrative approach and that are plausibly independent from the state of the economy, and (ii) shocks based on the identification hypothesis of Blanchard and Perotti [12] that government spending does not react to changes in macroeconomic variables within the same quarter. Ramey and Zubairy [33] argue that the Blanchard-Perotti (BP) shock is highly relevant in the short run (since it is the part of government spending not explained by lagged control variables), while defense news data are more relevant in the long run (as news happen several quarters before the spending actually occurs). As we are more interested in short run dynamics of fiscal policy, we focus on the BP shocks on our application.

To test for the nonlinear effects of the fiscal shock, we expand the linear regression as in Ramey and Zubairy [33] with a quadratic term of the fiscal shock, which is then estimated using the local projection method of Jordà [26]. Formally, this method consists of estimating the following equation for different time horizons h:

$$x_{t+h} = \alpha_h + \Psi_h(L) z_{t-1} + \beta_h^x \text{shock}_t + \beta_{2,h}^x \left(\text{shock}_t\right)^2 + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, ... \tag{2}$$

where x is either real GDP per capita y or government spending g, both divided by trend GDP, and z is a vector of lagged control variables, including real GDP per capita, government spending, and tax revenues (all divided by trend GDP). $\Psi_h(L)$ is a polynomial of order four in the lag operator, and shock_t is the BP spending shock.

Ramey and Zubairy [33] argue that in a dynamic environment the multiplier should not be calculated merely as the peak of the output response to the initial government spending variation but rather as the integral of the output variation to the integral of the government spending variation, [30, 36, 19]. This method has the advantage of measuring all the GDP gains in response to government spending variations in a given period. To calculate the cumulative multiplier we proceed in three steps: 1) estimate the output response to the fiscal shock, using equation (2); 2) estimate the government spending response to the fiscal shock using equation (2); 3) divide the output response by the government spending response.[8] The cumulative multiplier is then given by

$$\frac{\sum_{j=0}^{h}\frac{\Delta y_{t+j}}{shock_t}}{\sum_{j=0}^{h}\frac{\Delta G_{t+j}}{shock_t}} = \frac{\sum_{j=0}^{h}\frac{\beta_h^y shock_t+\beta_{2,h}^y shock_t^2}{shock_t}}{\sum_{j=0}^{h}\frac{\beta_h^G shock_t+\beta_{2,h}^G shock_t^2}{shock_t}}. \tag{3}$$

This three-step method produces points estimates for the fiscal multipliers, but not standard errors. We compute the standard errors for the fiscal multipliers using bootstrap methods. These allow us to generate distributions for the estimated multipliers, from where we can compute averages and standard deviations for each horizon h.

Table 4 presents the cumulative fiscal multipliers at horizons from 0 to 12 quarters and for five different shocks,in percentage of GDP: -1.5%, -0.5%, the marginal multiplier at a 0% shock, +0.5% and +1.5%. In the absence of size-dependence, fiscal multipliers should be approximately the same regardless of the fiscal shock. The results suggest otherwise, and are in line with the ones presented in section 2.1. The impact multiplier (at $h = 0$) already presents economically meaningful differences: going from the marginal multiplier of a 0% shock to a shock equal to 1.5% of GDP increases the fiscal multiplier by more that 50%. One year after the initial shock the differences are even larger: going from a 0% to a 1.5% shock increases the multiplier by a factor of 3.

Figure 1 plots the cumulative multipliers for the different time horizons, together

[8] For the linear case, Ramey and Zubairy [33] propose a one step approach which yields the same results as the three step approach. For the quadratic case, the one step approach and the three step are no longer equivalent.

Horizon/Shock	-1.5%	-0.5%	0%	+0.5%	+1.5%
0	0.064***	0.651***	0.849	1.014***	1.277***
	(0.725)	(0.223)	(0.134)	(0.176)	(0.366)
1	−0.774***	0.365***	0.819	1.219***	1.895***
	(0.609)	(0.203)	(0.142)	(0.213)	(0.428)
2	−1.394***	0.361***	1.012	1.564***	2.455***
	(0.693)	(0.214)	(0.134)	(0.193)	(0.394)
3	−1.028***	0.312***	0.923	1.502***	2.584***
	(0.540)	(0.195)	(0.112)	(0.177)	(0.433)
4	−1.155***	0.223***	0.877	1.514***	2.747***
	(0.420)	(0.159)	(0.101)	(0.157)	(0.397)
8	0.306***	0.780***	1.026	1.280***	1.815***
	(0.248)	(0.104)	(0.063)	(0.101)	(0.265)
12	0.866***	1.025***	1.108	1.195***	1.380***
	(0.196)	(0.081)	(0.044)	(0.079)	(0.217)

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Estimated cumulative multipliers for fiscal shocks of different sizes (columns) at different horizons (rows). Bootstrap standard errors in parentheses. Stars indicate the p-value of a t-test for the statistical difference of the multipliers of the different sized shocks relative to the the 0% multiplier: *** p<0.01, ** p<0.05, * p<0.1.

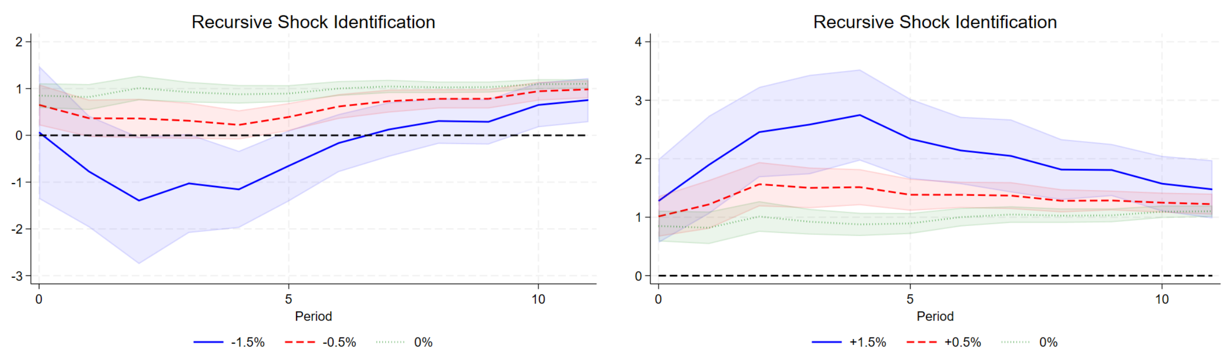

Figure 1: Cumulative multiplier for negative shocks on the left panel and for positive shocks on the right panel. Colored areas represent the 95th confidence interval.

with the 95th confidence intervals. The figure illustrates that the non-linearity is not only economically meaningful but also statistically different from each others.

Finally, we show in Appendix A.2 that our results are robust to changing several assumptions. First, we include taxes as a control variable.[9] Second, we include both a linear and a quadratic trend. Third, we include a polynomial of order eight in the lag operator instead of order four. Results can be found in Figures A.17-A.19 in Appendix A.2. We also test the nonlinear response of tax revenues as a percentage of GDP to the fiscal shocks. Figure A.20 in Appendix A.2 shows that tax revenues respond to a spending shock, in line with evidence by Ferriere and Navarro [18], but respond in linearly to different sized shocks, suggesting the nonlinear output response is not stemming from a nonlinear response of tax revenues.

2.2.1. Comparison with Barnichon et al. [8] and Ben Zeev et al. [10]

While we find the size of the fiscal multiplier to be larger for large positive shocks and smaller for large negative shocks, Barnichon et al. [8] find that negative shocks yield a larger multiplier than positive ones. A few differences in the approach and methods used explain the differences in results between the two papers. First, using military news shocks instead of the BP ones flips the results. Figure A.16 in Appendix A.2 shows that using military news shocks, we find a result similar to Ben Zeev et al. [10], where negative shocks yield larger multipliers but the multipliers are not statistically different from each other.

Ramey and Zubairy [33] advocate for the use of the BP shocks to capture short term effects of fiscal policy, as the military shocks have an average lag of two years between the time of the announcement and when they are actually implemented. For this reason, we prefer the BP shocks, as the model results presented in Section 5 will equally focus on the short run effects of fiscal policy.

Second, the method used may also play an important role. While Barnichon et al. [8] using the Functional Approximations of Impulse Responses (FAIR) method find, using

[9]Ferriere and Navarro [18] show that the response of taxes is an important determinant of the size of the fiscal multiplier. By controlling for taxes, we show that the nonlinear effect is independent of the taxes. Additionally, in section 2.1, we show the results to be robust to tax consolidations and to government consumption consolidations, controlling for the path of taxes.

the BP shocks, the fiscal multiplier to be larger for negative shocks, we find the opposite result using local projections. BDM advocate the use of the FAIR method based on efficiency gains, acknowledging the method induces bias.[10] This induced bias may, in part, explain the differences compared to the results we find using local projections.

Third, the average values for both positive and negative BP shocks are relatively small and close to zero. This means that, when simply comparing average positive to average negative shocks, the nonlinearity may not be strong enough to be statistically and economically significant, in line with what Ben Zeev et al. [10] suggest. Our quadratic specification effectively treats small and large shocks differently, thus allowing us to capture nonlinearities that would otherwise not be detected statistically.[11]

3. A Neoclassical Model of Fiscal Policy

In this section, we present a standard incomplete markets model that we then calibrate to the U.S. economy and use to study the nonlinear effects of fiscal policy.

3.1. Technology

The production sector is standard, with the representative firm having access to a Cobb-Douglas production function,

$$Y_t(K_t, L_t) = K_t^{\alpha} L_t^{1-\alpha}$$

where L_t is the labor input, measured in efficiency units, and K_t is the capital input. The law of motion for capital is

$$K_{t+1} = (1-\delta)K_t + I_t$$

[10] Ben Zeev et al. [10] shows the local projections method provides more precise estimates than the FAIR method.

[11] We explore this approach in Appendix A.3. When comparing just positive and negative shocks, we do not find multipliers to be statistically different from each other, in line with the findings of Ben Zeev et al. [10].

where δ is the capital depreciation rate and I_t is the gross investment. Firms choose labor and capital inputs each period in order to maximize profits:

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta)K_t.$$

In a competitive equilibrium, factor prices are paid their marginal products:

$$w_t = \frac{\partial Y_t}{\partial L_t} = (1-\alpha)\left(\frac{K_t}{L_t}\right)^{\alpha}$$
$$r_t = \frac{\partial Y_t}{\partial K_t} - \delta = \alpha\left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta$$

3.2. *Demographics*

The economy is populated by a continuum of infinitely lived households. Households differ with respect to their permanent ability levels assigned at birth, a, persistent idiosyncratic productivity shocks, u, asset holdings, k, and time discount factors that are uniformly distributed and can take three distinct values, $\beta \in \{\beta_1, \beta_2, \beta_3\}$. Agents choose how much to work, n, consume, c, and save, k', to maximize expected lifetime utility.

3.3. *Labor Income*

The hourly wage received by an individual depends on the wage per efficiency unit of labor, w, permanent ability $a \sim N(0, \sigma_a^2)$, and an idiosyncratic productivity shock u, which follows an AR(1) process:

$$u' = \rho u + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon^2).$$

The wage rate per hour worked by an individual i is given by

$$w_i(a, u) = w e^{\gamma + a + u}$$

where γ is a constant used to normalize the average earnings in the economy to 1.[12]

3.4. *Preferences*

Households' utility in a given period $U(c,n)$ is standard: time-additive, separable, and isoelastic, with $n \in (0,1]$:

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta}$$

Each household maximizes their expected lifetime utility:

$$\max_{\{c_t,n_t,k_t\}_{t=0}^{\infty}} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U(c,n)$$

3.5. *Government*

Government revenues include a distortionary labor tax τ_l. Tax revenues are used to finance public consumption of goods, G_t; lump-sum transfers, g_t; and interest expenses on public debt, rB_t. Denoting tax revenues as R, the government budget constraint is defined as:

$$g \int \mathrm{d}\Phi + G + rB = R$$

3.6. *Recursive Formulation of the Household Problem*

In a given period, a household is defined by their asset position k, time discount factor β, permanent ability a, and persistent idiosyncratic productivity u. Given this set of states, the household chooses consumption, c; work hours, n; and future asset holdings, k', to maximize the present discounted value of expected utility. The problem can be written

[12] Normalizing average earnings to 1 is for example helpful when mapping an estimated nonlinear income tax code from the data to the model, like we do in Appendix C. We estimate the tax function on income normalized by Average Earnings in the data y/AE. Thus a person with average earnings in the data and model will have an income of 1.

recursively as:

$$V(k,\beta,a,u) = \max_{c,k',n} \left[U(c,n) + \beta \mathbb{E}_{u'} \left[V(k',\beta,a,u') \right] \right]$$

$$\text{s.t.:}$$

$$c + k' = k(1+r) + g + nw(a,u)(1-\tau_l)$$

$$n \in [0,1], \quad k' \geq -b, \quad c > 0$$

where b is an exogenous borrowing limit.

3.7. *Stationary Recursive Competitive Equilibrium*

Let the measure of households with the corresponding characteristics be given by $\Phi(k,\beta,a,u)$. Then, we can define a stationary recursive competitive equilibrium (SRCE) as follows:

1. Taking the factor prices and the initial conditions as given, the value function $V(k,\beta,a,u,)$ and policy functions $c(k,\beta,a,u)$, $k'(k,\beta,a,u)$, $n(k,\beta,a,u)$ solve the households' optimization problems.

2. Markets clear:

$$K + B = \int k \mathrm{d}\Phi$$

$$L = \int n(k,\beta,a,u) \mathrm{d}\Phi$$

$$\int c \mathrm{d}\Phi + \delta K + G = K^{\alpha} L^{1-\alpha}.$$

3. Factor prices are paid their marginal products:

$$w = (1-\alpha)\left(\frac{K}{L}\right)^{\alpha}$$

$$r = \alpha\left(\frac{K}{L}\right)^{\alpha-1} - \delta.$$

4. The government budget balances:

$$g\int \mathrm{d}\Phi + G + rB = \int \left[nw\left(a,u\right)\left(1-\tau_l\right)\right]\mathrm{d}\Phi.$$

3.8. Fiscal Experiments and Transition

Our baseline fiscal experiments consist of changes in government spending G of different sizes (measured as a percentage of GDP) and under different financing regimes. This is important, as Ricardian equivalence does not hold in our model and therefore the type and timing of the financing of the shock can matter substantially for its effects on output. Our design of the fiscal experiments aims at capturing wealth effects from taxes and transfers, abstracting from substitution effects caused by changes in tax rates.

1. Permanent debt consolidations and expansions. In the case of a consolidation, G decreases temporarily so as to allow public debt to fall. The economy then transitions to a new SRCE with lower public debt and G returns to its original level. The expansion is defined symmetrically.

2. Temporary deficit-financed reductions and increases in G. Initially, the reduction in G leads to a fall in debt. Transfers adjust to pay back the debt and bring the economy back to the initial SRCE according to the following fiscal rule

$$g = g_{ss} + \phi_T\left(\frac{B_{-1}}{B_{ss}} - 1\right).$$

3. Temporary balanced-budget-financed reductions and increases in G. In the case of a reduction, lump-sum transfers increase to clear the government budget constraint and maintain debt at a constant level. Eventually, the economy transitions back to the initial SRCE.

We delegate the formal definition of a transition equilibrium to Appendix B.

4. Calibration

We calibrate the starting SRCE of our model to the US economy. Some parameters are calibrated directly from empirical counterparts, while others are calibrated using the simulated method of moments (SMM) so that the model matches key features of the US economy. Appendix D contains a table that summarizes the values for the parameters that are calibrated outside of the model.

4.1. *Preferences*

We set the Frisch elasticity of labor supply to 1, as in Trabandt and Uhlig [35], a standard value in the literature. The disutility of work and the three values for the discount factor (χ, β_1, β_2, β_3) are among the parameters calibrated to match four data moments: the share of hours worked and the three quartiles of the wealth distribution, respectively.

4.2. *Taxes and Government Spending*

Following Hagedorn et al. [21], we set transfers g to be 7% of GDP and government spending G to be 15% of GDP. The labor tax τ_l is then set so that total tax revenues clear the government budget.

4.3. *Endogenously Calibrated Parameters*

Some parameters that do not have any direct empirical counterparts are calibrated using SMM. These are the discount factors, borrowing limit, disutility from working, and variance of permanent ability. The SMM is set so that it minimizes the following loss function:

$$L(\beta_1, \beta_2, \beta_3, b, \chi, \sigma_a) = ||M_m - M_d|| \tag{4}$$

where M_m and M_d are the moments in the model and in the data, respectively.

We use six data moments to choose six parameters, so the system is exactly identified. The six moments we select in the data are (i) the share of hours worked, (ii-iv) the three quartiles of the wealth distribution, (v) the variance of log wages, and (vi) the capital-to-output ratio. Table 5 presents the calibrated parameters, and Table 6 presents the calibration fit.

Parameter	Value	Description
Preferences		
$\beta_1, \beta_2, \beta_3$	0.987, 0.988, 0.986	Discount factors
χ	10.3	Disutility of work
Technology		
b	1.70	Borrowing limit
σ_a	0.712	Variance of ability

Table 5: Endogenously calibrated parameters.

Data moment	Description	Source	Data value	Model value
K/Y	Capital-to-output ratio	PWT	12.292	12.292
$\mathrm{Var}(\ln w)$	Yearly variance of log wages	LIS	0.509	0.509
$\bar{n}$	Fraction of hours worked	OECD	0.248	0.248
Q_{25}, Q_{50}, Q_{75}	Wealth quartiles	LWS	-0.014, 0.004, 0.120	-0.006, 0.035, 0.135

Table 6: Calibration fit.

5. Quantitative Results

We now use the calibrated model as a laboratory to study the effects of government spending shocks of different sizes and under different financing regimes. We start by studying permanent debt consolidations: transitions where the debt level at the final steady state is different (lower or higher) than the debt level at the initial steady state. We then analyze temporary changes in G where the economy returns to the initial steady state. We consider both debt financing and balanced budget financing. In Appendix C we show that the results are robust to a more realistic tax structure, including labor tax progressivity, capital and consumption taxes.

5.1. *Permanent Debt Changes*

We start by considering permanent fiscal consolidations and expansions, the type of experiment that most closely resembles the policies that we empirically analyze in the first part of Section 2. The idea is that the fiscal authority temporarily changes its spending level so as to attain a new level of public debt, lower in the case of consolidations and higher in the case of expansions. More specifically, the experiment consists of temporary changes in G that last for 30 quarters, with no changes in taxes or transfers. At the end of those 30 periods, debt reaches a new steady-state target level and G returns to its initial level, while lump-sum transfers adjust to clear the government budget constraint given the new level of debt. The economy then takes 70 quarters to reach the new steady state with a new debt-to-GDP ratio and different lump-sum transfers.

Figure 2 plots the fiscal multiplier on impact (one quarter after the shock) depending on the size of the initial G variation. The multiplier is monotonically increasing in the shock: it is larger for larger increases in G and smaller for larger decreases in G. In other words, the effects of G on Y are nonlinear: the larger is the G shock, the larger the impact on output.[13]

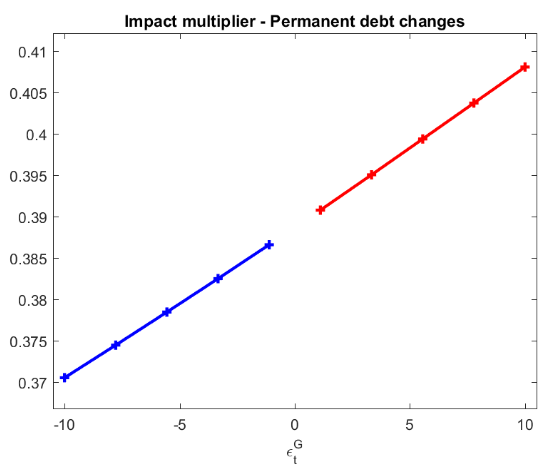

Figure 2: Fiscal multiplier on impact for the permanent change in debt experiment as a function of the fiscal shock. The blue line corresponds to G contractions, while the red line represents G expansions.

Figures 3 and 4 shed light on the mechanism at the heart of this paper that generates this pattern. Each presents one of two mechanisms that are key for the result: movements in the wealth distribution, and heterogeneous labor supply responses across the distribution. Figure 3 plots the share of financially constrained agents one year after

[13]While we plot the nonlinear pattern for the impact multiplier, we show that this nonlinear pattern persists even after several quarters in Appendix Appendix E.

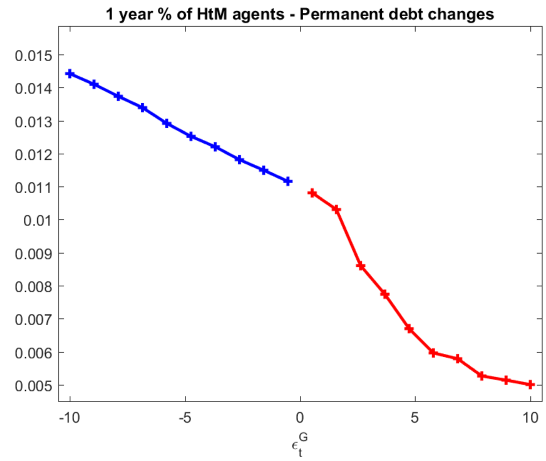

Figure 3: Percentage of financially constrained agents one year after the shock for the permanent change in debt experiment as a function of the fiscal shock. The blue line corresponds to G contractions, while the red line represents G expansions.

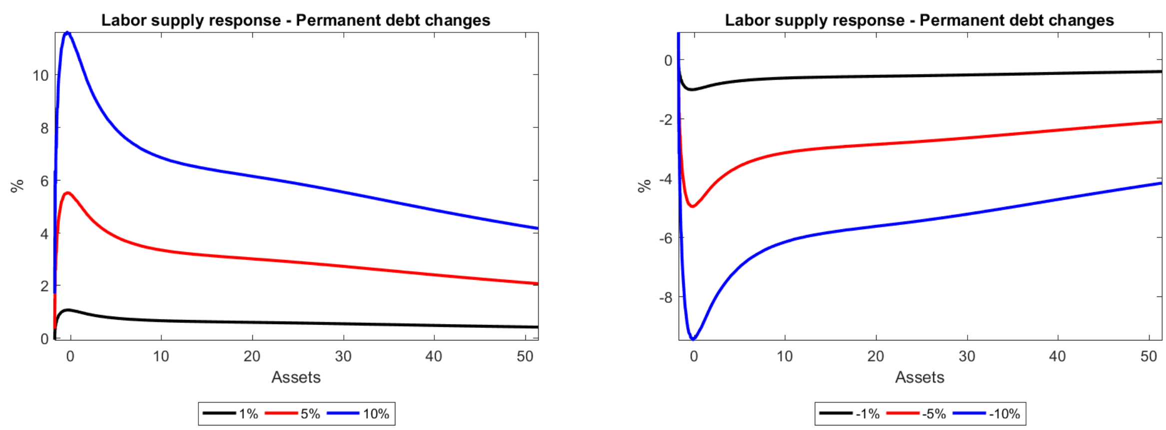

Figure 4: (Relative) labor supply response to different changes in G over the asset distribution, for the permanent change in debt experiment. Left panel plots the results for positive government spending shocks while the right panel presents the results for negative shocks.

the shock, as a function of the size of the shock. The mass of constrained agents is decreasing in the size of the shock: more negative shocks involve larger future reductions in public debt. This generates not only a positive wealth effect, as future lump-sum transfers will be higher, but also a future positive income (human wealth) effect, as debt is crowded out by capital and wages are increasing in the stock of capital. As agents internalize these positive wealth and income effects, they find it optimal to borrow more today. Thus more negative consolidations induce more agents to move towards the constraint in the short run.[14] More negative consolidations move agents from the middle of the wealth distribution to the bottom, while more positive consolidations induce the opposite movement of the distribution.

Figure 4 illustrates why these changes in the percentage of constrained agents matter for aggregate dynamics. This figure plots the labor supply response across the wealth distribution for shocks of three different sizes (1%, 5%, and 10% of GDP). Notice that the labor supply of constrained and low-wealth agents is less responsive than that of agents in the middle of the distribution. These wealthier agents react strongly to changes in future income and wealth, while constrained agents respond only to changes in the current state (i.e., current taxes and transfers) and not to changes in future states. For this reason, constrained agents essentially do not react to government spending shocks in the short run, regardless of their size. These wealthier agents perceive larger wealth effects from larger spending shocks, hence reduce or increase their labor supply by more.

The mechanism can then be summarized as follows: negative spending shocks move the wealth distribution to the left. As more agents become constrained, the result is a smaller aggregate labor supply response and, consequently, a relatively smaller effect on GDP. The opposite is true for positive spending shocks, which move the wealth distribution to the right, to a region where labor supply is more responsive. In summary, the elasticity of aggregate labor supply to government spending shocks is increasing in the size of the fiscal consolidation shock. The same pattern translates to the fiscal multiplier as well.[15]

A permanent change in government spending that is financed by taxes (or lump-sum transfers) would generate qualitatively similar results. In an incomplete markets environment where the Ricardian Equivalence fails to hold, a permanent increase in

[14]Figure F.30 in Appendix F illustrates this point by plotting the overall movement of the entire wealth distribution in response to the shocks of different sizes.

[15]Figures C.21-C.23 in Appendix C show that the results are robust to a richer tax structure that includes both capital and consumption taxes, as well as labor tax progressivity.

G that is financed by increased taxes generates a negative wealth effect, shifting the wealth distribution to the left. Assuming that debt remains constant and thus taxes rise contemporaneously, this generates a negative current income effect to which low wealth agents react most strongly. The combination of the leftwards shift in the distribution with this differential response would cause the multiplier to be increasing in the size of the shock, just as in the experiment described above. In Appendix G we illustrate and explain this mechanism, using iterated Euler equations. As a robustness test we also show that the nonlinearity is not driven by prices.

5.2. *Temporary Spending Shocks*

We now consider the case of temporary government spending shocks: sequences of shocks to G that result in the same original SRCE in the long run. This is the standard experiment that is typically the focus of quantitative analyzes of fiscal multipliers. We show that the same basic logic applies to this case. Additionally, we consider two types of financing regimes: (i) deficit financing, where the temporary shock is absorbed by changes in public debt until a certain point in time, after which transfers adjust to ensure that the economy returns to the initial (pre-shock) level of public debt, and (ii) balanced-budget financing, in which transfers adjust to keep public debt constant throughout the transition.

5.2.1. *Path of the Shocks*

We follow most literature on fiscal policy and assume that fiscal spending follows an AR(1) process in logs:

$$\log G_t = (1-\rho_G)\log G_{SS} + \rho_G \log G_{t-1} + \varepsilon_t^G$$

where ρ_G is assumed to be 0.975 at a quarterly frequency. For the deficit financing experiment, we set ϕ_T to 0.2 so that debt is back to the steady state level after 100 periods.

5.2.2. *Deficit Financing*

Panel (a) of Figure 5 plots the multiplier as a function of the size of the shock for the case of deficit financing. While the size of the multipliers is now slightly smaller since the shock is no longer permanent, the results are quantitatively similar and the overall pattern remains unchanged from the permanent debt change case.

Figures 7 and panel (a) of 6 show that the basic mechanism still applies. The mass of

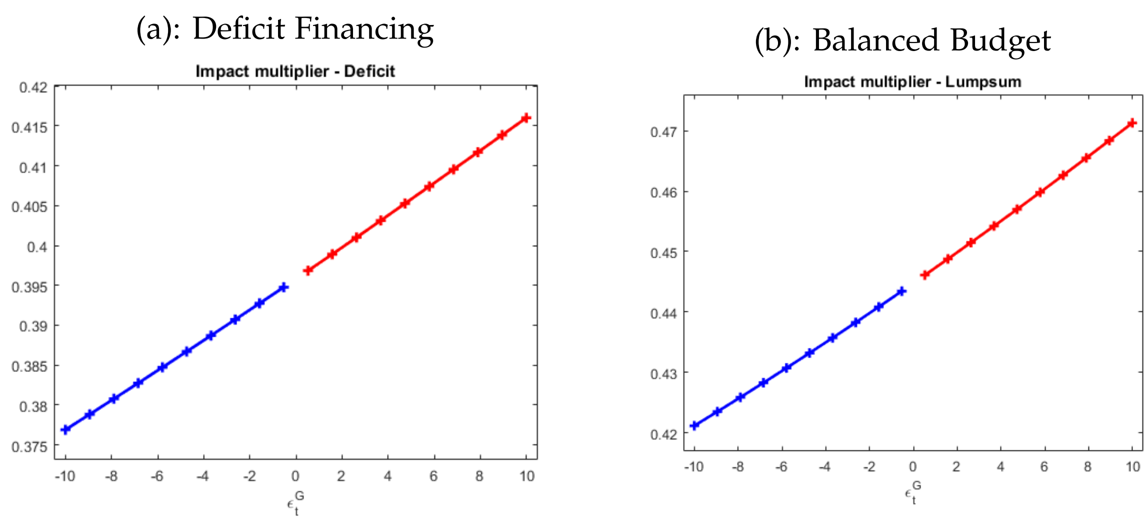

Figure 5: Fiscal multiplier on impact as a function of ε_t^G (the initial impulse), for the deficit financing (a) and balanced budget (b) experiments. The blue line corresponds to G contractions, while the red line represents G expansions.

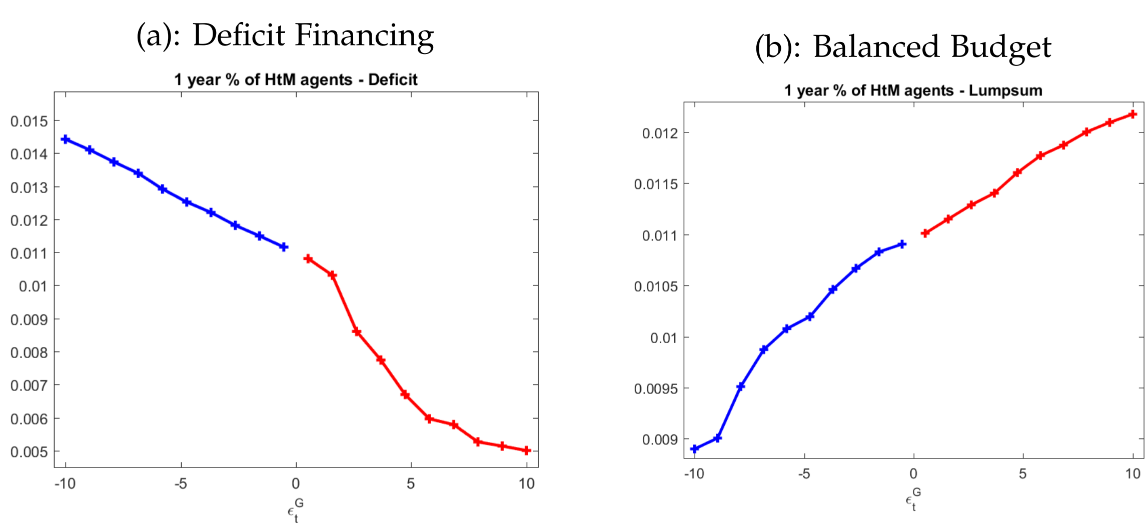

Figure 6: Percentage of financially constrained agents one year after the shock as a function of ε_t^G (the initial impulse), for the deficit financing (a) and balanced budget (b) experiments. The blue line corresponds to G contractions, while the red line represents G expansions.

financially constrained agents is decreasing on the size of the shock. As these shocks are deficit financed, they cause a future positive wealth effect to which only unconstrained agents respond. Therefore, the smaller the mass of agents that are constrained the larger the responses of the aggregate labor supply and GDP become. This explains why the multiplier is largest for large positive shocks and smallest for large negative shocks.[16] Figure F.31 in Appendix F shows the overall movement of the wealth distribution, explaining the mechanism at play. Table E.24 in the Appendix shows that the nonlinearity is persistent at different horizons, in line with the empirical findings in Section 2.2.

5.2.3. Balanced-Budget

Panel (b) of Figure 5 plots fiscal multipliers for the case where the government runs a balanced budget and thus decreases transfers when G increases so as to keep the level of debt constant. The qualitative results are identical, but the sizes of the multipliers are larger under this financing regime. While the core mechanism still revolves around differences in labor supply responses coupled with shifts in the wealth distribution, these now operate a bit differently. Due to contemporaneous changes in lump-sum transfers,

[16]Figures C.24-C.26 Appendix C present the results under a richer tax structure.

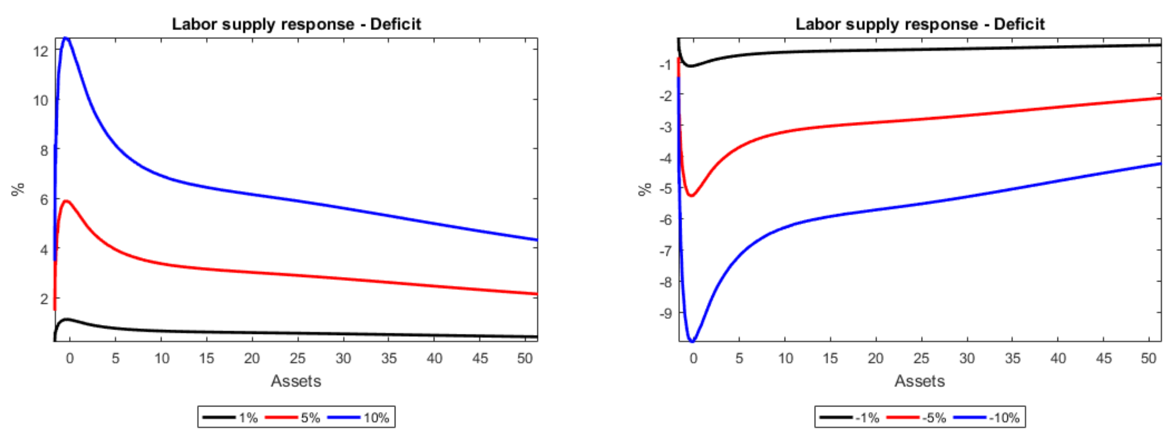

Figure 7: (Relative) labor supply response to different changes in G over the asset distribution, for the deficit financing experiment. Left panel plots the results for positive government spending shocks while the right panel presents the results for negative shocks.

constrained agents now display the largest labor supply responses. An increase in G is associated with a decline in lump-sum transfers, which elicits a much larger labor supply response by constrained and low-wealth agents.

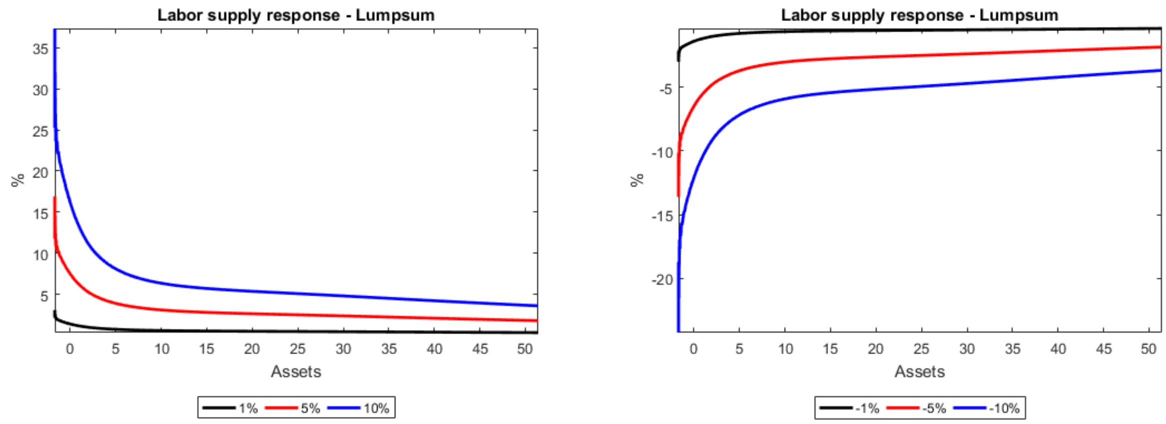

Figure 8: (Relative) labor supply response to different changes in G over the asset distribution, for the balanced budget experiment. Left panel plots the results for positive goverbnment spending shocks while the right panel presents the results for negative shocks.

Figure 8 displays the labor supply responses by wealth and the size of the spending shock. These labor supply responses behave in the manner that we would expect, with constrained agents greatly expanding their labor supply in response to a positive shock that decreases transfers. These labor supply responses can be combined with the movements in the distribution presented in panel (b) of Figure 6 to deliver our result: the mass of financially constrained agents is increasing in the size of the shock. A positive spending shock financed by a contemporary decrease in transfers moves agents towards the constraint, where labor supply is more responsive. Conversely, a negative shock moves agents away from the constraint, where their labor supply is less responsive. The key mechanism again revolves around larger shocks shifting the distribution towards regions where the labor supply response is strongest.[17] Figure F.32 in Appendix F illustrates exactly this point. Table E.25 shows that the nonlinearity is persistent at different horizons, in line with the empirical findings in Section 2.2.

[17]Figures C.27-C.29 Appendix C present the results under a richer tax structure.

5.3. *Validation: Marginal Propensities to Earn*

The mechanism that drives the sensitivity of the multiplier to the fiscal shock crucially hinges on the response of labor supply. This, in turn, is shaped by the individual labor supply responses of agents across the wealth distribution. One question, then, is whether our model generates reasonable individual responses to changes in taxes and transfers. To this end, we define the marginal propensity to earn (MPE) using a common definition in the literature [20, 5]: the negative of the response of earned income to a one time, unexpected payment:

$$MPE = -w_i(a, u)\frac{\partial n_t(k, \beta, a, u)}{\partial T_t}$$

where $w_i(a, u)$ corresponds to the effective wage rate per hour worked, and n_t the labor supply policy function. We compare the model-implied MPEs to those estimated by Golosov et al. [20]. In particular, we simulate an experiment similar to that leveraged by the authors in the stationary equilibrium of our model, and compare the MPE estimates. At the stationary equilibrium, we increase the wealth of an agent by an amount that is commensurate to a lottery win (relative to the average wage in the economy). We compute the MPE using the above formula, and average it across all agents and over a five-year period. This yields an average value of 0.032, which is close to the average value of 0.028 estimated by Golosov et al. [20]. Our estimates for the average MPE are also within the [0,0.04] range for average MPEs that have been reported in the literature, see Auclert et al. [5].

5.4. *The Role of Heterogeneity*

To illustrate the importance of household heterogeneity and movements in the distribution of wealth, which affect the distribution of labor supply responses, we solve a version of the baseline model with a representative agent. We run the same fiscal experiments and compute fiscal multipliers in this real business cycle (RBC) version of the model. The details of the RBC model can be found in Appendix J. We keep the calibration as close as possible to that of the heterogeneous agents neoclassical model (HANC): we change only preference parameters to ensure the model steady states have the same real interest rate, average MPE, and number of hours worked. Results for the balanced budget and deficit versions of our baseline experiment are reported in Figure 9, which compares the fiscal multiplier on impact depending on the size of the shock between the representative agent RBC and the baseline HANC models. The left panel presents the results for the balanced-budget experiment, while the right panel refers to the deficit-financed experiment. Since the levels of the multipliers are different across models, and our focus is on the extent of the variation of the multiplier, we plot the ratio of each multiplier relative to the multiplier for an infinitesimal shock.

The figure shows that while the RBC model can also generate a nonlinearity (due to a nonlinear income effect on labor supply), with the increasing pattern that we find in the data, the presence of heterogeneity is important to amplify that nonlinearity: in the RBC model, for the balanced-budget experiment, multipliers range from -3% to +3%, for fiscal shocks ranging from -10% to 10%. This is about half of the variation that is generated by the HANC model. Thus heterogeneity amplifies the nonlinear effects of fiscal policy by around 50%. The magnitudes are similar for the deficit-financed case.

Figure 10 replicates the left panel of Figure 9, but with two additional lines, corresponding to HANC models with a lower and larger shares of constrained agents than the baseline.[18] The figure shows that a smaller fraction of constrained agents reduces the extent of the nonlinearity, to a level closer to that of the representative-agent RBC model. Conversely, raising the share of constrained agents at the steady state raises the extent of the nonlinearity. These comparative statics align with our explanation for the mechanism in the previous sections, which relies on changes in the distribution of wealth to

[18]We change the fraction of constrained agents at the stationary equilibrium by both changing the borrowing limit and the discount factor of the least patient agents

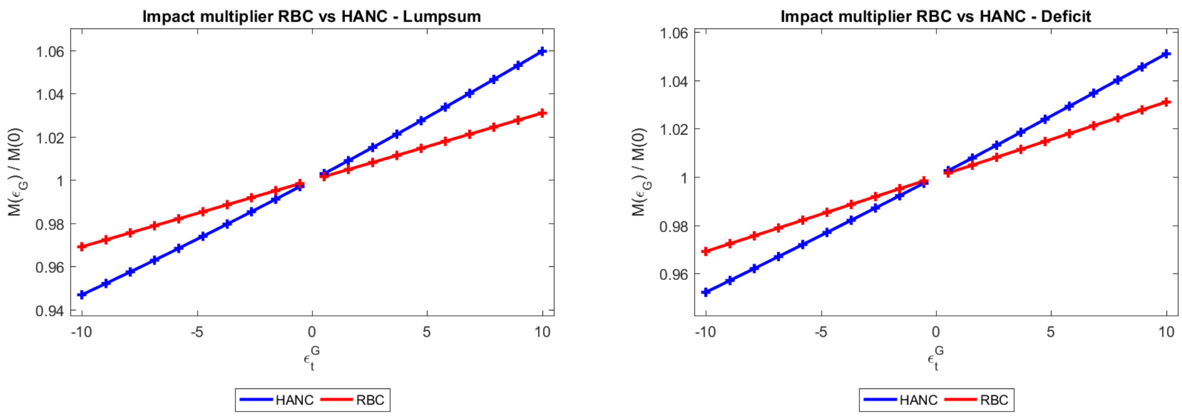

Figure 9: Fiscal multiplier on impact as a function of the fiscal shock, scaled by the multiplier of an infinitesimal shock. Left panel plots the results for balanced budget experiment while the right panel presents the results for deficit financed experiment.

generate the nonlinear responses to fiscal policy.

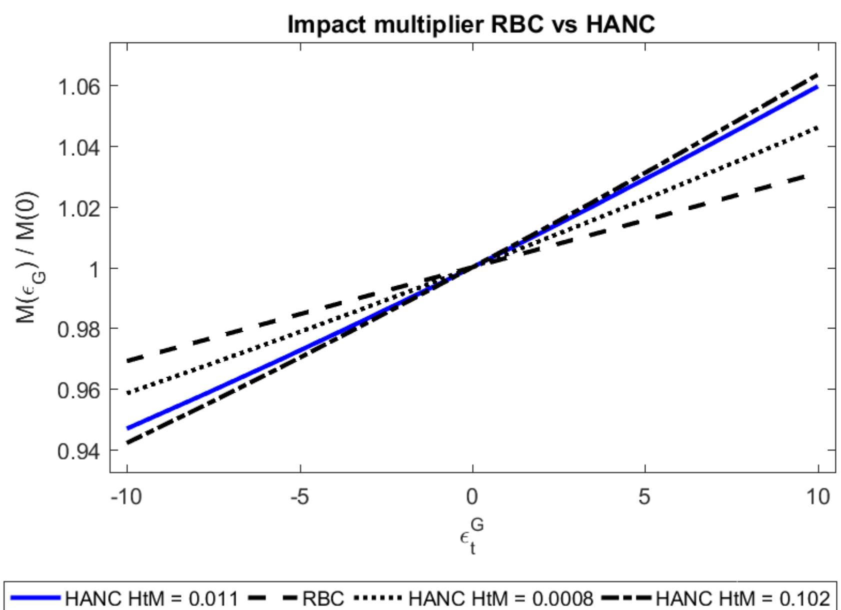

Figure 10: The figure shows how the impact multiplier changes for calibrations with varying percentages of hand-to-mouth agents.

5.5. Multipliers: Model vs. Data

It is well known that fiscal multipliers in neoclassical models without nominal (and real) rigidities tend to be lower than what empirical estimates typically find. This applies to our model: we find fiscal multipliers that are lower than those we estimate in section 2, as well as a weaker dependence on size of the shock. The next section tries to partly address this issue, by introducing nominal rigidities in an incomplete markets heterogeneous agents model. We show that not only the basic mechanism survives in the presence of nominal rigidities, but also that both the level of the multipliers and their sensitivity to the shock are larger.

6. Heterogeneous Agents New Keynesian Model

The main source of variation for multipliers that we discussed in the previous sections is a fundamentally neoclassical mechanism that operates via differential changes in the labor supply of agents across the wealth distribution. In principle, it is not clear whether such mechanism should survive the introduction of aggregate demand externalities. In this section, we show that it does in the context of a state-of-the-art heterogeneous agents New Keynesian (HANK) model that closely follows the set up in Auclert et al. [6]. The details of the HANK model are presented in Appendix H. We repeat the main fiscal experiments that we conducted in the neoclassical model, and show that they, along with the core mechanism, are robust to the introduction of nominal rigidities.

6.1. Balanced Budget

We assume again that government spending follows an AR(1) in logs, and consider a range of values for ϵ_t^G that correspond to changes from -10% to 10% of steady-state government spending on impact. Panel (a) of figure 11 plots the fiscal multipliers for the case where the government runs a balanced budget and adjusts lump-sum transfers so as to keep the level of debt constant. As expected, the HANK model generates larger multipliers than the neoclassical model. Additionally, the HANK model generates a larger sensitivity of multipliers to the shock, with range going from 0.54 to 0.57 in this experiment. Most importantly, the HANK model preserves the same pattern for the fiscal multipliers, increasing in the size of the government spending shock.

To confirm that these results are driven by a similar mechanism, Figure 12 plots labor supply responses as a function of wealth for spending shocks of different sizes. As before, constrained agents at the bottom of the wealth distribution expand their labor supply response by more in response to positive spending shocks, i.e. a decrease in lump-sum transfers. Panel (a) of figure 13 shows that, just as in the neoclassical model, an increase in government spending is associated with more constrained agents. These two facts combined help explain the pattern, as a fiscal contraction reduces the mass of agents that are most responsive to the shock, while a fiscal expansion increases the mass of agents that are most responsive. A natural question is whether our result could be overturned by sufficiently strong aggregate demand externalities: a fiscal expansion leads to a reduction in transfers, which in turn reduces consumption and potentially moderates the increase in output. Our results show that, quantitatively, the neoclassical labor supply effect dominates given our calibration.

6.2. Deficit Financing.

Panel (b) of figure 11 presents the fiscal multiplier as a function of the shock for the case where the government lets debt clear its budget constraint and sets lump-sum transfers according to the fiscal rule in H.2. As expected, deficit financing leads to larger multipli-

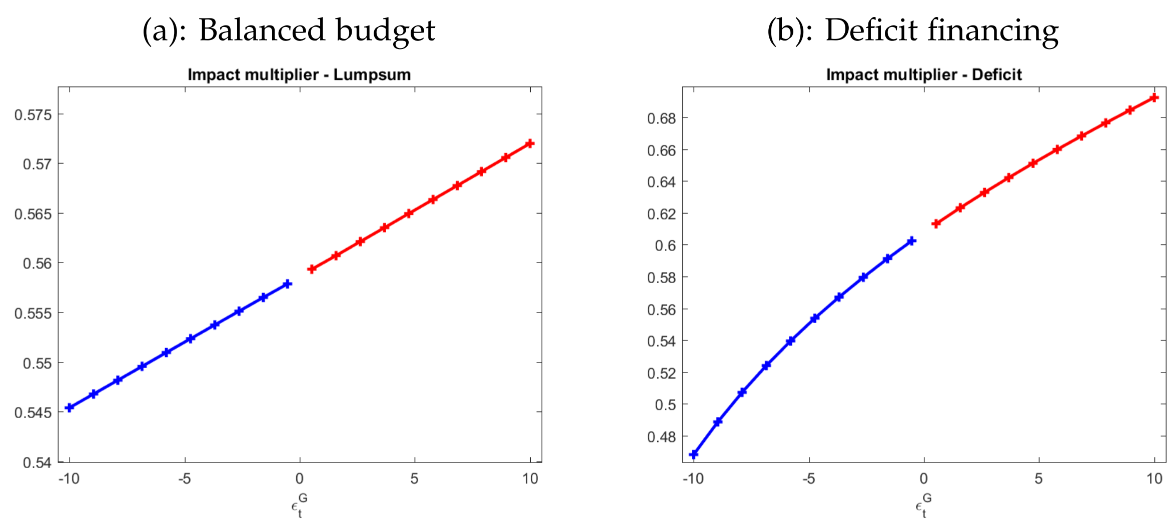

Figure 11: Fiscal multipliers on impact (one quarter after the shock) as a function of ϵ_t^G (the initial impulse)

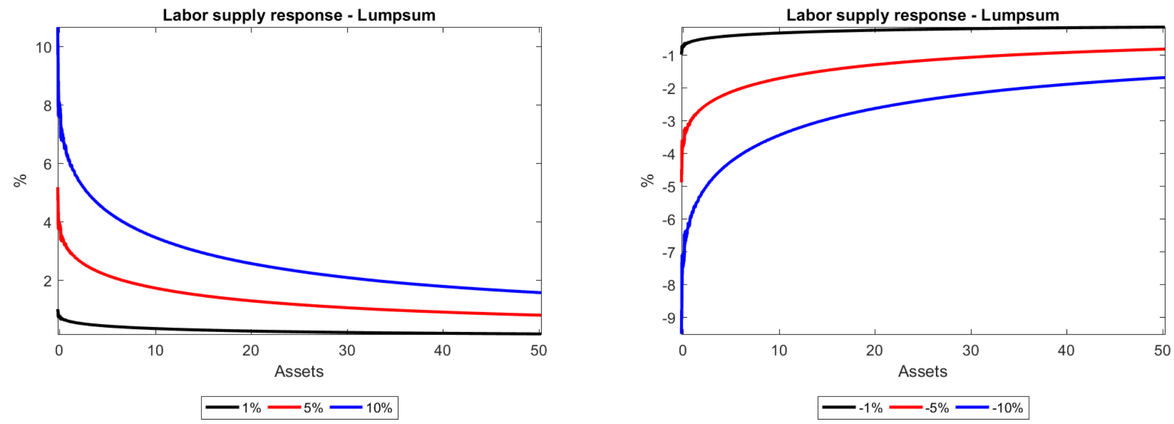

Figure 12: : (Relative) labor supply response to different changes in G over the asset distribution, for the balanced budget experiment. Left panel plots the results for positive government spending shocks while the right panel presents the results for negative shocks.

ers in the HANK model, as well as to more variability, with multipliers ranging between 0.47 and 0.69.

Figure 14 plots the labor supply responses by wealth and magnitude of the spending shock. Once again, the HANK model is able to replicate the same pattern as in the neoclassical model, with the labor supply of constrained agents reacting by relatively less, and the mass of agents at the constraint decreasing in the size of the shock as

(a): Balanced budget

(b): Deficit financing

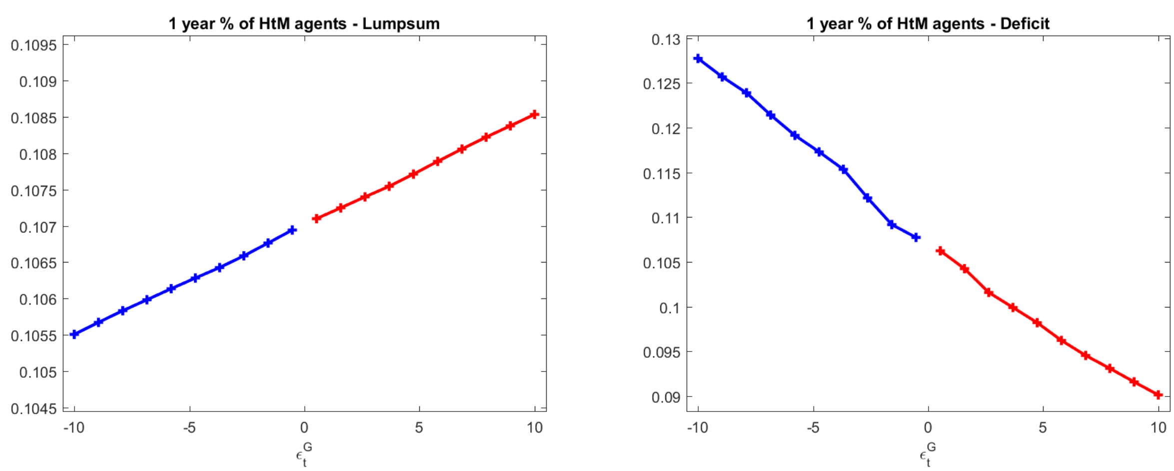

Figure 13: Percentage of agents with negative wealth (one year after the shock) as a function of ϵ_t^G (the initial impulse).

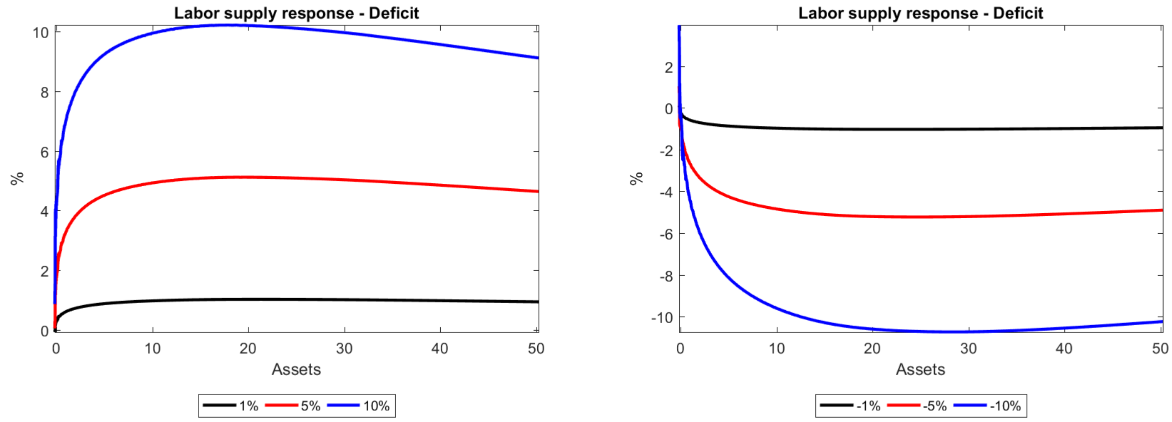

Figure 14: : (Relative) labor supply response to different changes in G over the asset distribution, for the balanced budget experiment. Left panel plots the results for positive government spending shocks while the right panel presents the results for negative shocks.

shown in panel (b) of figure 13.

6.3. Model vs. Data

The results presented above are based on a "standard" calibration for a HANK model, based on Auclert et al. [6]. Figure 11 shows that while multipliers are larger and more sensitive to the size of the shock, the variation that is generated by the model is still smaller than the one we estimate in the data, i.e. Table 4. To gauge the model's ability to replicate the empirical results, we perform a quantitative exploration in which we change the degree of responsiveness of monetary policy. The extent to which monetary policy responds to deviations of inflation from target has been shown to matter substantially for the size of the fiscal multiplier in models with nominal rigidities [29]. In particular, multipliers tend to be larger when monetary policy is "passive", i.e. the nominal interest rate reacts less to changes in inflation. While most standard models focus on "active monetary/passive fiscal" regimes, the frequency and length of such policy regime changes are areas of active research in monetary economics.

Figure 15 plots the impact multiplier under the deficit financing regime, which we consider the most empirically plausible case, in a version of the model where the central bank reacts less to changes in inflation ($\phi_\pi = 1$ vs. 1.25 in the baseline).[19] The relevant comparison with the baseline is relative to panel (b) of Figure 11. Notice first that the range of shocks is the same we focus on in our empirical exercise, $\epsilon_t^G \in [-1.5\%, 1.5\%]$ of GDP. The fiscal multiplier now ranges from about 0.2 to over 1.3, a similar order of magnitude as the empirical range that we estimate in Table 4. In reality, many other factors should influence the size and the range of the fiscal multiplier, but this numerical illustration shows that even our relatively simple model can do a reasonable job of approximating these characteristics. Table 7 presents cumulative multipliers at different horizons and for different shocks, and shows that the model also reproduces the weakening of the sensitivity as the multiplier horizon increases.

To summarize, we show that a HANK model with relatively passive monetary policy and active fiscal policy is able to reproduce three aspects of our empirical results in

[19] As it is known in the literature, there are limits to how low this parameter can go due to determinacy issues in the New Keynesian model. We discuss these issues in Appendix H.4.

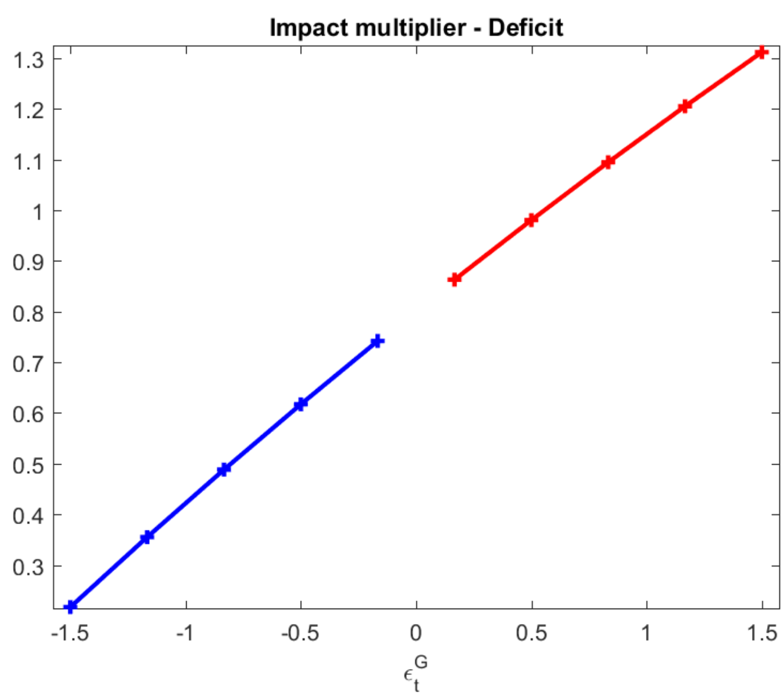

Figure 15: : Impact multipliers, deficit financing, less responsive Taylor rule $\phi_\Pi = 1$.

Horizon/Shock	-1.5%	-0.5%	+0.5%	+1.5%
0	0.217	0.617	0.980	1.311
1	0.232	0.628	0.988	1.316
2	0.243	0.634	0.990	1.314
3	0.252	0.639	0.990	1.311
4	0.261	0.643	0.991	1.308
8	0.295	0.658	0.989	1.292
12	0.324	0.671	0.987	1.277

Table 7: Cumulative multipliers for fiscal shocks of different sizes (columns) at different horizons (rows), HANK model

Table 4: (i) the level of the fiscal multiplier on impact; (ii) the sensitivity of the fiscal multiplier to the size of the fiscal shock (i.e., the range); and (iii) the dynamic behavior of the sensitivity, which weakens along the horizon for which the cumulative multiplier is computed.

7. Micro Evidence for the Mechanism

The mechanism we propose hinges on three key factors: (i) the elasticity of intertemporal substitution is increasing in wealth, (ii) there is a shift in the wealth distribution, and (iii) the financing regime for the fiscal shock. Intuitively, we propose that a positive tax-financed shock shifts the wealth distribution to the left. This, along with the fact that the labor supply response to a current income shock is decreasing in wealth, generates a fiscal multiplier that is increasing in the shock. A positive debt-financed shock, on the other hand, shifts the distribution to the right, which combined with a labor supply response to a future income shock that is increasing in wealth, again leads to a fiscal multiplier that is increasing in the shock. Large positive shocks would have the largest multiplier and large negative shocks the smallest.

A number of papers have documented that the EIS is increasing in wealth, see Vissing-Jørgensen [38] for example for the relationship between wealth and the EIS of consumption and, most notably in our context, Domeij and Floden [16] for the relationship between wealth and the EIS of labor. Brinca et al. [13] show that wealthier agents respond more to fiscal consolidation shocks. We here proceed to test for the dependence of the labor supply responses to fiscal shocks on wealth and whether they at all depend on the implied financing regime for the fiscal shocks. To do so we combine micro data from the PSID (1999-2015), which contains bi-annual data on wealth and hours worked, with the data on government spending shocks from Ramey and Zubairy [33], which we use in Section 2.2.

We identify fiscal shocks as in Section 2.2 (using quarterly data) and then sum these shocks over a 2-year period, which coincides with the interval between wealth-data collection in the PSID. Given that we are aggregating the shocks over a two year period, to get enough variation we use the sum of both Blanchard and Perotti and defense news fiscal shocks.

Table (8) provides an overview of the dataset constructed. We report the aggregate statistics for the sum of the fiscal shock over a two year span, $\sum_{i=0}^{1} G_{t-i}$, and the variations in debt from t-1 to t as percentage of GDP, ΔB_t, as well as statistics for the microdata on the change in hours worked, $\Delta \ln h_t$, and on net wealth, defined as the net value of all assets. We consider a household to be wealthy if it is in the top quartile of the distribution of net wealth. The median change in hours worked is zero, with the top quartile having increases above 10% and the bottom one decreases above 13%. Our sample includes wide variation in government debt, with a median change of 1% and a standard deviation above 4, which provides a good environment to test how different financing regimes affect the response of hours worked to fiscal shocks. To test this, we estimate

	p25	p50	p75	sd
$\Delta \ln h_t$	-0.13	0.00	0.10	(1.96)
ΔB_t	-0.17	1.05	2.39	(4.42)
$\sum_{i=0}^{1} G_{t-i}$	-2.16	0.52	2.00	(4.98)
Net wealth$_t$	2,019	36,000	152,680	(512,553)

Table 8: Descriptive statistics for the micro data

VARIABLES	(1) Total wealth <0	(2) Total wealth >0	(3) Total wealth < Wealth Q1	(4) Total wealth < Wealth Q2	(5) Total wealth > Wealth Q2	(6) Total wealth > Wealth Q3
β_1	1.060**	0.047	0.257**	0.095*	0.070*	0.058
	(0.477)	(0.037)	(0.109)	(0.058)	(0.040)	(0.047)
β_2	6.355**	0.750**	1.580*	1.035*	0.533	0.269
	(2.603)	(0.349)	(0.883)	(0.533)	(0.361)	(0.399)
β_3	-0.315**	-0.037**	-0.080*	-0.052**	-0.027	-0.014
	(0.129)	(0.017)	(0.043)	(0.026)	(0.017)	(0.019)
Observations	7,075	61,980	14,911	33,230	40,821	20,688
Number of ID	2,308	11,390	4,232	8,179	7,437	3,871

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: G shock, labor supply response, total wealth, and financing regime

the following equation:

$$\Delta \ln h_{it} = \beta_1 G_t + \beta_2 \Delta B_t + \beta_3 \Delta B_t \times G_t + \alpha_i + \epsilon_{it}$$

where ΔB_t is the change in government debt as a percentage of GDP, which we take as a proxy for whether fiscal shocks are deficit or tax financed. Similar to what we do in Section 2.2, we instrument G_t with the sum of the government spending shocks between $t-1$ and t, $\sum_{i=0}^{1} G_{t-i}$.

The results for this specification are in Table 9 and are consistent with the predictions from our model. The marginal effect of a fiscal shock is given by $\beta_1 + \beta_3 \times \Delta B_t$. A balanced-budget fiscal shock has a marginal effect equal to β_1: our model predicts that this effect should be positive and larger for households at the bottom of the wealth distribution. The neoclassical version of our model also predicts that deficit-financed fiscal shocks generate smaller multipliers than balanced-budget ones, an effect that is consistent with $\beta_3 < 0$. Since wealthier households respond relatively more to deficit-financed fiscal shocks, this coefficient should be increasing in the wealth quantile (decreasing in absolute value, since it is negative). As the results in Table 9 show, all these predictions are borne by the data and for different sample splits. Appendix I shows that these results are robust to: (i) different splits of the sample by net wealth, (ii) using liquid

VARIABLES	(1) Total wealth <0	(2) Total wealth >0	(3) Total wealth < Wealth Q1	(4) Total wealth < Wealth Q2	(5) Total wealth > Wealth Q2	(6) Total wealth > Wealth Q3
β_1	0.992***	0.493***	0.938***	0.798***	0.363***	0.228***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.004)
β_2	-0.501***	0.005***	-0.416***	-0.234***	0.077***	0.128***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.004)
Observations	5,559,876	24,440,124	7,499,997	15,000,000	15,000,000	7,500,000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: G shock, labor supply response, total wealth, and financing regime with neoclassical model simulated data.

wealth as opposed to wealth, which is defined as net wealth minus real estate assets, (iii) controlling for wages, and (iv) pooling all households in a single regression, and interacting the fiscal shock and debt terms with household wealth levels. The results for these robustness checks can be found in Tables I.28- I.31.

7.1. Model vs. Data

Lastly, we run a similar regression in the neoclassical model, using simulated data. We simulate both labor supply and wealth sequences for five million agents over both balanced budget and deficit financed transitions. We do it for G shocks of different sizes: 1%, 5% and 10% of GDP, so as to generate enough variation in both G and B. We then run the following regression with the model data:

$$\Delta \ln h_{it} = \beta_1 G_t + \beta_2 \Delta B_t + \epsilon_i,$$

where $\Delta \ln h_{it}$ is the log change in hours worked from the steady state level to the period of the shock for individual i and transition period t, G_t is government spending in the period of the shock for transition period t and ΔB_t the change in government debt from steady state to the period of the shock for transition t.[20] The marginal effect of a fiscal shock, in this case, is given by $\beta_1 + \beta_2$. The purpose of including an interaction term in

[20] Hours worked are annualized so that the coefficients are comparable to the empirical ones.

the empirical regression is to isolate the additional effect of debt changes from the fiscal shock. As all changes in B_t in the model are caused by the fiscal shock, there is no need to include the interaction term in the regression and β_2 in the model regression is the equivalent to β_3 in the empirical regression.

The results are presented in Table 10 and are in line with the empirical results. First, the overall response to balanced budget fiscal shocks, captured by the β_1 coefficient, is larger for wealth poor agents. For deficit financed shocks, the additional effect of debt changes, captured by the β_2 coefficient, causes wealth poor agents to reduce their response to the shock by more than wealthier agents, in line with the β_3 coefficient from the empirical regression.

8. Conclusion

In this paper, we contribute to the analysis of the aggregate effects of government spending shocks by empirically documenting that fiscal multipliers are increasing in the size of the shock, contrary to what is commonly assumed in the literature. We show that the standard incomplete markets model can reproduce this fact, generating a multiplier that is nonlinear in the spending shock. Large negative shocks yield smaller multipliers, and large positive shocks yield larger multipliers. This holds both for debt-financed and balanced-budget-financed shocks.

We have shown that the response of labor supply across the wealth distribution, along with the response of this very same distribution, are crucial in generating this pattern of multipliers that are increasing in the shock. The EIS is increasing in wealth, which implies that low-wealth agents respond more to current income shocks and less to future income shocks. A positive tax-financed shock shifts the wealth distribution to the left. This, along with the fact that the labor supply response to a current income shock is decreasing in wealth, generates a fiscal multiplier that is increasing in the shock. A positive debt-financed shock, on the other hand, shifts the wealth distribution to the right, which combined with a labor supply response to a future income shock that is increasing in wealth, leads again to a fiscal multiplier that is increasing in the shock. Using micro-data from the PSID, we validate the relationship between wealth, labor supply responses and fiscal shocks.

Recent events such as the COVID-19 crisis have led to large fiscal programs that will likely require some type of consolidation in the future. We believe our work is important to understand how the effects of these consolidation programs vary with their size.

We see this paper as contributing to understanding how the size of fiscal shocks can have different aggregate implications depending on the distributional features of the economy. We show that introducing nominal rigidities can greatly magnify the aggregate effects of this size and sign-dependence. Extending the model along other dimensions could further amplify these nonlinearities: for example, if wealthier consumers could be borrowing constrained as in Kaplan and Violante [27]. This would allow for larger masses of agents to be shifted to and from the constraint. Furthermore, in this paper we focused essentially on the role of heterogeneous marginal propensities to work in the transmission of fiscal policies. We leave for future research a more detailed investigation on how the joint distribution between marginal propensities to work and consume can affect the sign and size dependence of fiscal policy shocks.

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Appendix A. Additional Empirical Evidence

Appendix A.1. IMF Shocks

Table A.11 presents the multipliers for different shocks using the coefficients on Table 3. Table A.12 presents the results of equation (1) amplified with both anticipated and unanticipated shocks. Tables A.13-A.15 report the average consolidation shocks during transfer, consumption and tax based consolidations.[21] Results in Table A.16 control for previously announced consolidation plans implemented at time t.

			h	
Instrument	Variable	0	1	2
G	Multiplier 0%	1.011	2.009	0.613
	Multiplier -0.5%	0.811	1.723	0.513
	Multiplier -1.5%	0.410	1.150	0.312
g	Multiplier 0%	-0.250	0.494	-0.011
	Multiplier -0.5%	-0.260	0.434	0.032
	Multiplier -1.5%	-0.280	0.313	0.073
t	Multiplier 0%	0.975	1.915	1.504
	Multiplier -0.5%	0.832	1.747	1.309
	Multiplier -1.5%	0.546	1.410	0.919

Table A.11: Fiscal multipliers for different unanticipated government consumption, transfers and taxed based consolidation shocks, including controls, at different horizons *h*.

[21] We follow the Alesina et al. [1] consolidation classification. A consolidation is classified as a tax, transfer, or consumption consolidation depending on the largest component out of the three for the horizon of the consolidation plan.

	h		
Variable	0	1	2
β_1^u	-0.455***	-1.165***	-0.474***
	(0.135)	(0.172)	(0.144)
β_2^u	0.114***	0.189***	0.099***
	(0.034)	(0.043)	(0.038)
β_1^a	-0.377**	-0.018	-0.327*
	(0.167)	(0.208)	(0.193)
β_2^a	-0.035	-0.138	0.141
	(0.064)	(0.096)	(0.100)
Observations	495	480	465
Number of countries	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.12: Non-linear effects of fiscal unanticipated and announced consolidation shocks. β_1 and β_2 stand for the coefficients associated with the linear and quadratic terms, respectively. β^u and β^a stand for the coefficients associated with unanticipated and anticipated shocks, respectively.

	Mean	Median	Std. Dev.	Observations
Unanticipated t	0.290	0	0.587	63
Unanticipated G	0.222	0.0302	0.392	63
Unanticipated g	0.310	0.0959	0.420	63
Anticipated t	0.102	0.0432	0.391	63
Anticipated G	0.135	0.0802	0.184	63
Anticipated g	0.215	0.0742	0.330	63

Table A.13: Average anticipated and unanticipated transfer, consumption and tax consolidation components, for a transfer based consolidation in % of GDP.

	Mean	Median	Std. Dev.	Observations
Unanticipated t	0.230	0.00318	0.479	71
Unanticipated G	0.455	0.276	0.523	71
Unanticipated g	0.0843	0	0.181	71
Anticipated t	0.0556	0	0.392	71
Anticipated G	0.183	0	0.339	71
Anticipated g	0.0740	0	0.142	71

Table A.14: Average anticipated and unanticipated transfer, consumption and tax consolidation components, for a consumption based consolidation in % of GDP.

	Mean	Median	Std. Dev.	Observations
Unanticipated t	0.462	0.223	0.678	77
Unanticipated G	0.109	0	0.214	77
Unanticipated g	0.0147	0	0.132	77
Anticipated t	0.186	0	0.406	77
Anticipated G	0.0676	0	0.163	77
Anticipated g	0.0365	0	0.151	77

Table A.15: Average anticipated and unanticipated transfer, consumption and tax consolidation components, for a tax-based consolidation in % of GDP.

		h	
Variable	0	1	2
β_1^G	-0.845***	-1.894***	-0.487
	(0.320)	(0.322)	(0.304)
β_2^G	0.341***	0.544***	0.183*
	(0.104)	(0.104)	(0.101)
β_1^g	0.392*	-0.465	0.117
	(0.212)	(0.294)	(0.201)
β_2^g	-0.004	0.117*	-0.060
	(0.057)	(0.069)	(0.061)
β_1^t	-0.889***	-1.769***	-1.483***
	(0.321)	(0.336)	(0.299)
β_2^t	0.213	0.299**	0.396***
	(0.131)	(0.126)	(0.118)
Observations	495	480	465
Number of countries	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.16: Non-linear effects of fiscal unanticipated consumption, transfers and taxed based consolidation shocks, including controls and planned consolidations.

Appendix A.1.1. 1991-2014 period including Germany

Results in Tables A.17 and A.18 reproduce results in Tables 1 and 3 while including Germany in the sample of countries and restricting the sample to the 1991-2014 period.

	h		
Variable	0	1	2
β_1	-0.546***	-1.024***	-0.820***
	(0.107)	(0.110)	(0.092)
β_2	0.087***	0.192***	0.181***
	(0.026)	(0.026)	(0.027)
Observations	352	336	320
Number of countries	16	16	16

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.17: Nonlinear effects of fiscal consolidation shocks at different horizons h.

	h		
Variable	0	1	2
β_1^G	-1.030***	-1.278***	-0.682***
	(0.200)	(0.216)	(0.224)
β_2^G	0.431***	0.409***	0.168
	(0.091)	(0.102)	(0.103)
β_1^g	0.228*	-0.316**	-0.079
	(0.131)	(0.144)	(0.159)
β_2^g	0.003	0.116***	0.042
	(0.034)	(0.037)	(0.041)
β_1^t	-0.509***	-1.350***	-1.295***
	(0.192)	(0.203)	(0.238)
β_2^t	0.088	0.116	0.281***
	(0.085)	(0.087)	(0.105)
Observations	495	480	465
Number of countries	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A.18: Non-linear effects of fiscal unanticipated consumption, transfers and taxed based consolidation shocks, including controls.

Appendix A.2. US Historical data

Figure A.16 reproduces the exercise from Figure 1 but using the military news shocks instead of the BP ones. Figures A.17 to A.19 replicate Figure 1 controlling for taxes, including both a linear and a quadratic time trends, and including 8 lags instead of 4, respectively. Figure A.20 presents the IRF of taxes to BP shocks of different sizes.

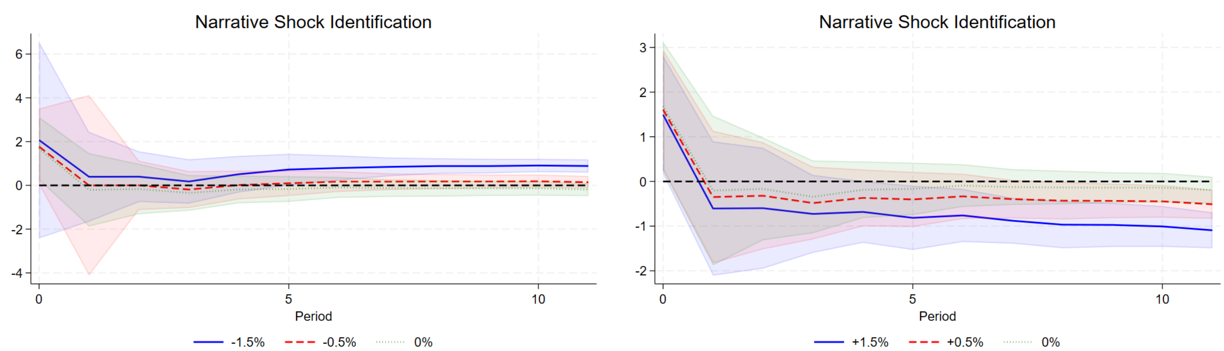

Figure A.16: Cumulative multiplier for negative shocks in the left panel and for positive shocks in the right panel. Color areas represent the 95th confidence interval.

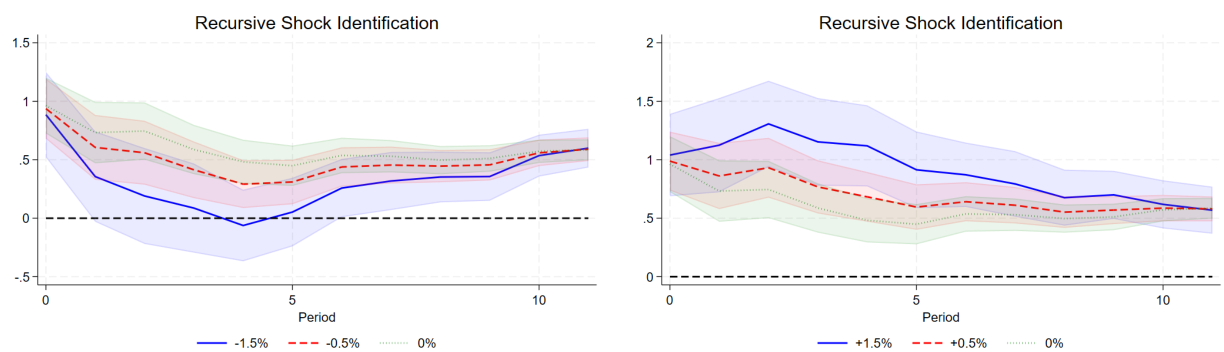

Figure A.17: Cumulative multiplier for negative shocks in the left panel and for positive shocks in the right panel, controlling for taxes. Color areas represent the 95th confidence interval.

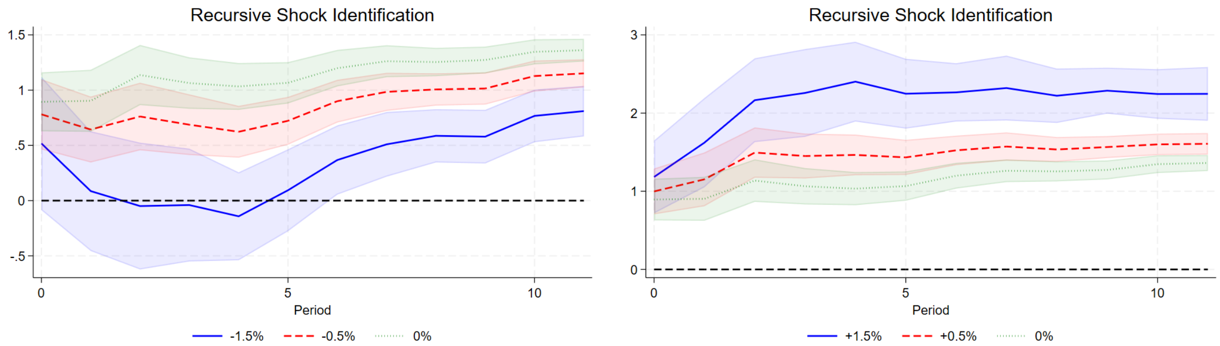

Figure A.18: Cumulative multiplier for negative shocks in the left panel and for positive shocks in the right panel, controlling for both linear and quadratic time trends. Color areas represent the 95th confidence interval.

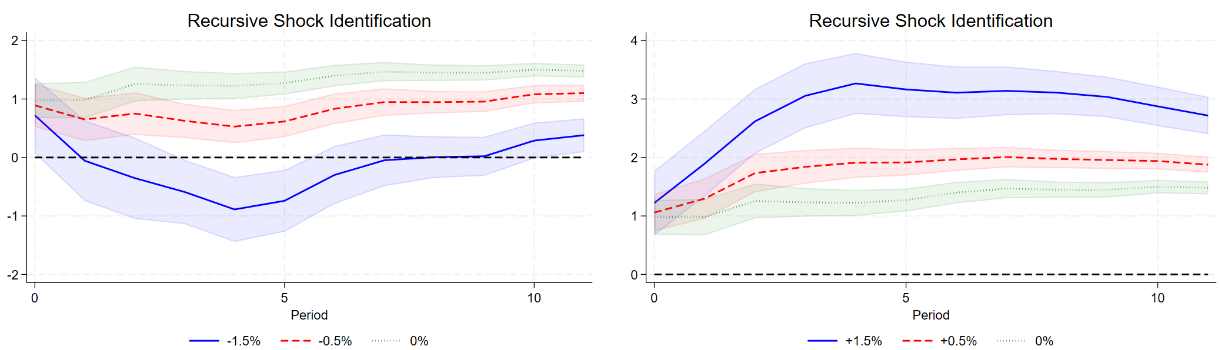

Figure A.19: Cumulative multiplier for negative shocks in the left panel and for positive shocks in the right panel, with 8 lags. Color areas represent the 95th confidence interval.

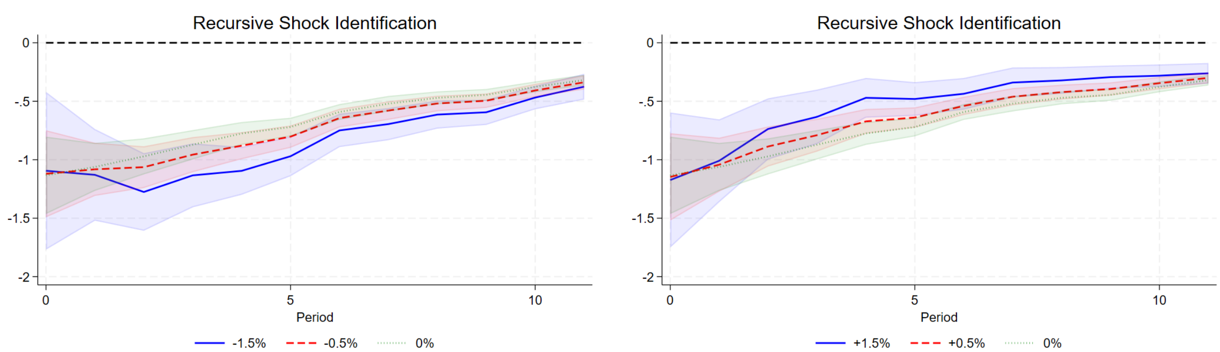

Figure A.20: Cumulative tax multiplier for negative shocks in the left panel and for positive shocks in the right panel, with 4 lags. Color areas represent the 95th confidence interval.

Appendix A.3. Threshold-based local projections

We investigate whether our results are robust to estimating size- and sign-dependence directly, by allowing the LP coefficient to depend on size and/or sign of the fiscal shock, as in Ben Zeev et al. [10]. Specifically, we estimate regressions of the following type:

$$\sum_{j=0}^{h} \Delta^j y_{t+j} = \alpha_h + \Psi_h(L) z_{t-1} + \sum_{n=1}^{N} \mathbb{I}[\text{shock}_t \in \text{group}_n] m_{n,h} \sum_{j=0}^{h} \Delta^j g_{t+j} + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, ...$$

where $\{\text{group}_n\}_{n=1}^{N}$ are specific groupings for the shocks, which are used as instruments for $\Delta^j g_{t+j}$. We consider these groups to be quartiles, terciles, and negative vs. positive shocks. Note that due to the absence of the quadratic term, we can now interpret $m_{n,h}$ directly as the cumulative multiplier over horizon h for a shock included in group n (i.e. first quartile, or positive). For example, Ben Zeev et al. [10], in their main specification, consider two groups: negative shocks, and positive shocks.

Results for quartiles are reported in Table A.19. The quartiles are relatively small, with 63 observations in each group, which results in very imprecise estimates with large standard errors. To address the small number of observations, Table A.20 repeats the exercise using terciles instead (84 observations in each tercile). While the standard errors are still very high, a pattern of increasing multipliers starts emerging, especially at longer horizons. Finally, Table A.21 reports the same exercise when shocks are split between negative and positive. In this case, we find larger multipliers for positive shocks at shorter horizons, in spite of large standard errors: we find the reverse pattern at longer horizons, but note that the standard errors are smaller for multipliers associated with positive shocks and larger for multipliers associated with negative shocks.

Regardless of the qualitative patterns that we find for the point estimates, results from t-tests reveal that none of these multipliers are statistically different from each other. As we explain in the main text, the average values for both positive and negative Blanchard-Perotti shocks are relatively small and close to zero. Simple comparisons of average positive to average negative shocks do not generate a nonlinearity that is strong enough to be statistically and economically significant. Our baseline quadratic specification treats small and large shocks differently, which allows us to capture nonlinearities that would otherwise not be detected statistically

Horizon	Q1	Q2	Q3	Q4
1	14.680	11.679	14.318	7.454
	(40.692)	(32.587)	(41.114)	(19.481)
4	14.186	10.449	12.859	6.876
	(22.513)	(15.997)	(20.249)	(9.113)
8	4.186	3.831	4.595	2.690
	(2.623)	(1.917)	(2.790)	(1.131)
12	3.635	4.104	4.566	2.484
	(2.141)	(1.846)	(2.843)	(1.093)
16	3.460	3.609	4.744	2.326
	(2.620)	(2.050)	(3.539)	(1.106)
# shocks	63	63	63	63

Table A.19: Estimated cumulative multipliers for fiscal shocks in different quartiles (columns) at different horizons (rows) using level-zero splines. Robust standard errors in parenthesis.

Horizon	T1	T2	T3
1	4.577	2.484	1.883
	(6.681)	(3.126)	(2.030)
4	2.977	1.277	1.581
	(6.958)	(3.912)	(2.229)
8	1.082	1.092	1.467
	(2.519)	(1.789)	(0.876)
12	0.746	0.926	1.445
	(1.618)	(1.687)	(0.779)
16	0.725	0.873	1.453
	(1.535)	(2.067)	(0.770)
# shocks	83	85	84

Table A.20: Estimated cumulative multipliers for fiscal shocks in different tertiles (columns) at different horizons (rows) using level-zero splines. Robust standard errors in parenthesis.

Horizon	Neg	Pos
1	0.391	0.528
	(0.440)	(0.325)
4	0.399	0.726
	(0.632)	(0.334)
8	0.840	0.889
	(1.009)	(0.564)
12	1.342	1.155
	(1.446)	(0.675)
16	1.431	1.190
	(1.256)	(0.542)
# shocks	150	102

Table A.21: Estimated cumulative multipliers for negative and positive fiscal shocks (columns) at different horizons (rows) using level-zero splines. Robust standard errors in parenthesis.

Appendix B. Definition of a Transition Equilibrium During the Fiscal Experiments

We define the recursive competitive transition equilibrium as follows. For a given level of initial capital stock, initial distribution of households, and initial debt, respectively, K_0, Φ_0, and B_0, a competitive equilibrium is a sequence of individual functions for the household, $\{V_t, c_t, k_t', n_t\}_{t=1}^{t=\infty}$; production plans for the firm, $\{K_t, L_t\}_{t=1}^{t=\infty}$; factor prices, $\{r_t, w_t\}_{t=1}^{t=\infty}$; government transfers, $\{g_t, G_t\}_{t=1}^{t=\infty}$; government debt, $\{B_t\}_{t=1}^{t=\infty}$; and measures $\{\Phi_t\}_{t=1}^{t=\infty}$ such that the following hold for all t:

1. For given factor prices and initial conditions, the value functions $V_t(k, \beta, a, u)$ and the policy functions, $c_t(k, \beta, a, u)$, $k_t'(k, \beta, a, u)$, and $n_t(k, \beta, a, u)$ solve the consumers' optimization problem.

2. Markets clear:

$$K_{t+1} + B_t = \int k_t d\Phi_t$$

$$L_t = \int \left(n_t(k_t, \beta, a, u)\right) d\Phi_t$$

$$\int c_t d\Phi_t + K_{t+1} + G_t = (1-\delta)K_t + K^{\alpha} L^{1-\alpha}.$$

3. The factor prices are paid their marginal productivity:

$$\begin{aligned} w_t &= (1-\alpha)\left(\frac{K_t}{L_t}\right)^{\alpha} \\ r_t &= \alpha\left(\frac{K_t}{L_t}\right)^{\alpha-1} - \delta \end{aligned}$$

4. The government budget balances:

$$g_t \int \mathrm{d}\Phi_t + G_t + rB_t = \int \left[\tau_k r_t k_t + \tau_c c_t + n_t w_t\left(a,u\right)\left(1-\tau_l\left(n_t w_t\left(a,u\right)\right)\right)\right] \mathrm{d}\Phi_t.$$

5. The distribution follows an aggregate law of motion:

$$\Phi_{t+1} = \Upsilon_t(\Phi_t)$$

Appendix C. Richer Tax Structure

Government

Government revenues include flat-rate taxes on consumption, τ_c, and capital income, τ_k. To model the nonlinear labor income tax, we use the functional form proposed in Benabou [11] and recently used in Heathcote et al. [23] and Holter et al. [24]:

$$\tau(y) = 1 - \theta_0 y^{-\theta_1} \tag{C.1}$$

where θ_0 and θ_1 define the level and progressivity of the tax schedule, respectively; y is the pre-tax labor income; and $y_a = [1 - \tau(y)]y$ is the after-tax labor income.

Tax revenues from consumption, capital, and labor income are used to finance public consumption of goods, G_t; interest expenses on public debt, rB_t; and lump-sum transfers to households, g_t. Denoting tax revenues as R and the measure of households by $\Phi(k, \beta, a, u)$, the government budget constraint is defined as:

$$\int g d\Phi + G + rB = R \tag{C.2}$$

Recursive Formulation of the Household Problem

In a given period, a household is defined by its asset position k, time discount factor β, permanent ability a, and persistent idiosyncratic productivity u. Given this set of states, household chooses consumption, c; work hours, n; and future asset holdings, k', to maximize the present discounted value of expected utility. The problem can be written recursively as

$$V(k,\beta,a,u) = \max_{c,k',n} \left[U(c,n) + \beta \mathbb{E}_{u'} \left[V(k',\beta,a,u') \right] \right]$$

s.t.:

$$c(1+\tau_c) + k' = k\left(1 + r(1-\tau_k)\right) + g + nw(a,u)\left(1 - \tau_l\left(nw(a,u)\right)\right)$$

$$n \in [0,1], \quad k' \geq -b, \quad c > 0 \tag{C.3}$$

where b is an exogenous borrowing limit.

Stationary Recursive Competitive Equilibrium

Let the measure of households with the corresponding characteristics be given by $\Phi(k,\beta,a,u)$. Then, we can define a stationary recursive competitive equilibrium (SRCE) as follows:

1. Taking the factor prices and the initial conditions as given, the value function $V(k,\beta,a,u,)$ and policy functions $c(k,\beta,a,u)$, $k'(k,\beta,a,u)$, $n(k,\beta,a,u)$ solve the households' optimization problems.

2. Markets clear:

$$K + B = \int k \mathrm{d}\Phi$$

$$L = \int n(k,\beta,a,u)\mathrm{d}\Phi$$

$$\int c\mathrm{d}\Phi + \delta K + G = K^{\alpha} L^{1-\alpha}.$$

3. Factor prices are paid their marginal productivity:

$$w = (1-\alpha)\left(\frac{K}{L}\right)^{\alpha}$$

$$r = \alpha\left(\frac{K}{L}\right)^{\alpha-1} - \delta.$$

4. The government budget balances:

$$g \int d\Phi + G + rB = \int \left[\tau_k rk + \tau_c c + nw\left(a,u\right)\left(1 - \tau_l\left(nw\left(a,u\right)\right)\right)\right] d\Phi.$$

Calibration

Taxes and Government Spending

We use the labor income tax function of Benabou [11] to capture the progressivity of both the tax schedule and direct government transfers. We use the estimate of Holter et al. [24], who estimate the parameter θ_1 for the US.[22] Consumption and capital tax rates are set to 5% and 36%, respectively, as in Trabandt and Uhlig [35]. Finally, following Hagedorn et al. [21], we set transfers, g, to be 7% of GDP and government spending, G, to be 15% of GDP. θ_0 is then set so that total tax revenues clear the government budget.

Parameters Calibrated Endogenously

Some parameters that do not have any direct empirical counterparts are calibrated using the SMM. These are the discount factors, borrowing limit, disutility from working, and variance of permanent ability. The SMM is set so that it minimizes the following loss function:

$$L(\beta_1, \beta_2, \beta_3, b, \chi, \sigma_a) = ||M_m - M_d|| \tag{C.4}$$

where M_m and M_d are the moments in the model and in the data, respectively.

We use six data moments to choose six parameters, so the system is exactly identified. The six moments we select in the data are (i) the share of hours worked, (ii-iv) the three quartiles of the wealth distribution, (v) the variance of log wages, and (vi) the capital-to-output ratio. Table C.23 presents the calibrated parameters, and Table C.22 presents the calibration fit.

[22] They use OECD data on labor income taxes to estimate the function for different family types. They then weight the value of the parameter by the weight of each family type in the overall population to get an aggregate measures of tax progressivity.

Data moment	Description	Source	Data value	Model value
K/Y	Capital-to-output ratio	PWT	12.292	12.292
$\text{Var}(\ln w)$	Yearly variance of log wages	LIS	0.509	0.509
$\bar{n}$	Fraction of hours worked	OECD	0.248	0.248
Q_{25}, Q_{50}, Q_{75}	Wealth quartiles	LWS	-0.014, 0.004, 0.120	-0.018, 0.003, 0.121

Table C.22: Calibration Fit

Parameter	Value	Description
Preferences		
$\beta_1, \beta_2, \beta_3$	0.991, 0.993, 0.992	Discount factors
χ	11.1	Disutility of work
Technology		
b	1.99	Borrowing limit
σ_a	0.712	Variance of ability

Table C.23: Parameters Calibrated Endogenously

Permanent Debt Consolidations

Figures C.21-C.23 replicate some of the main results of the model for permanent debt consolidations under the richer tax structure.

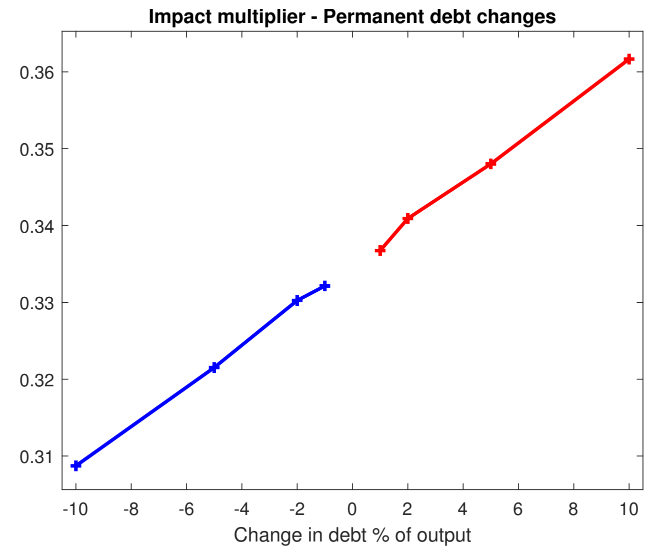

Figure C.21: Fiscal multiplier on impact (one quarter after the shock) for the permanent change in debt experiment as a function of the size of the variation in G (as a % of GDP). The blue line corresponds to G contractions, while the red line represents G expansions.

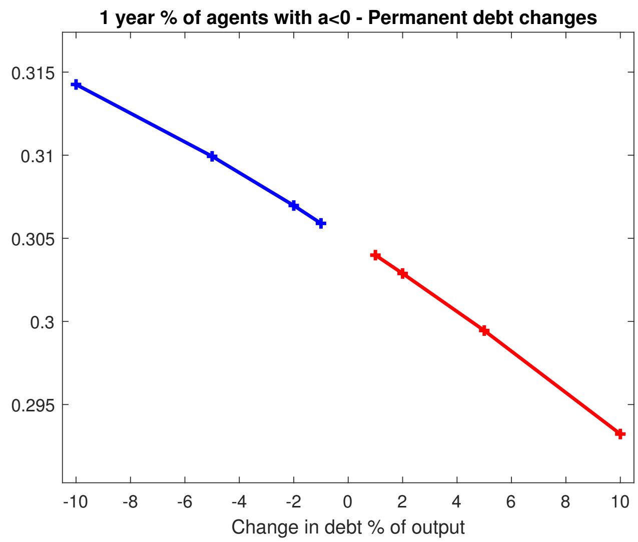

Figure C.22: Percentage of agents with negative wealth (one year after the shock) for the permanent change in debt experiment as a function of the size of the variation in G (as a % of GDP). The blue line corresponds to G contractions, while the red line represents G expansions.

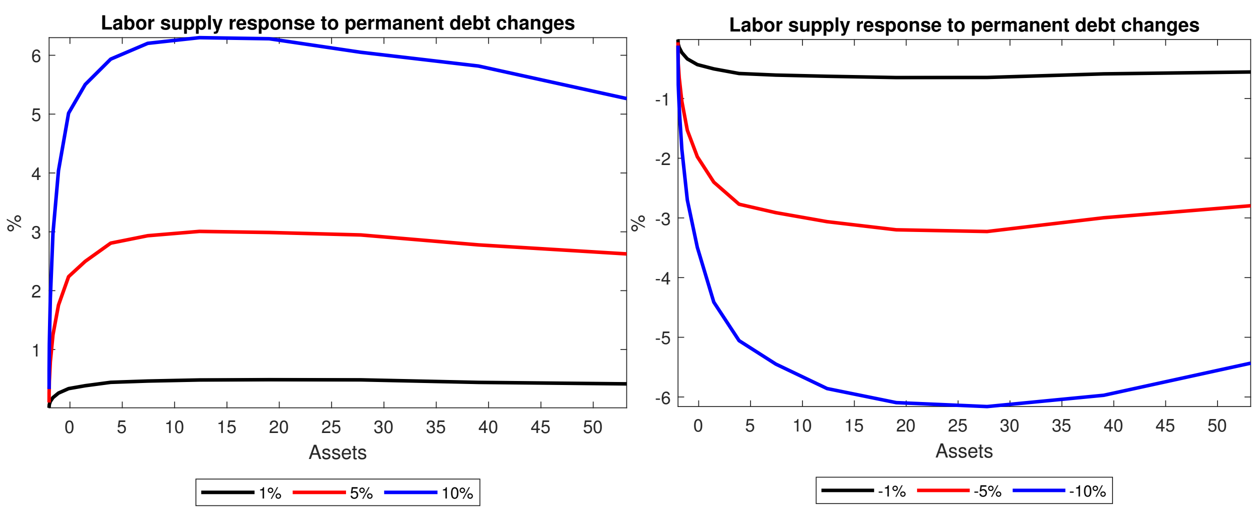

Figure C.23: (Relative) labor supply response to different changes in G over the asset distribution, for the permanent change in debt experiment. Left panel plots the results for positive fiscal shocks while the right panel presents the results for negative shocks.

Deficit financing

Figures C.24-C.26 replicate some of the main results of the model for the case of deficit financing under the richer tax structure. See the main text for details.

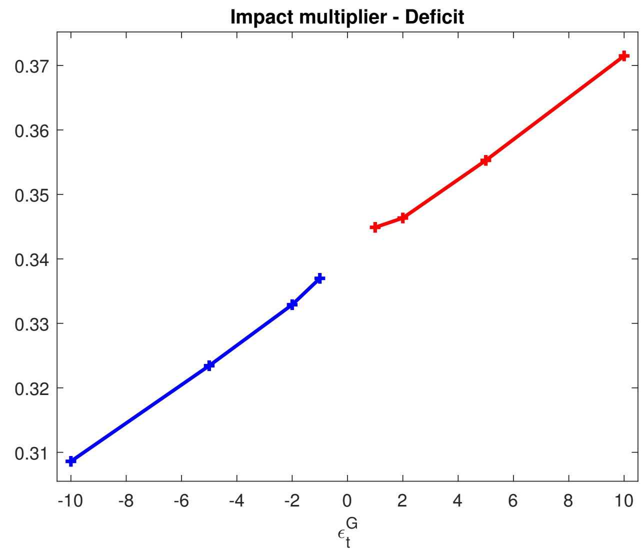

Figure C.24: This figure plots the fiscal multiplier on impact (one quarter after the shock) as a function of ε_t^G (the initial impulse), for the deficit financing experiment. The blue line corresponds to G contractions, while the red line represents G expansions.

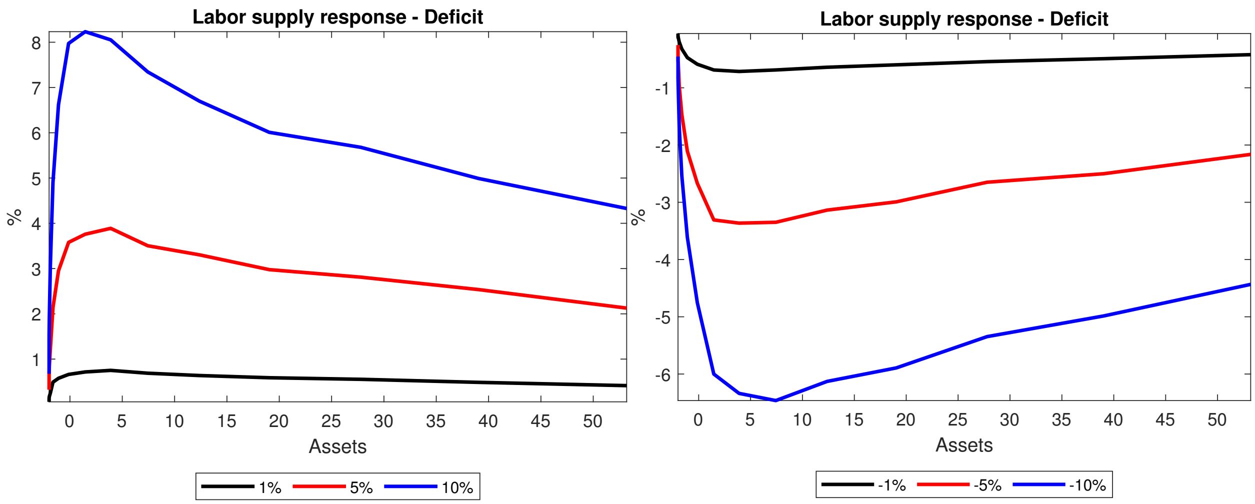

Figure C.25: (Relative) labor supply response to different changes in G over the asset distribution, for the deficit financing experiment. Left panel plots the results for positive fiscal shocks while the right panel presents the results for negative shocks.

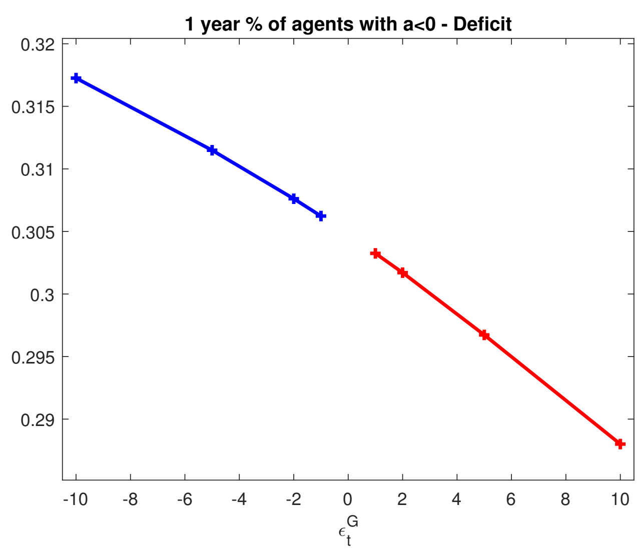

Figure C.26: This figure plots the percentage of agents with negative wealth (one year after the shock) as a function of ε_t^G (the initial impulse), for the deficit financing experiment. The blue line corresponds to G contractions, while the red line represents G expansions.

Balanced budget

Figures C.27-C.29 replicate some of the main results of the model for the case of balanced-budget financing under the richer tax structure. See the main text for details.

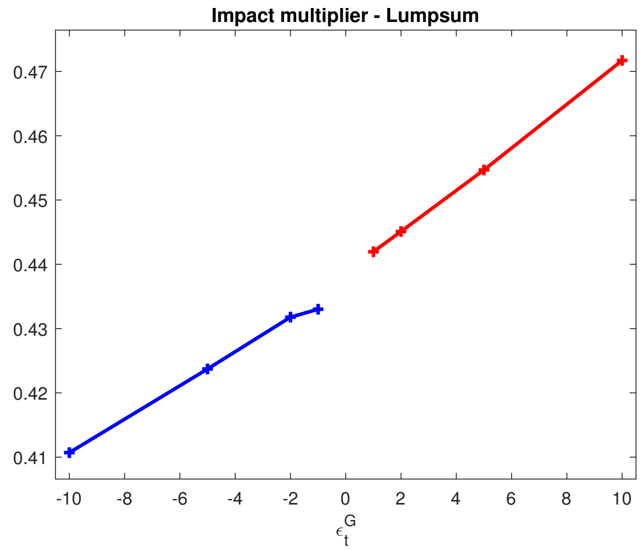

Figure C.27: This figure plots the fiscal multiplier on impact (one quarter after the shock) as a function of ε_t^G (the initial impulse), for the balanced budget experiment. The blue line corresponds to G contractions, while the red line represents G expansions.

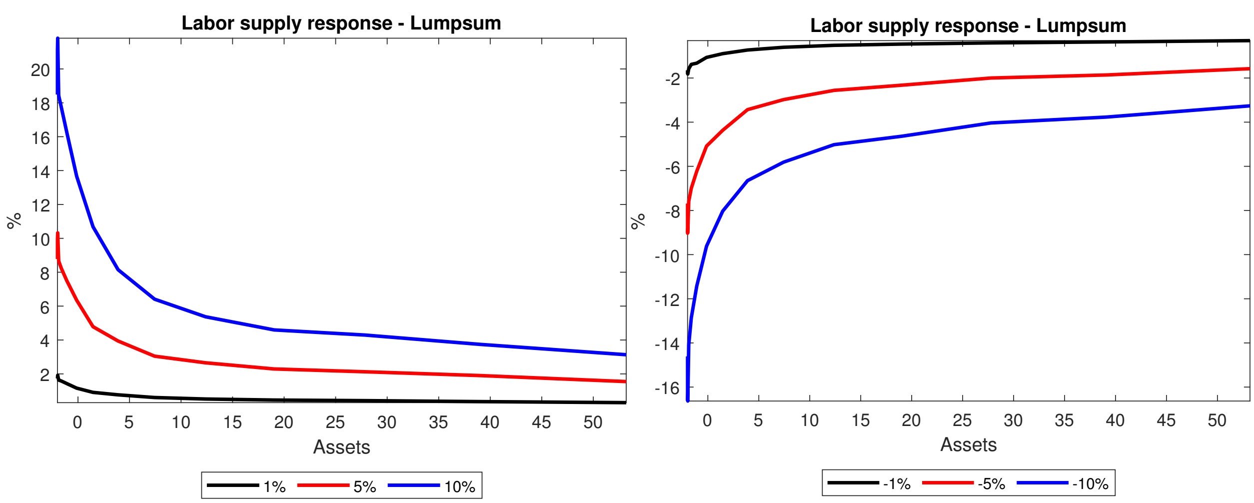

Figure C.28: (Relative) labor supply response to different changes in G over the asset distribution, for the balanced budget experiment. Left panel plots the results for positive fiscal shocks while the right panel presents the results for negative shocks.

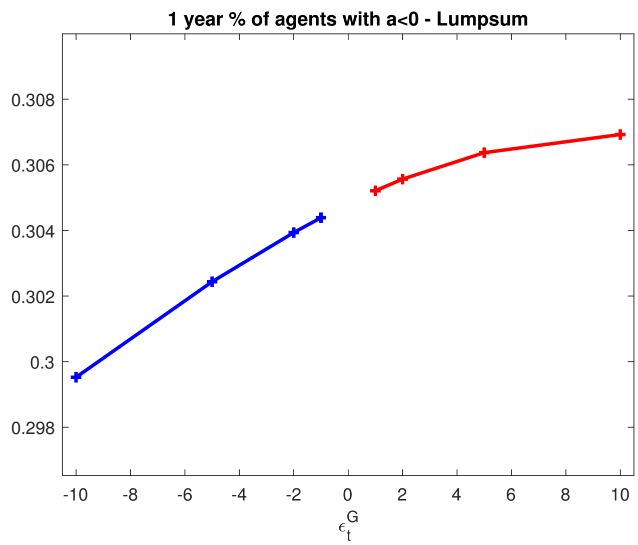

Figure C.29: This figure plots the percentage of agents with negative wealth (one year after the shock) as a function of ε_t^G (the initial impulse), for the balanced budget experiment. The blue line corresponds to G contractions, while the red line represents G expansions.

Appendix D. Parameters Calibrated Outside of the Model

Parameter	Value	Description	Source
Preferences			
η	1	Inverse Frisch elasticity	Trabandt and Uhlig (2011)
σ	1.2	Risk aversion parameter	Consistent w. literature
Technology			
α	0.33	Capital share of output	Consistent w. literature
δ	0.015	Capital depreciation rate	Consistent w. literature
ρ	0.761	$u' = \rho u + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon^2)$	PSID 1968-1997
σ_ϵ	0.211	Variance of risk	PSID 1968-1997
Taxes			
τ_l	0.358	Labor income tax	Budget balance
Macro ratios			
B/Y	1.714	Debt-to-GDP ratio	U.S. Data
G/Y	0.15	Government spending-to-GDP ratio	Hagedorn et al. [21]
g/Y	0.07	Transfers-to-GDP ratio	Hagedorn et al. [21]

Appendix E. Dynamic Multipliers

Table E.24 reports cumulative multipliers at different horizons for shocks of different sizes, financed with a deficit-financed shock experiments. Table E.25 does the same for balanced budget financed shocks. The tables show that the pattern of dependence of the multipliers on the shock persists even in the medium-term (12 quarters).

Horizon/Shock	-10%	-1%	+1%	+10%
0.0	0.3769	0.3939	0.3978	0.4160
1.0	0.3757	0.3927	0.3967	0.4149
2.0	0.3747	0.3918	0.3957	0.4140
3.0	0.3738	0.3910	0.3949	0.4132
4.0	0.3731	0.3903	0.3942	0.4125
8.0	0.3711	0.3883	0.3923	0.4105
12.0	0.3700	0.3872	0.3912	0.4093

Table E.24: Cumulative multipliers for fiscal shocks of different sizes (columns) at different horizons (rows), Deficit Financed

Horizon/Shock	-10%	-1%	+1%	+10%
0	0.4212	0.4422	0.4473	0.4712
1	0.4208	0.4419	0.4469	0.4709
2	0.4205	0.4416	0.4467	0.4706
3	0.4202	0.4414	0.4464	0.4704
4	0.4199	0.4412	0.4462	0.4702
8	0.4192	0.4405	0.4456	0.4696
12	0.4186	0.4401	0.4452	0.4691

Table E.25: Cumulative multipliers for fiscal shocks of different sizes (columns) at different horizons (rows), Balanced Budget

Appendix F. Distribution

This appendix plots changes in the distribution of wealth for shocks of different sizes, under different assumptions regarding the financing of the fiscal shock. Figure F.30 considers the case of permanent changes in G that result in permanent changes in the level of debt, with the left panel presenting the results for positive fiscal shocks and the right panel presenting the results for negative fiscal shocks.

Figures F.31 and F.32 plot changes in the distribution in response to temporary fiscal shocks, financed with deficits and balanced budgets, respectively.

Permanent Shock: Permanent Changes in Debt

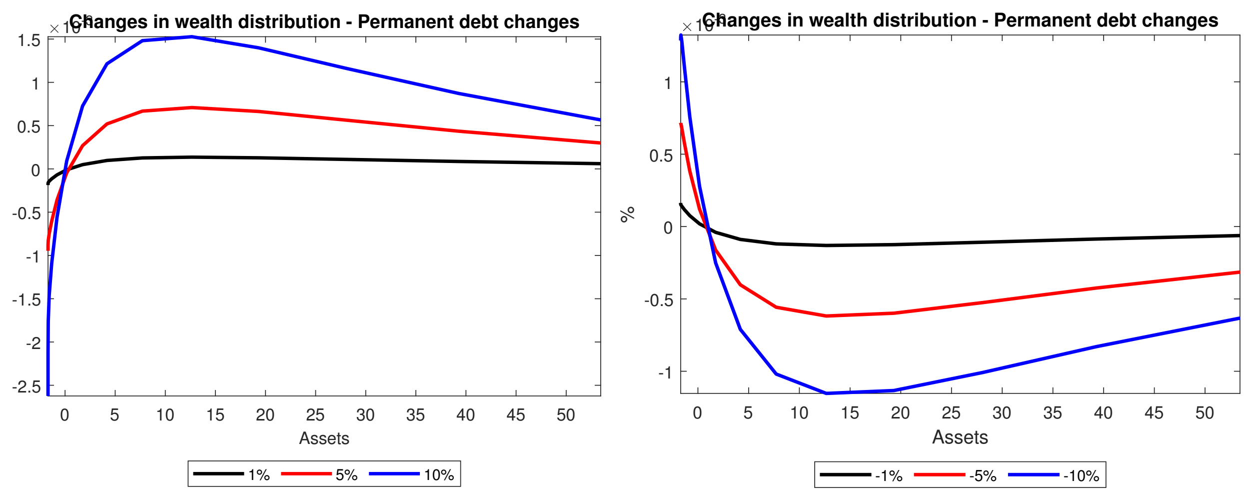

Figure F.30: Changes in the distribution in response to a permanent change in G.

Temporary Shock: Deficit Financing

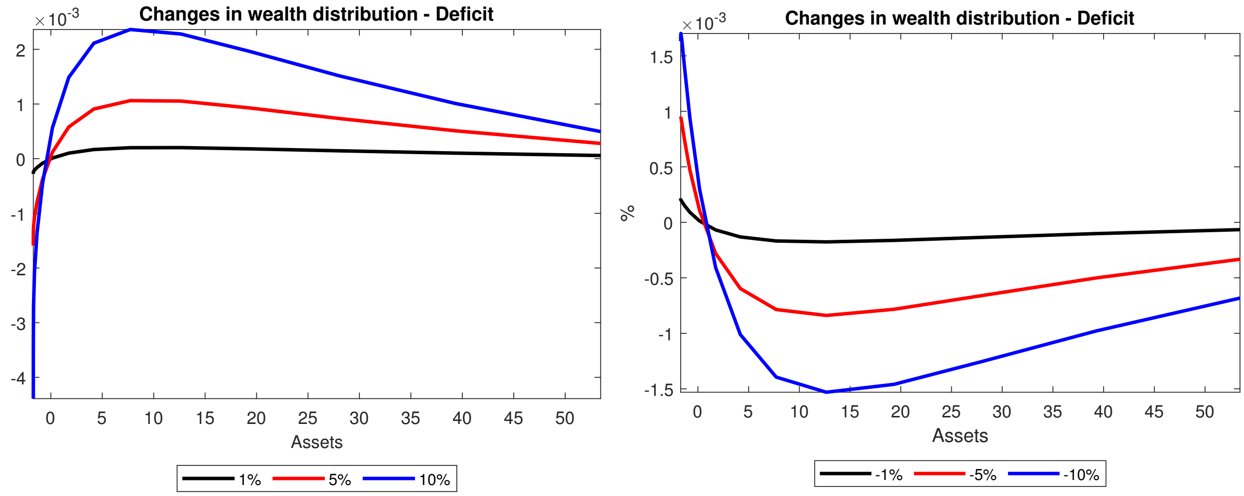

Figure F.31: Changes in the distribution in response to a temporary change in G.

Temporary Shock: Balanced Budget

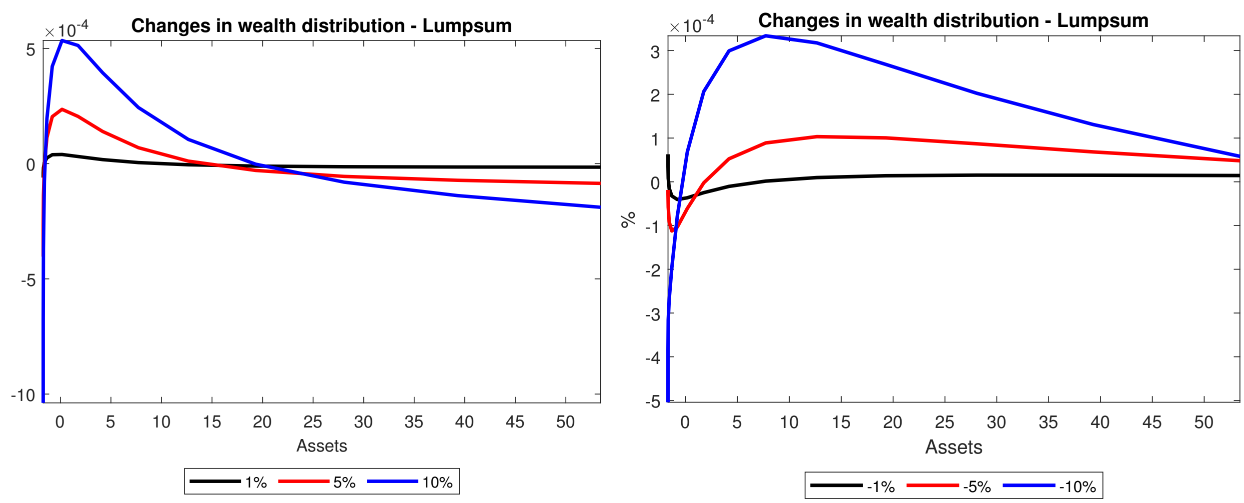

Figure F.32: Changes in the distribution in response to a temporary change in G.

Appendix G. Illustrating and Explaining the Mechanism

We argue that the nonlinearity of the multiplier is related to the movement of the wealth distribution. In other words, the current asset choice, k', and future choices, k'', k''' etc. are different for different sizes of the government spending shock. In the case of a positive, balanced-budget financed, government spending shock all agents are moving closer to the borrowing constraint in the current as well as future periods. This makes agents less forward looking, or in other words *the intertemporal elasticity of substitution is falling*. It is a well known finding in the literature that the intertemporral elasticity of substitution is increasing in wealth and it has been illustrated among others by Domeij and Floden [16] for labor supply and Vissing-Jørgensen [38] for consumption. To see this, one can consider the Euler equation in the standard incomplete markets model:

$$(k(1+r)+y-k')^{-\sigma}=\max\{\beta(1+r')\mathbb{E}[(k'(1+r')+y'-k'')^{-\sigma}],(k(1+r)+y+b)^{-\sigma}\}$$

Where y is income and b is the borrowing limit. In the case that the borrowing constraint in the current period binds, $k'=b$, the *Elasticity of Intertemporal Substitution* is 0. A change in current income will only affect current consumption and labor supply and a change in expected future consumption due to future income changes will have no effect on consumption and labor supply today. However, the EIS is also smaller when there is a probability of the borrowing limit binding in the future, $k''=b$ or $k'''=b$, etc. To see this one can iterate on the Euler equation.

$$c^{-\sigma}=\max\{\beta(1+r')\mathbb{E}[(k'(1+r')+y'-k'')^{-\sigma}],(k(1+r)+y+b)^{-\sigma}\}$$
$$c^{-\sigma}=\max\{\beta(1+r')\mathbb{E}[\max\{\beta(1+r'')E[(c'')^{-\sigma}],(k'(1+r')+y'+b)^{-\sigma}\}],(k(1+r)+y+b)^{-\sigma}\}$$

We observe that if the borrowing constraint is expected to be binding at t', a transfer of resources from t to t' will change the right-hand side of the Euler faster (no resources

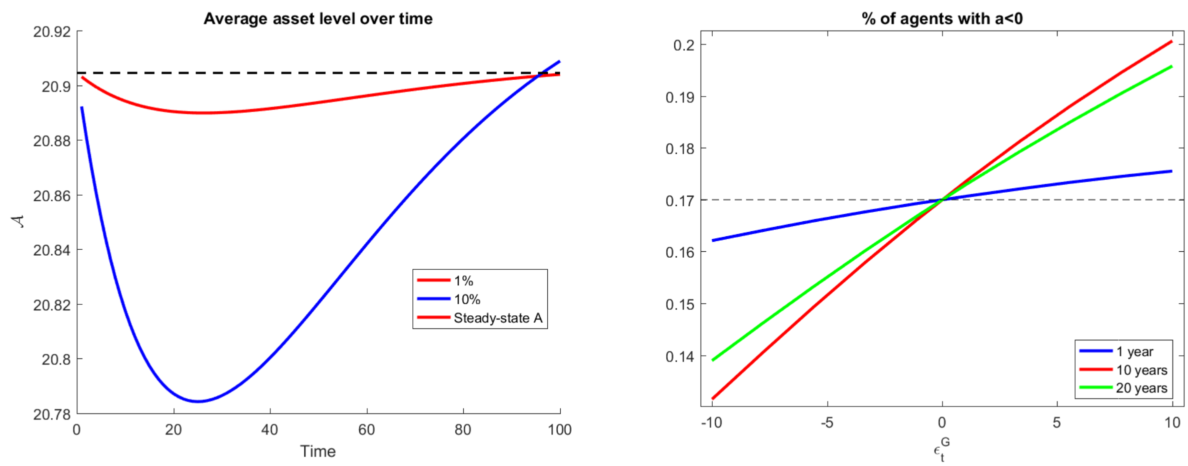

Figure G.33: The left panel displays the change in aggregate asset holdings over time by the size of the fiscal shock. The right panel displays the fraction of agents with negative wealth after 1, 10 and 20 years by the size of the fiscal shock.

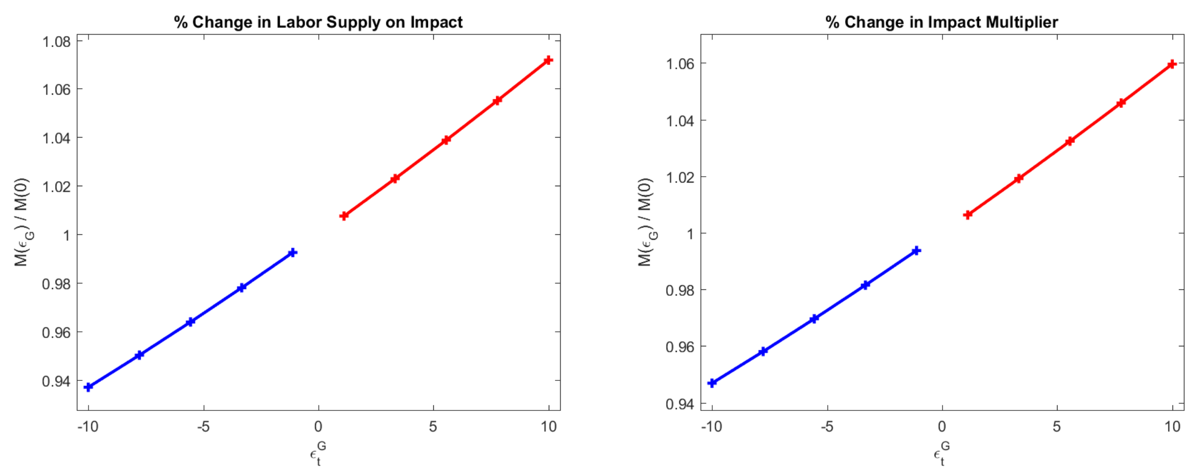

Figure G.34: The left panel displays $\frac{\Delta L_t/\Delta G}{\Delta L_t/\Delta G_{small}}$ as a function of the fiscal shock. The right panel displays the fiscal multiplier as a function of the fiscal shock.

transferred from t is transferred further into the future through k''). Therefore, less of an income change at t is transferred to t' to solve the Euler when these future borrowing constraints have a greater likelihood of binding. In Figure G.33, we illustrate how aggregate savings change over time in our model, by the size of the fiscal shock (left panel) and how the fraction of people with negative wealth changes after 1, 10 and 20 periods for different values of a shock. In the left panel of Figure G.34 we plot the "labor supply multiplier" from the fiscal shock relative to the multiplier for a small fiscal shock, $\frac{\Delta L_t/\Delta G}{\Delta L_t/\Delta G_{small}}$. The right panel displays the fiscal multiplier by the size of the fiscal shock.

Larger positive fiscal shocks is associated with more wealth poor agents in the future, a smaller intertemporal elasticity of substitution, a larger labor supply response today and a larger fiscal multiplier.

Appendix G.1. The Nonlinearity is Not Driven by Prices or Nonlinear Tax Hikes

Next, in Figures G.35 and G.36 and we repeat the above experiment with constant prices. We show that exactly the same mechanism is present, and thus the nonlinearity of the fiscal multiplier is not related to a movement of prices. Furthermore, unless labor supply is moving nonlinearly (we do, however, know that it is) taxes are moving linearly with the size of the fiscal shock in this experiment and because prices are constant the net present value of taxes is also moving linearly.

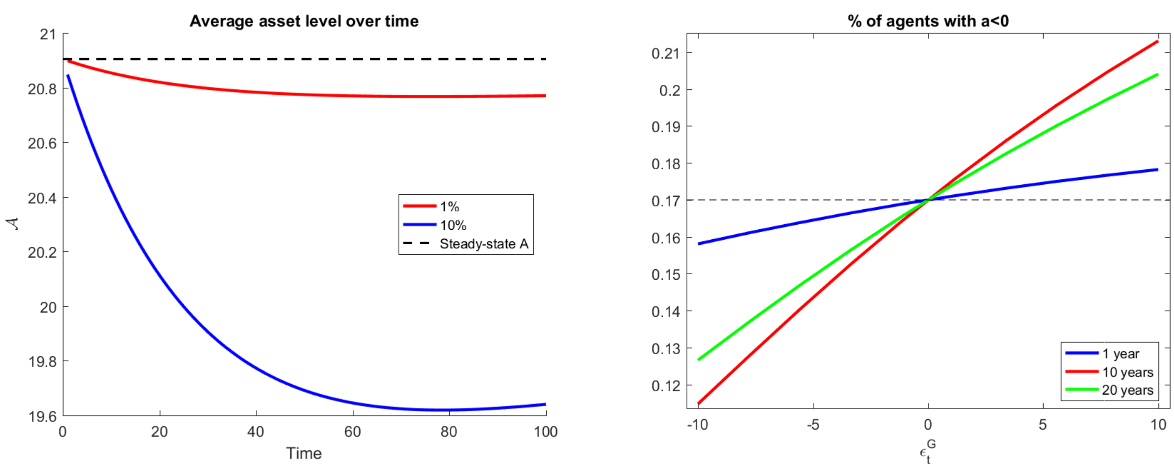

Figure G.35: The left panel displays the change in aggregate asset holdings over time by the size of the fiscal shock. The right panel displays the fraction of agents with negative wealth after 1, 10 and 20 years by the size of the fiscal shock.

As a final experiment, we continue to keep prices fixed but let the lumpsum tax, i.e. the change in g, equal exactly the change in G. Since labor supply is changing the government budget is no longer balanced in this experiment, so it is meant to illustrate the change in household behavior only. We compute the change in output in this experiment, using the change in labor supply and assuming a constant K/L ratio. In Figure G.37 we plot the % change in labor supply on impact and the % change in the impact multiplier for this experiment alongside our benchmark general equilibrium model and

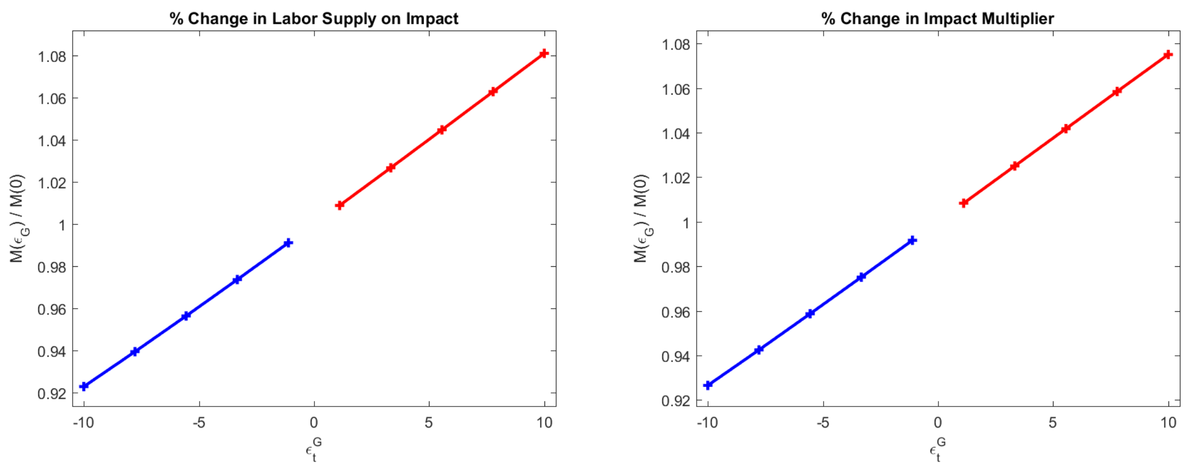

Figure G.36: The left panel displays $\frac{\Delta L_t/\Delta G}{\Delta L_t/\Delta G_{small}}$ as a function of the fiscal shock. The right panel displays the fiscal multiplier as a function of the fiscal shock.

the partial equilibrium model (PE) with fixed prices. We observed that the nonlinearities are quite similar in all cases but somewhat smaller in the general equilibrium case. If anything, flexible prices lead to smaller nonlinearity.

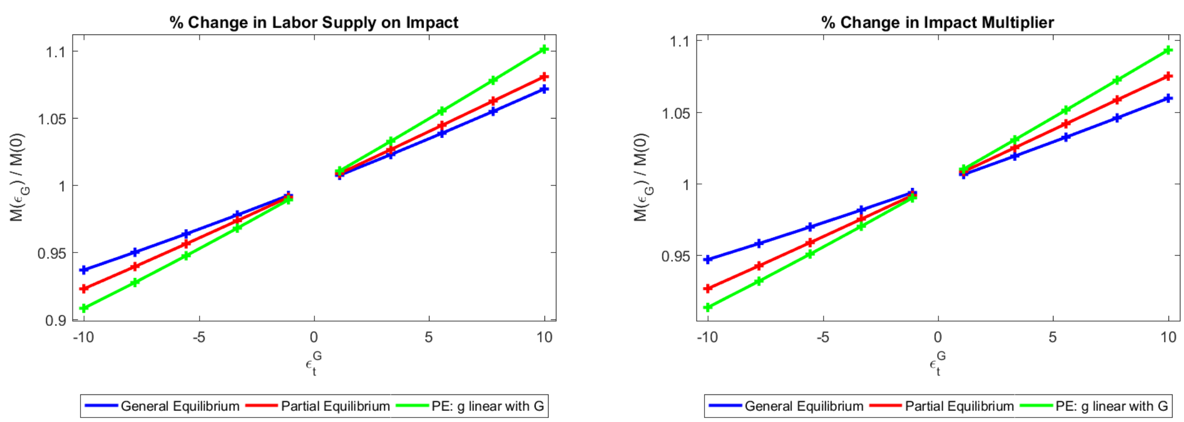

Figure G.37: The left panel displays $\frac{\Delta L_t/\Delta G}{\Delta L_t/\Delta G_{small}}$ as a function of the fiscal shock. The right panel displays the fiscal multiplier as a function of the fiscal shock.

Appendix H. HANK Model

Appendix H.1. Setup

The setup follows closely that of the neoclassical model, with the main differences being (i) the addition of nominal rigidities in the form monopolistically competitive producers of differentiated varieties that are subject to quadratic costs of price adjustment, (ii) the addition of a central bank that follows a standard Taylor rule, and (iii) the exclusion of physical capital for computational tractability.

Households. Households are ex-ante heterogeneous with respect to their discount factor $\beta_i \in \{\beta_1, \beta_2, \beta_3\}$ and choose how much to consume, c, work, n, and save, b', in order to maximize the same period utility function, subject to the same budget constraint as before. Note that savings are expressed in real terms. Additionally, since monopolistically competitive firms make positive profits at the stationary equilibrium, we assume that they are equally distributed across households in a lump-sum manner, d_t. The problem of the household can be written as:

$$
\begin{aligned}
& V(b, \beta, u) = \max_{c,n,b'} \left\{ \frac{c^{(1-\sigma)}}{1-\sigma} - \chi \frac{n^{(1+\eta)}}{1+\eta} + \beta \mathbf{E}_{u'} V(b', \beta, u') \right\} \\
& c + b' = (1+r)b + (1-\tau_l)wnu + g + d \\
& b' \geq \underline{b}
\end{aligned}
\tag{H.1}
$$

Firms. A competitive final goods firm aggregates a continuum of intermediate goods indexed by j with a constant elasticity of substitution $\mu/(\mu-1) > 1$. Intermediate goods are produced by monopolistically competitive firms with a linear production function:

$$
y_i = F(n_j) \equiv n_j
$$

Each firm sets the price of its product p'_j subject to quadratic adjustment costs, with κ moderating the extent of price rigidity. As $\kappa \to \infty$, we approach flexible prices:

$$
\psi(p', p) = \frac{\mu}{\mu - 1} \frac{1}{2\kappa} [\log(p'/p)]^2 Y
$$

The firm's value function is given by

$$V(p) = \max_{p'} \left\{ \frac{p'}{p} y - wy - \frac{\mu}{\mu - 1} \frac{1}{2\kappa} [\log(p'/p]^2 Y + \mathbb{E}\left[\frac{V(p')}{1+r'} \right] \right\}$$
$$\text{s.t.} \qquad y = \left(\frac{p'}{p} \right)^{-\frac{\mu}{\mu-1}} Y$$

The first-order condition of the firm's problem plus the assumption that firms adopt symmetric pricing strategies give rise to a New Keynesian Phillips curve that relates aggregate output to price inflation:

$$\log(1+\pi) + \kappa \left(\frac{1}{\mu} - w \right) = \mathbb{E}\left[\frac{1}{1+r'} \frac{Y'}{Y} \log(1+\pi') \right]$$

Households receive dividends from the ownership of firms, and dividends equal output net of labor and price adjustment costs: $d = Y - wL - \psi$

Fiscal and Monetary Policies. For simplicity, we assume that government debt is denominated in real terms. The government budget constraint is given by

$$\tau_l wN + B = (1+r)B_{-1} + G + g$$

In the case of balanced budget experiments, we assume that lump-sum transfers adjust to keep the real stock of debt constant. In the case of deficit-financed changes in spending, we assume that lump-sum transfers follow a simple fiscal rule of the type

$$g = g_{ss} + \phi_T \left(\frac{B_{-1}}{B_{ss}} - 1 \right) \tag{H.2}$$

The monetary authority sets the nominal interest following a standard Taylor rule:

$$i = r^* + \phi_\pi \pi$$

where r^* is the real interest rate target, π_t is the inflation rate, and ϕ_π is the inflation Taylor rule coefficient. For simplicity, we assume that the central bank's inflation target is zero (and so the nominal and real rate targets coincide).

Appendix H.2. Equilibrium

The equilibrium is defined in a manner that is similar to that of the neoclassical model. Given a distribution of agents Φ, a competitive equilibrium with symmetric price-setting choices can be summarized as follows:

1. Taking a sequence of factor prices and initial conditions as given, households maximize the value function $V(b, \beta, u)$ with the respective policy functions being given by $c(b, \beta, u)$, $n(b, \beta, u)$, and $b'(b, \beta, u)$.

2. Firms optimally choose sequences of prices, production, and employment.

3. Fiscal and monetary authorities follow fiscal and interest rate rules.

4. Markets clear:

$$
\begin{aligned}
B &= \int b \mathrm{d}\Phi \\
N &= \int n(b, \beta, u) u \mathrm{d}\Phi \\
Y &= \int c(b, \beta, u) \mathrm{d}\Phi + G + \psi
\end{aligned}
$$

Appendix H.3. Calibration

The calibration of the HANK model is kept as close as possible to that of the neoclassical model. There are two sets of parameters that we change: the first set is parameters unique to the New Keynesian model, and the second set is parameters that are recalibrated to match certain targets.

New Keynesian parameters.. The NK features of the HANK model add a few parameters that are not present in the neoclassical model. We use similar parameter values to those of Auclert et al. [6]: the degree of price rigidity is set to $\kappa = 0.1$ and the elasticity of substitution between varieties is set to target a steady state markup of 20%, $\mu = 1.2$. The central bank's sensitivity to deviations of inflation from its target is set to $\phi_\pi = 1.25$.

Internally calibrated parameters.. We internally recalibrate a series of parameters in order to match some of the same targets we consider in the neoclassical model at the stationary equilibrium: the discount factors $\{\beta_1, \beta_2, \beta_3\}$, the borrowing limit b, the disutility of labor χ, and the variance of the idiosyncratic component of log earnings σ_ϵ. These parameters are calibrated to match the three quartiles of the wealth distribution, the level of the real interest rate, the aggregate fraction of hours worked, and the annual variance of log wages. Table H.26 summarizes the values for the endogenously calibrated parameters, and table H.27 presents the model fit.

Parameter	Value	Description
$\beta_1, \beta_2, \beta_3$	0.9690, 0.9747, 0.9758	Discount factors
$\underline{b}$	0.147	Borrowing limit
σ_e	0.473	Cross-sectional std of log earnings
χ	12.537	Disutility of labor

Table H.26: Internally calibrated parameters, HANK model

Data moment	Description	Source	Data	Model
$\text{Var}(\ln w)$	Yearly variance of log wages	LIS	0.509	0.509
$\bar{n}$	Fraction of hours worked	OECD	0.248	0.248
Q_{25}, Q_{50}, Q_{75}	Wealth quartiles	LWS	-0.014, 0.004, 0.120	-0.014, 0.004, 0.245
r	Real interest rate	Neoclassical model	0.0115	0.0120

Table H.27: Model fit, HANK

Appendix H.4. Determinacy

Figure H.38 analyzes the determinacy properties of our calibrated HANK model, studying whether the equilibrium is determinate for different values of ϕ_{Pi} and ϕ_T, the degree of monetary responsiveness to deviations of inflation from its target and of tax responsiveness to deviations of debt from its steady state value, respectively. The figure shows, as to be expected, that the equilibrium is not determinate if fiscal policy is "excessively active", as reflected by a low value of ϕ_T. For larger values of ϕ_T, meaning that the fiscal authority now stabilizes debt by adjusting taxes, the equilibrium is not determinate for low values of ϕ_Π. For the equilibrium to be determinate, both the responses of taxes to public debt and nominal interest rates to inflation must be sufficiently large.

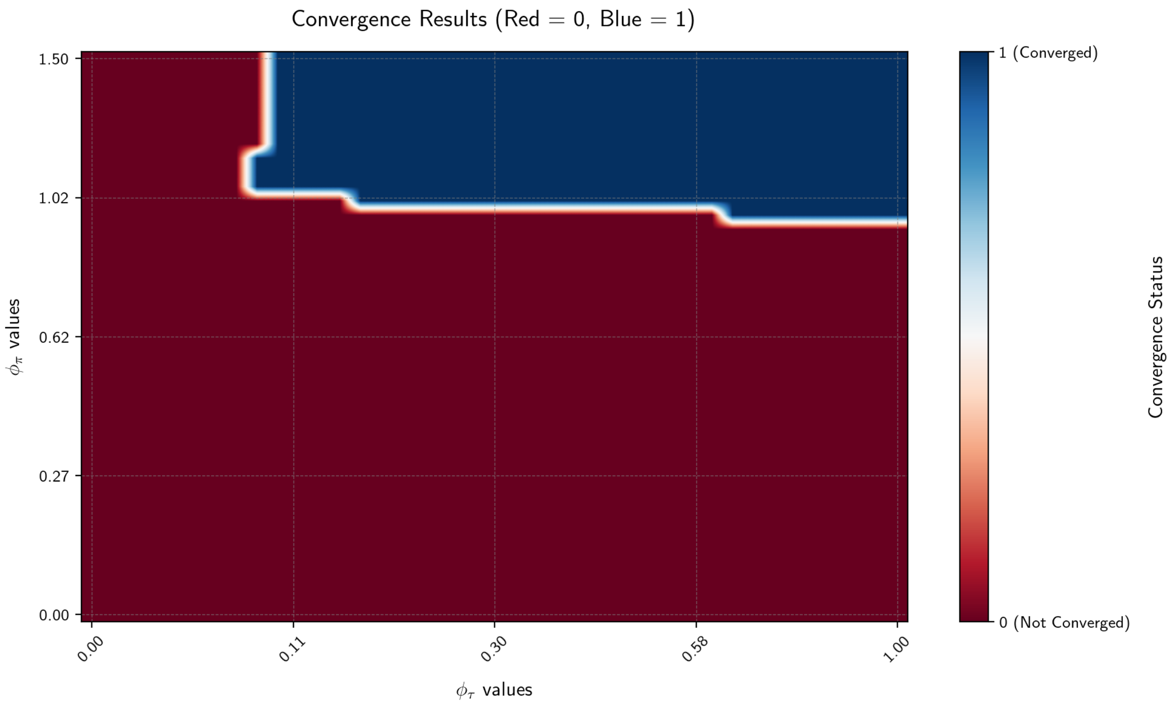

Figure H.38: Determinacy analysis of the HANK model with respect to responsiveness of monetary policy to inflation ϕ_Π and responsiveness of fiscal policy to debt ϕ_T.

Appendix I. Robustness: Micro Evidence of the Mechanism

Table I.28 splits the sample by different thresholds of net wealth, when compared to Table 9. Table I.29 uses liquid wealth as opposed to total wealth. Liquid wealth is defined as total wealth minus real estate. Table I.30 replicates the results in Table 9 while controling for wages. Table I.31 presents the results of estimating equation I.1.

VARIABLES	(1) Total wealth < 0	(2) Total wealth > 0	(3) Total wealth $> \$12000$	(4) Total wealth $< 1/2i^y$	(5) Total wealth $> 1/2i^y$	(6) Total wealth $> i^y$
β_1	1.060**	0.047	0.055	0.062	-0.030	0.012
	(0.477)	(0.037)	(0.039)	(0.057)	(0.034)	(0.036)
β_2	6.355**	0.750**	0.700**	1.548***	0.193	-0.282
	(2.603)	(0.349)	(0.357)	(0.519)	(0.306)	(0.328)
β_3	-0.315**	-0.037**	-0.035**	-0.076***	-0.009	0.014
	(0.129)	(0.017)	(0.017)	(0.025)	(0.015)	(0.016)
Observations	7,075	61,980	47,914	36,080	37,328	31,399
Number of ID	2,308	11,390	8,734	8,711	7,397	6,308

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table I.28: G shock, labor supply response and financing regime by total wealth. i^y is the annual income of the household.

VARIABLES	(1) Liquid wealth < 0	(2) Liquid wealth > 0	(3) Liquid wealth $<$ Wealth Q1	(4) Liquid wealth $<$ Wealth Q2	(5) Liquid wealth $>$ Wealth Q2	(6) Liquid wealth $>$ Wealth Q3
β_1	0.476**	0.055	0.476**	0.146***	0.028	0.034
	(0.185)	(0.038)	(0.185)	(0.056)	(0.041)	(0.052)
β_2	3.549***	0.575	3.549***	0.521	0.954***	0.458
	(1.214)	(0.356)	(1.214)	(0.566)	(0.357)	(0.425)
β_3	-0.176***	-0.029*	-0.176***	-0.027	-0.047***	-0.023
	(0.060)	(0.017)	(0.060)	(0.027)	(0.017)	(0.021)
Observations	9,478	57,981	9,478	33,851	39,471	20,133
Number of ID	2,968	10,929	2,968	8,311	7,568	3,910

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table I.29: G shock, labor supply response, liquid wealth, and financing regime

VARIABLES	(1) Total wealth <0	(2) Total wealth >0	(3) Total wealth < Wealth Q1	(4) Total wealth < Wealth Q2	(5) Total wealth > Wealth Q2	(6) Total wealth > Wealth Q3
β_1	-0.005	-0.022	-0.149	-0.153***	0.012	0.008
	(0.267)	(0.028)	(0.103)	(0.049)	(0.029)	(0.032)
β_2	1.769	0.063	1.584**	1.211***	-0.260	-0.714**
	(1.539)	(0.258)	(0.753)	(0.406)	(0.258)	(0.289)
β_3	-0.086	-0.003	-0.076**	-0.058***	0.013	0.035**
	(0.076)	(0.012)	(0.037)	(0.020)	(0.012)	(0.014)
Observations	7,075	61,980	14,911	33,230	40,821	20,688
Number of ID	2,308	11,390	4,232	8,179	7,437	3,871

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table I.30: *G* shock, labor supply response, total wealth, and financing regime while controlling for wages

VARIABLES	(1) G Shock	(2) G Shock	(3) G Shock	(4) G Shock
β_1	0.327	0.068**	0.166	0.073**
	(0.232)	(0.031)	(0.180)	(0.032)
β_2			3.423	1.262
			(2.923)	(1.837)
β_3		0.873***		0.647*
		(0.304)		(0.347)
β_4			-0.173	-0.069
			(0.145)	(0.096)
β_5		-0.044***		-0.033*
		(0.015)		(0.017)
β_6				-0.650
				(0.919)
β_7				0.032
				(0.045)
Observations	81,678	81,678	81,678	81,678
Number of ID	17,670	17,670	17,670	17,670

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table I.31: G shock, labor supply response, total wealth and financing regime

$$\begin{aligned} \ln h_{it} = & \beta_1 G_t + \beta_2 a_t + \beta_3 \Delta B_t + \beta_4 a_t G_t + \beta_5 \Delta B_t G_t + \beta_6 a_t \Delta B_t \\ & + \beta_7 a_t \Delta B_t G_t + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \quad (I.1)$$

ΔB_t is the change of government debt as a percentage of GDP. Given that we are controlling for government debt changes and wealth, β_1 can be interpreted as the labor supply response of an agent with zero wealth when debt does not change. According to the model predictions, β_1 should be positive, as agents increase their labor supply in response to a positive fiscal shock. β_4 captures how the labor supply response depends on wealth, given that the public debt does not change. Our model predicts this term will be negative because in a financing regime with a balanced budget, wealthier agents will respond the least to the shock. β_7 captures how the relation between wealth and the spending shock changes when the shock is financed with debt. To be in line with our model, this coefficient should be positive, as the labor supply of wealthier agents responds the most for deficit-financed shocks. Lastly, the coefficient β_5 tells us whether the financing regime affects the average labor supply response: deficit-financed shocks in the model generate smaller fiscal multipliers, due to a more muted labor supply response. This would be consistent with $\beta_5 < 0$.

Results in Table I.31 show that the coefficient signs are all in line with what we would expect, thus validating the model's mechanism. For a 1% fiscal spending shock, when debt does not change, an increase in wealth by one standard deviation decreases the labor supply response by 94.5%. If debt increases by 1%, the response of a household with zero wealth decreases by 45.2%, while that for a household with wealth equal to one standard deviation increases by 800%.

Appendix J. Real Business Cycle Model

Appendix J.1. Set up and differences from the HANC

We set up the RBC model to resemble the HANC model as closely as possible. The non-household part of the model is identical to that of the HANC model. Instead of a continuum of households, we now consider a representative household with the same preferences:

$$U(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi^{RBC} \frac{n^{1+\eta^{RBC}}}{1+\eta^{RBC}}$$

The representative household maximizes expected lifetime utility:

$$\max_{\{c_t, n_t, k_t\}_{t=0}^{\infty}} \mathbb{E}_t \sum_{t=0}^{\infty} (\beta^{RBC})^t U(c,n)$$

subject to a sequence of budget constraints of the type:

$$c_t + k_{t+1} = k_t(1+r_t) + g_t + n_t w_t (1-\tau_l)$$

Notice that the key difference is that the effective wage no longer depends on permanent ability a or idiosyncratic productivity u. Additionally, we abstract from the borrowing constraint.

The government budget constraint no longer integrates transfers over the distribution of agents and is given by:

$$g_t + G_t + (1+r_t)B_{t-1} = (1-\tau_l)w_t n_t + B_t$$

Appendix J.2. Calibration

We try to make the RBC calibration as close as possible to that of the HANC. We keep most parameters the same, and recalibrate a few preference parameters to ensure the two models have the same steady state in terms of the macroeconomic aggregates. The parameters we recalibrate are the following:

1. We choose the discount factor β^{RBC} to ensure that the real interest rate is the same across economies. This yields $\beta^{RBC} = 0.988$.

2. We choose the inverse of the Frisch elasticity η^{RBC} to ensure that the MPE in the steady state of the RBC model is equal to the average MPE in the HANC model. To compute the MPE in the RBC model, we use the following formula:

$$MPE = -w \frac{\partial n}{\partial y}$$

where $\frac{\partial n}{\partial y}$ is the effect on labor supply of an exogenous increase in income. Using the endogenous labor supply condition, we can write the above expression as

$$MPE = \frac{\sigma}{\eta^{RBC}} \frac{wn}{c} MPC$$

where $MPC = \frac{\partial c}{\partial y}$. We approximate the MPC in the representative agent model using the formula for the "certainty MPC" in Violante and Kaplan [37], for an agent without income uncertainty or borrowing constraints:

$$MPC = 1 - \frac{1}{1+r} \left[\beta^{RBC}(1+r) \right]^{1/\sigma}$$

This procedure yields $1/\eta^{RBC} = 3.308$.

3. We choose χ^{RBC} to ensure the number of hours worked at the RBC steady state is the same as the aggregate number of hours worked in the stationary equilibrium of the HANC, which yields $\chi^{RBC} = 1.918$.