The Nonlinear Effects of Fiscal Policy*

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Abstract

We argue that the fiscal multiplier of government purchases is *nonlinear* in the spending shock, in contrast to what is assumed in most of the literature. In particular, the multiplier of a fiscal consolidation is decreasing in the size of the consolidation. We empirically document this fact using aggregate fiscal consolidation data across 15 OECD countries. We show that a neoclassical life-cycle, incomplete markets model calibrated to match key features of the U.S. economy can explain this empirical finding. The mechanism hinges on the relationship between fiscal shocks, their form of financing, and the response of labor supply across the wealth distribution. The model predicts that the aggregate labor supply elasticity is increasing in the fiscal shock, and this holds regardless of whether shocks are deficit- or balanced-budget financed. We find evidence of our mechanism in microdata for the US.

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

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1 Introduction

During the 2008-2009 financial crisis, many OECD countries adopted expansionary fiscal policies to stimulate economic activity. In many countries, these fiscal expansions were promptly followed by a period of austerity measures aimed at reducing the size of the resulting high levels of government debt (often 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, demography, tax progressivity, and the stage of development, among others.[1] More recently, the Covid-19 crisis has led many countries to incur in unprecedented budget deficits. Thus, concerns about debt sustainability will likely spur consolidation programs of different sizes and forms of financing after the crisis

However, most of the literature treats the effects of government interventions as being *linear*: small and large shocks are assumed to have the same (linear) effects.[2] In this paper, we argue that fiscal multipliers from negative government spending shocks are *increasing* in the shock (decreasing in the absolute size). That is, larger fiscal contractions are associated with relatively smaller effects on output, i.e., smaller fiscal multipliers. We verify this fact empirically and show that it can be generated by a standard calibrated neoclassical life-cycle model with incomplete markets and heterogeneous agents. We also show that such nonlinearities are absent from the standard representative agent framework, with or without nominal rigidities, and even if we use global solution methods.

We begin our analysis by empirically documenting the size dependence of fiscal multipliers across different time periods, countries, and types of shocks. The key empirical

[1]See for example Auerbach and Gorodnichenko (2012), Ramey and Zubairy (2018), Brinca et al. (2016), Brinca et al. (2019), Hagedorn et al. (2016), Krueger et al. (2016), Basso and Rachedi (2017), Ferrière and Navarro (2018), Ilzetzki et al. (2013), and Faria-e-Castro (2018).

[2]Some notable recent exceptions include Barnichon and Matthes (2017) and Fotiou (2017), who study the asymmetry and nonlinear effects of fiscal policy from an empirical perspective. Barnichon and Matthes (2017) find that contractionary multipliers are larger than expansionary ones during periods of slack for the US. Fotiou (2017) uses a panel of countries to assess how different types of fiscal consolidations (i.e., tax or expenditure based) can have nonlinear effects.

exercises adapt the methodology and data of Alesina et al. (2015a), who use annual data on exogenous fiscal consolidation shocks (reduction of government debt), identified via a narrative approach based on Romer and Romer (2010), 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 consolidations.

We test the external validity of our results by borrowing data and methodology from Ramey and Zubairy (2018), who use quarterly data for the US economy going back to 1889 and an identification scheme for government spending shocks that combines news about forthcoming variations in military spending as in Ramey (2011) and the identification assumptions of Blanchard and Perotti (2002). Using the projection method of Jordà (2005) and pooling observations across high- and low-unemployment periods, the authors find no evidence of a state-dependent fiscal multiplier. We find suggestive evidence that the fiscal multiplier is increasing in the shock. This corroborates the finding that the multiplier of larger consolidations is smaller than that of smaller negative fiscal shocks.

Next, we rationalize these empirical findings in the context of a neoclassical life-cycle, heterogeneous agents model with incomplete markets, similar to Brinca et al. (2016) and Brinca et al. (2019). The model is calibrated to match key features of the US economy, such as the income and wealth distribution, hours worked, taxes, and Social Security. 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 decreasing in wealth, with constrained agents having the lowest EIS.[3] Thus the labor supply elasticity of constrained and low-wealth agents is higher (lower) and their

[3]See Domeij and Floden (2006) for the relationship between wealth and EIS of labor and Vissing-Jørgensen (2002) for the relationship between wealth and the EIS of consumption.

work hours are more (less) responsive to contemporaneous (future) changes in income.

We study how the economy responds to different types of fiscal contractions: permanent or temporary, deficit-financed (i.e., consolidations) 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 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 fiscal shock. Combining these two forces delivers our result: larger fiscal consolidations increase by more the mass of constrained agents, and these are the agents whose labor supply does not respond much to the shock. Therefore, larger fiscal consolidations elicit a relatively smaller aggregate labor supply response, which results in a smaller fiscal multiplier.[4] 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 fiscal contractions result in the same pattern of size dependence thanks to the same mechanisms. Consider the case of a fiscal contraction that is accompanied by a contemporary increase in transfers (so that the debt is constant): the contemporary positive income effect elicits a much larger labor supply response by constrained and low-wealth agents. This positive income effect at the same time increases the agents' wealth and moves some of them away from the borrowing limit. This rightward shift in the wealth distribution therefore 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 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

[4] In related work, Athreya et al. (2017) study how redistributive policies can affect output due to heterogeneity in labor supply elasticities.

fiscal multiplier.

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

The rest of the paper is organized as follows: Section 2 presents the empirical results on the aggregate nonlinearity of fiscal multipliers. Section 3 argues that standard representative agent models cannot match the nonlinear patterns of multipliers that we find in the data. Section 4 introduces the main quantitative model, and Section 5 describes our calibration strategy. Section 6 presents the results from the quantitative model, and Section 7 empirically tests and validates the mechanisms combining micro data from the PSID with data on government spending and debt. Section 8 concludes.

2 Empirical Results

In this section we provide empirical evidence for nonlinear effects of fiscal shocks on output. We begin by using the dataset of Alesina et al. (2015a) to illustrate that larger fiscal consolidations (reductions of government debt) generate smaller fiscal multipliers. This nonlinear effect is more evident in unanticipated fiscal shocks and applies to consolidations based both on revenue increases and on spending contractions. We then provide some additional evidence based on the historical dataset of Ramey and Zubairy (2018) for the U.S. and the local projection method of Jordà (2005) and show that the nonlinear effects of fiscal shocks are not specific to consolidation shocks.

2.1 IMF Shocks

In this section we provide evidence that fiscal consolidations have nonlinear effects on output by showing that larger fiscal consolidations (i.e., more negative spending shocks) are associated with smaller multipliers. This result is shown in the context of the Alesina et al. (2015a) annual dataset of fiscal consolidation episodes, which includes 15 OECD countries and ranges from 1981 to 2014.[5]

Alesina et al. (2015a) expand the original dataset of Pescatori et al. (2011) with exogenous fiscal consolidations episodes, known as IMF shocks. Pescatori et al. (2011) use the narrative approach of Romer and Romer (2010) 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, guaranteeing that the identified consolidations are independent from the current state of the economy.

Besides expanding the dataset of Pescatori et al. (2011), Alesina et al. (2015a) use the methodological innovation introduced by Alesina et al. (2015b), 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. (2015a) define a fiscal consolidation as deviations of public expenditure relative to their level 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 included fiscal consolidation episodes are assumed to be fully credible.

It is instructive to start with a non-parametric approach and look for signs of a nonlinear relationship between output and consolidation shocks in the data. Figure 1 shows

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

log GDP on the y-axis, and the fiscal consolidation shocks as a percentage of GDP on the x-axis. The red line is a fitted quadratic polynomial: this line is decreasing, which implies that the fiscal multiplier is *positive* (larger consolidations lower GDP); moreover, the line is *convex*, suggesting that output decreases by relatively less for larger consolidation shocks.

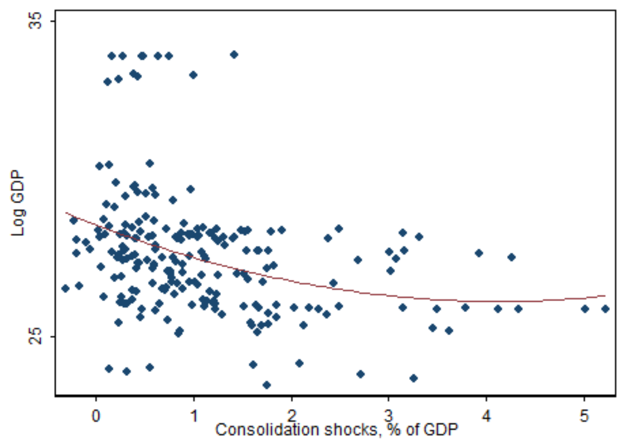

Figure 1: Log GDP on the y-axis and fiscal consolidation shocks as a % of GDP on the x-axis. The red line represents the quadratic fitted polynomial between the two variables. The coefficient of the first-order term of the quadratic fitted polynomial is -1.17 (p-value < 0.01) and of the second-order term is 0.14 (p-value 0.10).

To formally investigate the nonlinear impact of consolidation shocks on GDP, we estimate the following specification to test for the existence of nonlinear effects of the consolidation shocks:

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

where $\Delta y_{i,t}$ and $e_{i,t}$ are the output growth rate and the fiscal consolidation shock, respectively, in country i and year t. 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 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 percentile.

The results are shown in Table 1, and they 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. Not only is β_2 statistically significant but is also economically meaningful. An increase of one standard deviation of the fiscal consolidation shock is associated with a fiscal multiplier that is 78% smaller.

Table 1: Nonlinear effects of fiscal consolidation shocks.

Variable	(1) Benchmark
β_1	-0.908***
	(0.170)
β_2	0.261***
	(0.051)
Observations	510
Number of countries	15

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

Unanticipated vs. Announced Shocks

We proceed by investigating whether it matters that fiscal shocks are unanticipated or announced in advance.[6] As before, we begin our analysis with a non-parametric approach to the nonlinear effects of both types of shocks on output. Figure 2 shows that both shocks have a negative correlation with GDP (fiscal consolidations reduce GDP, as expected), but the nonlinearity is stronger for the unanticipated shocks. While for unanticipated consolidation shocks the quadratic term is positive (0.13) and statistically significant, for announced consolidations the quadratic term is negative (-0.12) and is not statistically significant.

[6] Announced shocks are the sum of consolidation plans announced in the previous three years that are to be implemented in the current year t.

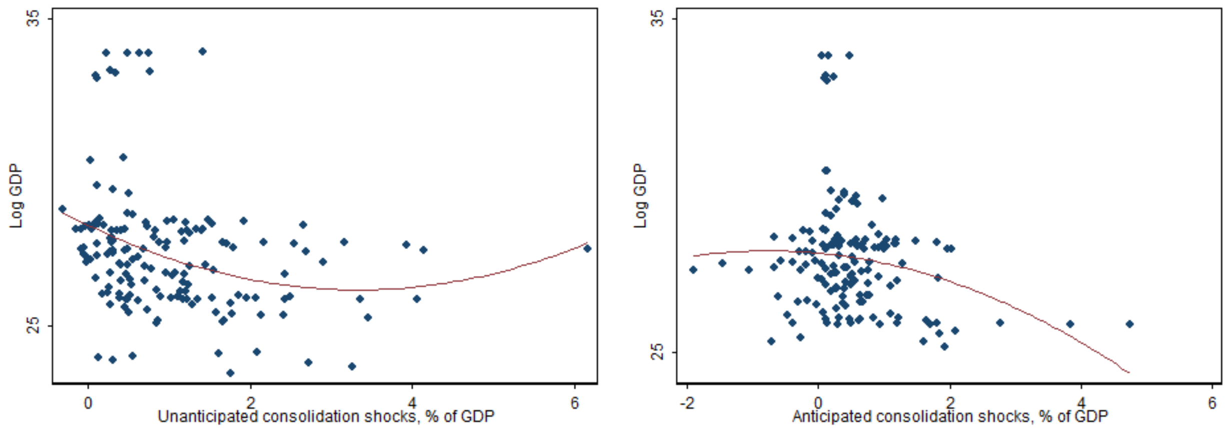

Figure 2: Log GDP on the y-axis and fiscal consolidation shocks as a % of GDP on the x-axis. On the left panel unanticipated and on the right panel the anticipated shocks. The red line represents the quadratic fitted polynomial between the two variables. The coefficient of the first-order term of the quadratic fitted polynomial of unanticipated consolidation shocks is -1.26 (p-value 0.00) and of the second-order term is 0.19 (p-value 0.03). The coefficient of the first-order term of the quadratic fitted polynomial of announced consolidation shocks is -0.18 (p-value 0.47) and of the second-order term is -0.12 (p-value 0.16).

To more formally test for nonlinear effects of both unanticipated and announced consolidations, we use the same methodology as in the previous section to estimate the following specification,

$$\Delta y_{i,t} = \beta_1 e^u_{i,t} + \beta_2 (e^u_{i,t})^2 + \beta_3 e^a_{i,t} + \beta_4 (e^a_{i,t})^2 + \alpha_i + \gamma_t + \epsilon_{it} \tag{2}$$

where $e^u_{i,t}$ are the unanticipated shocks and $e^a_{i,t}$ are the announced shocks. Results are presented in Table 2 and validate the intuition gained from the non-parametric approach: the nonlinear impacts of consolidations on output come from unanticipated shocks and not from announced consolidations. While β_4 is not statistically significant, β_2 is positive, statistically significant, and economically meaningful. An increase of one standard deviation of unanticipated consolidations reduces the size of the fiscal multiplier by 22%.

Our results are robust to the inclusion of further lags (for both types of shocks) as well as to the inclusion of consolidations announced in the current year to be implemented in the following three years. These results are presented in Tables 10 and 11 in Appendix A.1 and establish that the unanticipated quadratic term β_2 is positive and statistically

Table 2: Non-linear effects of fiscal unanticipated and announced consolidation shocks.

Variables	Benchmark
β_1	-0.465**
	(0.183)
β_2	0.150***
	(0.058)
β_3	-0.547**
	(0.215)
β_4	0.034
	(0.087)
Observations	510
Number of countries	15

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

significant across specifications.

Financing Instrument

Lastly, we test if it matters whether consolidations are spending or revenue based. We estimate the following specification,

$$\Delta y_{i,t} = \sum_{i=0}^{3} \beta_{1,t-i} e^{u}_{i,t} + \sum_{i=0}^{3} \beta_{2,t-i} (e^{u}_{i,t})^2 + \sum_{i=0}^{3} \beta_{3,t-i} e^{a}_{i,t} + \sum_{i=0}^{3} \beta_{4,t-i} (e^{a}_{i,t})^2 + \sum_{i=0}^{3} \beta_{5,t-i} r^{u}_{i,t} + \sum_{i=0}^{3} \beta_{6,t-i} (r^{u}_{i,t})^2 + \sum_{i=0}^{3} \beta_{7,t-i} r^{a}_{i,t} + \sum_{i=0}^{3} \beta_{8,t-i} (r^{a}_{i,t})^2 + \alpha_i + \gamma_t + \epsilon_{it} \quad (3)$$

where $e^{u}_{i,t}$ and $e^{a}_{i,t}$ are the unanticipated and announced expenditure-based consolidation shocks and $r^{u}_{i,t}$ and $r^{a}_{i,t}$ are revenue-based consolidation shocks. Results are shown in Table 3, and establish that the quadratic terms for both expenditure- and revenue-based (unanticipated) consolidations – β_2 and β_6, respectively – are positive and statistically significant at all horizons (up to three years).[7] Moreover, both coefficients are economically meaningful, with an increase by one standard deviation of a expenditure- and revenue-consolidation shocks lowering the respective multipliers by 26% and 20%.

[7] To simplify presentation, we do not report the announced consolidations parameters, which are not

Table 3: Non-linear effects of fiscal unanticipated expenditure and revenue consolidation shocks, including three lags of each shock.

	β_1	β_2	β_3	β_4
t	-0.580*	0.367*	-1.158***	0.571***
	(0.344)	(0.205)	(0.346)	(0.170)
$t-1$	-1.174***	0.487**	-1.074***	0.249
	(0.358)	(0.208)	(0.347)	(0.179)
$t-2$	-0.414	0.473**	-0.904***	0.249
	(0.354)	(0.207)	(0.330)	(0.188)
$t-3$	-1.209***	0.614***	-0.891***	0.578***
	(0.361)	(0.219)	(0.332)	(0.201)
Observations		510		
Number of countries		15		

Standard errors in parentheses

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

Table 12 in Appendix A.1 shows that our results are robust to the inclusion of future consolidation-plan announcements. Finally, Tables 13 to 15 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 historical dataset constructed by Ramey and Zubairy (2018), which contains quarterly time series for the US economy ranging from 1889 to 2015. The dataset includes real GDP, the GDP deflator, government purchases, federal government receipts, population, the unemployment rate, interest rates, and defense news. Quarterly US historical data provides us with long 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 (2018) use two different approaches: (i) a defense news series proposed by Ramey (2011), 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

statistically significant.

Blanchard and Perotti (2002) that government spending does not react to changes in macroeconomic variables within the same quarter. Ramey and Zubairy (2018) argue that including both instruments simultaneously can bring advantages, as the Blanchard-Perotti 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).

We follow Barnichon and Matthes (2017) and first estimate the Blanchard-Perotti VAR to recover the structural government spending shocks. Figure 3 plots the time series for both shocks. Large variations in the 1910s, 1940s, and 1950s reflect defense spending for World Wars I and II and the Korean War. Smaller variations throughout the rest of the sample mostly reflect Blanchard-Perotti shocks. The figure highlights that there is ample variation in this measure of exogenous spending shocks, both in terms of sign and size.

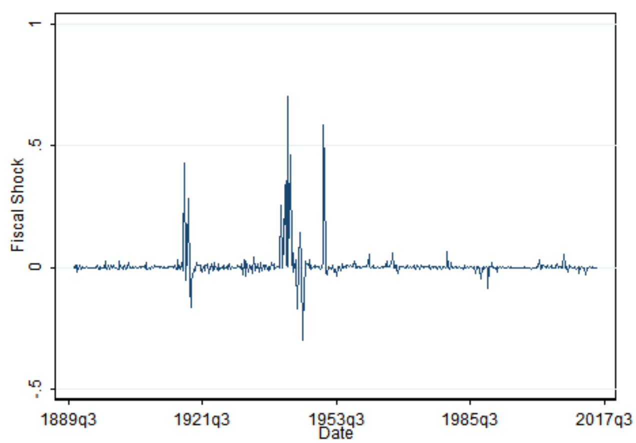

Figure 3: Government spending shocks as a percentage of real GDP.

To abstract from the large shocks around the two world wars and the Korean War, our baseline specification tests for the presence of nonlinear effects of fiscal shocks on the post-Korean War sample.[8] We apply the same methodology as Ramey and Zubairy (2018), which is based on the local projection method of Jordà (2005). This method consists of estimating the following equation for different time horizons h:

[8]Our results are nevertheless robust to including the Korean War and the two world wars as we show in Appendix A.2.

$$y_{t+h} = \alpha_h + \Psi_h(L)z_{t-1} + \beta_h \text{shock}_t + \beta_{2,h}\left(\text{shock}_t\right)^2 + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, \ldots \tag{4}$$

where y is real GDP per capita (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. z also includes the defense news variable to control for serial correlation. $\Psi_h(L)$ is a polynomial of order four in the lag operator, and shock_t is the exogenous shock, which consists of the defense news variable and the Blanchard-Perotti spending shock.

Ramey and Zubairy (2018) follow a literature that highlights that in a dynamic environment, the multiplier should not be calculated 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.[9] This method has the advantage of measuring all the GDP gains in response to government spending variations in a given period. Ramey and Zubairy (2018) propose estimating the following instrumental variables specification that allows for the direct estimation of the integral multiplier:

$$\sum_{j=0}^{h} y_{t+j} = \delta_h + \phi_h(L)z_{t-1} + m_h \sum_{j=0}^{h} g_{t+j} + m_{2,h}\left(\sum_{j=0}^{h} g_{t+j}\right)^2 \epsilon_{t+h}, \text{ for } h = 0, 1, 2, \ldots \tag{5}$$

where shock_t is used as an instrument to $\sum_{j=0}^{h} g_{t+j}$, which is the sum of government spending from t to $t+h$. This way, the cumulative multiplier at horizon h can be directly interpreted as $m_h + 2 \times m_{2,h} \sum_{j=0}^{h} g_{t+j}$.

If the effects of fiscal policy are size dependent, the coefficient $m_{2,h}$ should be statistically different from zero. Table 4 reports the estimation results: the quadratic coefficient

[9] See Mountford and Uhlig (2009), Uhlig (2010), and Fisher and Peters (2010).

is positive, suggesting the multiplier to be increasing in the shock, as we found before, but not statistically significant. Barnichon and Matthes (2017) alert for the fact that negative shocks yield larger multipliers than do positive shocks. This may be affecting our results, as we pool both negative and positive shocks in the same regression.

Table 4: Linear and quadratic coefficients for impact, 1-, 2-, 3 and 4-year horizons. The specification includes both Blanchard-Perotti (BP) shocks and news shocks. The sample is for the post-Korean War, and the BP shocks are identified as in Barnichon and Matthes (2017). Standard errors in parentheses.

	Linear	Quadratic
Impact	-5.022	6.878
	(5.657)	(6.571)
1 year	-5.931	3.973
	(6.548)	(3.726)
2 year	-8.574	2.715
	(12.131)	(3.450)
3 year	12.058	-2.101
	(40.011)	(7.619)
4 year	-1.371	0.354
	(35.177)	(4.971)

To account for this sign dependence of the fiscal multiplier, we estimate equation (5) separately for positive and negative shocks. The results in Table 5 show that the quadratic term is positive across all horizons and statistically significant at longer horizons. While these results are weaker, they help corroborate our previous findings that the fiscal multiplier is increasing in the size of the shock.

When computing the average multiplier for negative and positive shocks, we find the average multiplier for negative shocks to be larger than for positive shocks, 1.12 vs. 1.04 on impact and 2.03 vs. 1.87 at the 1-year horizon, consistent with the results found by Barnichon and Matthes (2017).

Finally, we test if results are robust to a series of alternative specifications. In Table 16 we present the results when including government debt as a control variable; in Table 17 we test if the results go through when using the entire sample (1889-2015), while in Table 18 we assess the results under Ramey and Zubairy (2018) Blanchard-Perotti shocks identification strategy, where instead of running a VAR in advance to extract the shocks we include in the regressions just the lagged value of the government spending variable,

Table 5: Linear and quadratic coefficients for impact, 1, 2, 3 and 4-year horizons for both Blanchard-Perotti and news shocks in the same specification when considering the post-Korean war sample and Barnichon and Matthes strategy to identify the BP shocks.

	Positive shocks		Negative shocks	
	Linear	Quadratic	Linear	Quadratic
Impact	2.526	-3.518	0.528	1.411
	(2.268)	(5.046)	(4.255)	(9.821)
1 year	-3.889	2.731	-3.199	2.481
	(4.777)	(2.721)	(4.886)	(2.706)
2 year	-10.423	3.174	-16.127	4.967
	(6.035)	(1.684)	(8.430)	(2.381)
3 year	-16.328	3.247	-23.377	4.716
	(6.361)	(1.168)	(9.259)	(1.775)
4 year	-17.988	2.683	-26.872	4.025
	(6.661)	(0.910)	(10.323)	(1.469)

which is equivalent to running the Blanchard-Perotti VAR. Because in section 2.1 we show anticipated shocks do not generate the nonlinear effects, in Table 19 we test the results only when including the Blanchard-Perotti shocks . Overall, the results hold for all specifications, with the quadratic term for both positive and negative shocks being positive.

3 Fiscal Policy in Representative Agent Environments

We are interested in understanding what mechanisms may generate the nonlinearities that we empirically documented in the previous section. To do so, we proceed incrementally and show that standard representative agent models are unable to generate the nonlinearities that we find in the data. Even adding standard ingredients that are known to amplify the effects of fiscal policy, such as nominal rigidities or adjustment costs of investment, is not enough to match the data.

3.1 *Real Business Cycle Model*

Set-up

We start with the textbook real business cycle (RBC) model, where preferences of the representative agent are separable in consumption and labor, and the representative firm produces according to a Cobb-Douglas function that depends on capital and labor.

The framework follows Cooley and Prescott (1995), and the details of the model are presented in Appendix B.[10]

We augment the model with a government that engages in socially wasteful spending. The aggregate resource constraint can then be written as

$$C_t + K_t - (1-\delta)K_{t-1} + G_t = z_t K_{t-1}^{\alpha} N_t^{1-\alpha}$$

where C_t is aggregate consumption, K_{t-1} is the current stock of capital, N_t is labor, and G_t is government spending. The Ricardian equivalence ensures that the mode of financing is irrelevant for allocations. The calibration is standard and can be found in Appendix B.

Fiscal Shock

We assume that government spending follows an AR(1) in logs:

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

where ρ_G is assumed to be 0.9 at a quarterly frequency, consistent with the estimates of Nakamura and Steinsson (2014) for military procurement spending.

Experiment

We consider a range of values for ε_t^G that correspond to changes from -10% to 10% of steady-state government spending on impact. The resulting fiscal multipliers, at different horizons, are plotted in Figure 4. We adopt the standard definition of discounted integral multiplier that accounts for the cumulative effects of fiscal policy on output at a given horizon h:

$$\mathcal{M}_h = \frac{\sum_{i=0}^{h}\prod_{j=0}^{i} R_j^{-1}(Y_i - Y_{SS})}{\sum_{i=0}^{h}\prod_{j=0}^{i} R_j^{-1}(G_i - G_{SS})} \tag{6}$$

[10]The main deviations from the cited benchmark are separable preferences in consumption and leisure and no trend growth for total factor productivity (TFP).

This corresponds to the traditional definition of the multiplier measured at impact for $h = 0$.

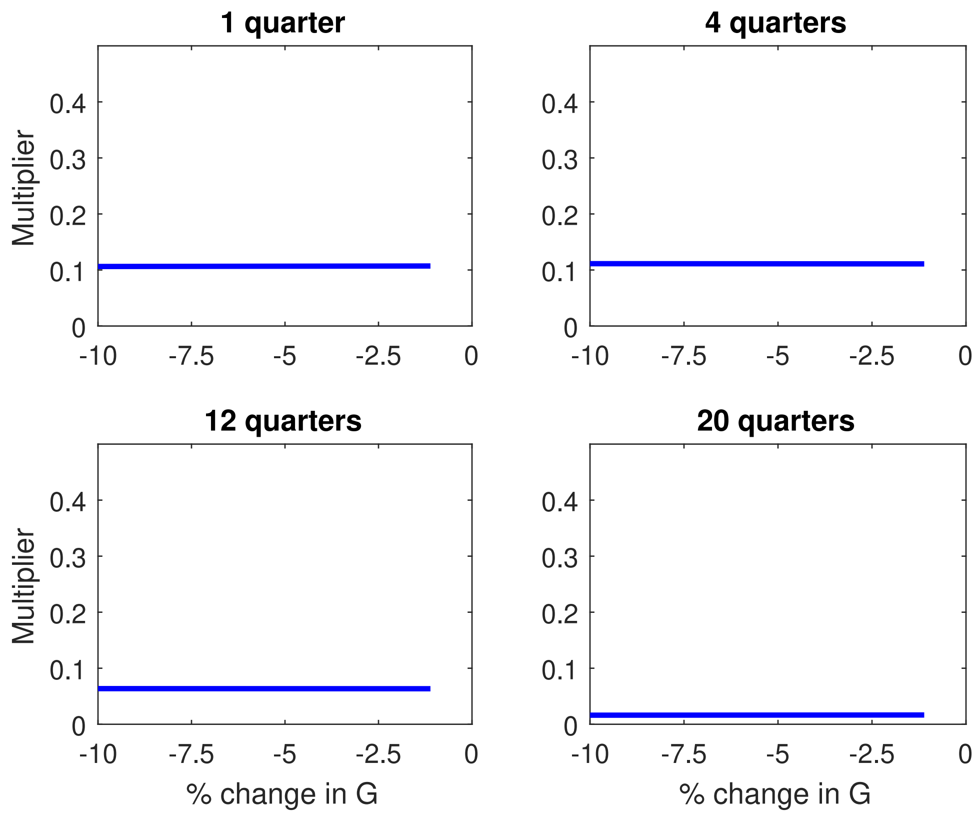

Figure 4: Representative agent, RBC model: fiscal multipliers as a function of the size of the variation in G, at different horizons.

The figure shows that, as is well known, the basic RBC model is not able to match the size of the fiscal multipliers in the data. Additionally, the standard model implies that the fiscal multiplier is roughly constant with the change in G: the model is not able to capture the nonlinearity that we find in the data. In fact, the model predicts the multiplier to be slightly *increasing* with the size of the shock to G, violating the pattern that we find. These results hold regardless of the horizon.

3.2 *Nominal Rigidities*

One standard way of generating fiscal multipliers that more closely match those measured in the data is by providing a role for aggregate demand to affect economic activity, which can be achieved by including nominal rigidities. We augment the model to include quadratic costs of price adjustment for firms, which generates a Phillips curve relating output and inflation, as well as a Taylor rule for the central bank. Again, the model ingredients and calibration are standard, and can be found in Appendix B.

Figure 5 shows the outcome of the same experiment in the context of a New Keynesian model with investment: multipliers do not vary with the size of the shock in an economically meaningful way. For this particular example, we use a standard Volcker-Greenspan calibration for the Taylor rule, which is known to produce relatively low multipliers.[11] It is well known that the level of the fiscal multiplier is very sensitive to the specific parametrization of the Taylor rule. What is important is that alternative parameterizations that raise the level of the fiscal multiplier, such as making the central bank less responsive to changes in inflation, do not alter the fact that the multiplier is essentially constant with respect to the size of the shock to G_t.

3.3 *Adjustment Costs of Investment*

One reason why the basic RBC and New Keynesian models with capital are unable to generate large multipliers is the high sensitivity of investment to government spending shocks via movements in the real rate. As discussed, one way that New Keynesian models partially address this is by making the central bank, who sets the real rate, less responsive to output and inflation. Still, in order to generate multipliers of empirically plausible magnitudes, one would need to parametrize the Taylor rule to be at odds with a multitude of empirical estimates (at least prior to 2007, which is the sample considered in the previous section).

A direct way to address this excess sensitivity of investment is to introduce adjustment costs, which have become a standard feature of medium-scale dynamic stochastic general equilibrium (DSGE) models.

Figure 6 repeats the baseline experiment by introducing adjustment costs of invest-

[11] In particular, we assume a standard Taylor rule with interest rate smoothing:

$$\log R_t = \rho_R \log R_{t-1} + (1-\rho_R)[\log R_{SS} + \phi_\Pi(\log \Pi_t - \log \Pi_{SS}) + \phi_Y(\log Y_t - \log Y_{SS})]$$

with $\rho_R = 0.80, \phi_\Pi = 1.50, \phi_Y = 0.50$.

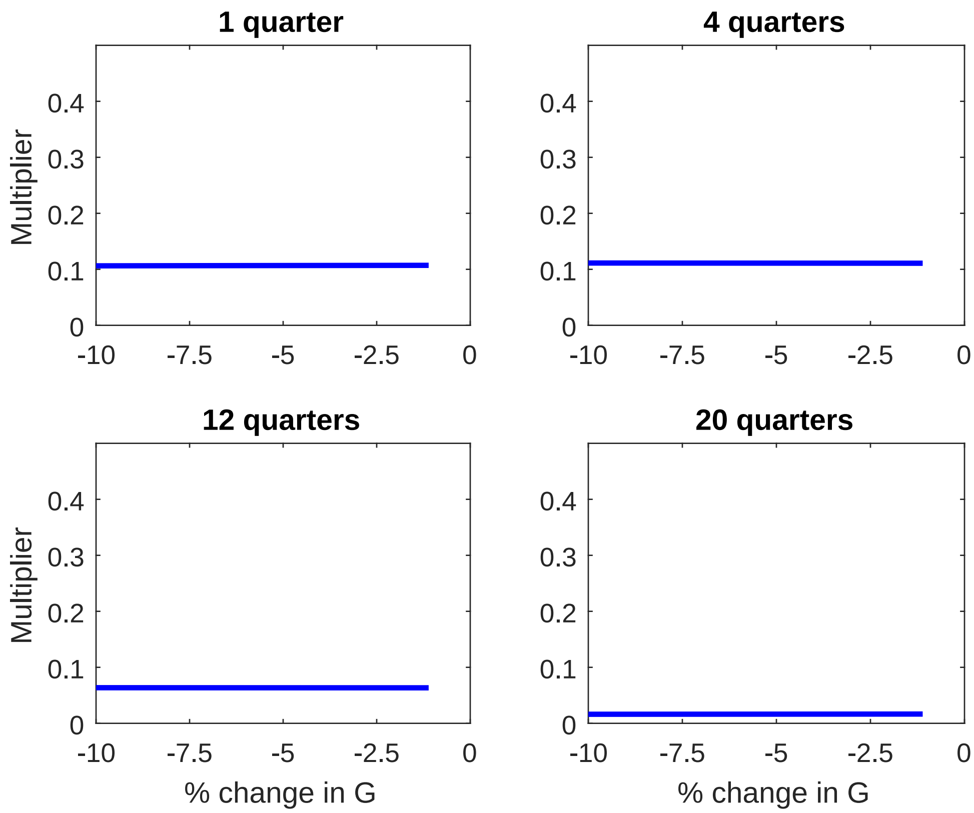

Figure 5: Representative agent, New Keynesian model: fiscal multipliers as a function of the size of the variation in G, at different horizons.

ment in the New Keynesian specification. It shows that adjustment costs of investment are unable to generate empirically plausible nonlinearities in the fiscal multiplier.

An increase in government spending affects the supply of the two factors of production with opposing effects: on the one hand, real interest rates rise, which crowds out investment and causes the capital stock to fall; on the other hand, the negative income effect expands labor supply. Adjustment costs of investment dampen the sensitivity of investment to real rates, thereby curbing the first effect and raising the fiscal multipliers. Still, none of this is sufficient to match the patterns that are detected in the data.[12]

[12] In the appendix, we show that the extreme case of infinite adjustment costs substantially helps in raising the levels but does not generate any meaningful nonlinearity either.

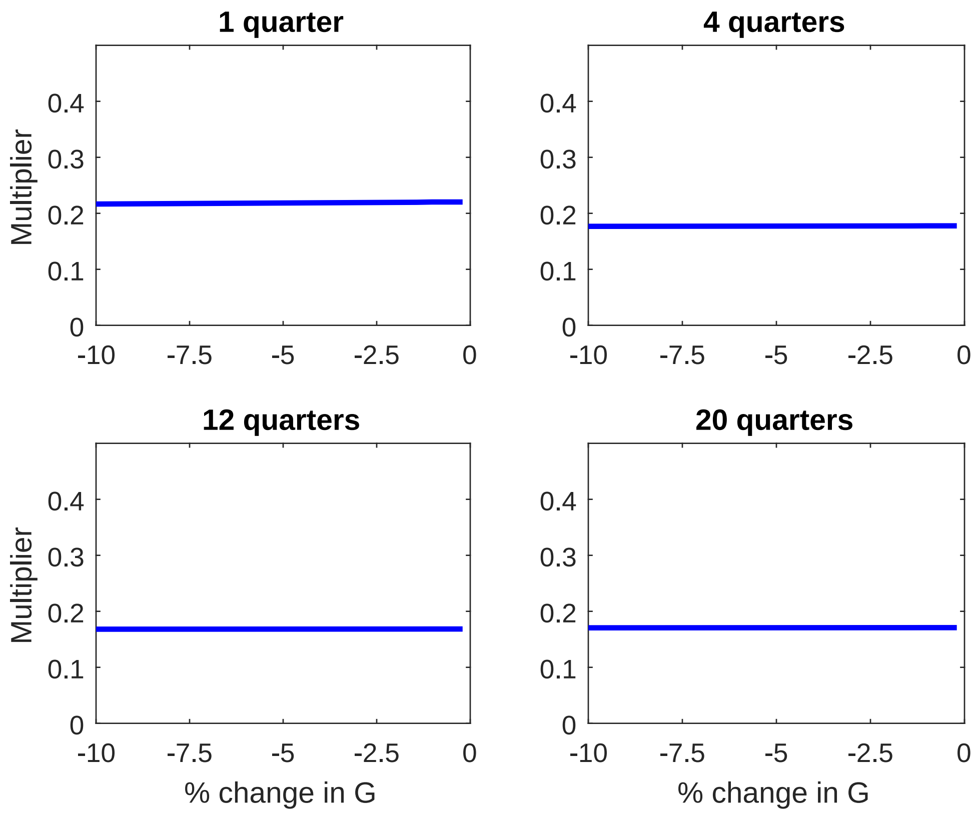

Figure 6: Representative agent, New Keynesian model with adjustment costs of investment: fiscal multipliers as a function of the size of the variation in G, at different horizons.

4 Heterogeneous Agents Model

In the previous sections, we presented empirical evidence that the macroeconomic effects of a fiscal spending shock depend on the size of that shock. In this section, we present a quantitative model that allows us to rationalize these findings. The model is similar to the models in Brinca et al. (2016) and Brinca et al. (2019), except that the time period is one quarter.

Technology

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

$$Y_t(K_t, L_t) = K_t^{\alpha} \left[L_t\right]^{1-\alpha} \tag{7}$$

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

$$K_{t+1} = (1-\delta)K_t + I_t \tag{8}$$

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:

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta)K_t. \tag{9}$$

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

$$w_t = \frac{\partial Y_t}{\partial L_t} = (1-\alpha)\left(\frac{K_t}{L_t}\right)^{\alpha} \tag{10}$$

$$r_t = \frac{\partial Y_t}{\partial K_t} - \delta = \alpha \left(\frac{L_t}{K_t}\right)^{1-\alpha} - \delta \tag{11}$$

Demographics

The economy is populated by J overlapping generations of households.[13] Households start their life at age 20 and retire at age 65, after which they face an age-dependent probability of dying, $\pi(j)$. They die with certainty at age 100. $j \in \{0.25, \ldots, 81.0\}$ is the household's age minus 19.75. A period in the model corresponds to 1 quarter and households work for 180 quarters (45 years). We assume no population growth and that everyone survives until retirement and normalize the size of each new cohort to 1. $\omega(j) = 1 - \pi(j)$ defines the age-dependent probability of surviving in retirement; applying the law of large numbers, this means that the mass of retired agents in any given period is equal to $\Omega_j = \prod_{q=65}^{q=J-1} \omega(q)$.

Households also differ with respect to permanent ability levels assigned at birth, persistent idiosyncratic productivity shocks, asset holdings, and discount factors that

[13] The life-cycle and the incomplete markets has been highlighted as key reasons for the failure of Ricardian equivalence. Peterman and Sager (2016) highlight the importance of the life cycle when assessing the effects of government debt.

are uniformly distributed and can take three distinct values, $\beta \in \{\beta_1, \beta_2, \beta_3\}$. Working-age agents choose how much to work, n; consume, c; and save, k, to maximize expected life-time utility. Retired households make consumption and saving decisions and receive a retirement benefit Ψ_t.

Stochastic survivability after retirement implies that a share of households leave unintended bequests Γ. We assume that these bequests are uniformly redistributed across living households. We also assume that retired households gain utility from these bequests in order to better match the data on wealth over the life cycle.

Labor Income

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

$$u' = \rho u + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon^2). \tag{12}$$

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

$$w_i(j, a, u) = w e^{\gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + a + u} \tag{13}$$

where the age-profile of wages is captured by $\gamma_i, i = 1, 2, 3$.

Preferences

Household utility $U(c, n)$ is standard: time-additive, separable, and isoelastic, with $n \in (0, 1]$:

$$U(c, n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta} \tag{14}$$

Retired households gain utility from the bequest they leave when they die:

$$D(k) = \varphi \log(k). \tag{15}$$

Government

The government runs a balanced budget social security system that operates independently from the main government budget constraint. Social security levies taxes on employees' gross labor income at rate τ_{ss} as well as on the representative firm at rate $\tilde{\tau}_{ss}$. The proceeds are used to pay retirement benefits, Ψ_t.

In the main government budget, 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 (2002) and recently used in Heathcote et al. (2017) and Holter et al. (2019):

$$\tau(y) = 1 - \theta_0 y^{-\theta_1} \tag{16}$$

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 social security revenues by R^{ss} and the other tax revenues as R, the government budget constraint is defined as

$$g\left(45 * 4 + \sum_{j \geq 65} \Omega_j\right) = R - G - rB, \tag{17}$$

$$\Psi\left(\sum_{j \geq 65} \Omega_j\right) = R^{ss} \tag{18}$$

Recursive Formulation of the Household Problem

In a given period, a household is defined by its age j, asset position k, time discount factor β, permanent ability a, and persistent idiosyncratic productivity u. Given this set of states, a working-age 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

$$
\begin{aligned}
V(k,\beta,a,u,j) &= \max_{c,k',n}\left[U(c,n)+\beta\mathbb{E}_{u'}\left[V(k',\beta,a,u',j+1)\right]\right] \\
&\text{s.t.:} \\
c(1+\tau_c)+k' &= (k+\Gamma)\left(1+r(1-\tau_k)\right)+g+Y^L \\
Y^L &= \frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}}\left(1-\tau_{ss}-\tau_l\left(\frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}}\right)\right) \\
n\in[0,1],&\quad k'\geq -b,\quad c>0
\end{aligned}
\tag{19}
$$

where Y^L is the household's labor income net of social security (paid by both the employee and the employer) and labor income taxes and b is an exogenous borrowing limit. The problem of a retired household differs along three dimensions: there is an age-dependent probability of dying, $\pi(j)$; there is a bequest motive, $D(k')$; and labor income replaced by retirement benefits. We can write the problem as

$$
\begin{aligned}
V(k,\beta,j) &= \max_{c,k'}\left\{U(c,n)+\beta[1-\pi(j)]V(k',\beta,j+1)+\pi(j)D(k')\right\} \\
&\text{s.t.:} \\
&c(1+\tau_c)+k' = (k+\Gamma)\left[1+r(1-\tau_k)\right]+g+\Psi, \\
&k'\geq 0,\quad c>0.
\end{aligned}
\tag{20}
$$

Stationary Recursive Competitive Equilibrium

Let the measure of households with the corresponding characteristics be given by $\Phi(k,\beta,a,u,j)$. 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 $V(k,\beta,a,u,j)$ and policy functions $c(k,\beta,a,u,j)$, $k'(k,\beta,a,u,j)$, $n(k,\beta,a,u,j)$ solve the households' optimization problems.

2. Markets clear:

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

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

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

3. Factor prices are paid their marginal productivity:

$$\begin{aligned} w &= (1-\alpha)\left(\frac{K}{L}\right)^{\alpha} \\ r &= \alpha\left(\frac{K}{L}\right)^{\alpha-1} - \delta. \end{aligned}$$

4. The government budget balances:

$$g \int \mathrm{d}\Phi + G + rB = \int \left[\tau_k r(k+\Gamma) + \tau_c c + n\tau_l \left(\frac{nw(a,u,j)}{1+\tilde{\tau}_{ss}}\right)\right] \mathrm{d}\Phi.$$

5. The social security system budget balances:

$$\Psi \int_{j \geq 65} \mathrm{d}\Phi = \frac{\tilde{\tau}_{ss} + \tau_{ss}}{1+\tilde{\tau}_{ss}} \left(\int_{j<65} nw \mathrm{d}\Phi\right).$$

6. The assets of the dead are uniformly distributed among the living:

$$\Gamma \int \omega(j) \mathrm{d}\Phi = \int \left[1 - \omega(j)\right] k \mathrm{d}\Phi.$$

Fiscal Experiments and Transition

Our fiscal experiments consist of decreases in government spending G (fiscal contractions) of different sizes (measured as a percentage of GDP) and under different financing regimes. This is important, as the 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.

In our experiments, we consider four different types of fiscal contractions:

1. Permanent debt consolidations, where 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).

2. Permanent reductions in G, which are initially financed with debt (that falls). After some time, transfers fall and debt returns to its original level as the economy transitions to a new SRCE.

3. Temporary reductions in G that are deficit financed. Initially, the reduction in G leads to a fall in debt only. Eventually, G returns to its original level and transfers adjust so that debt also returns to its original. The economy returns to the initial SRCE.

4. Temporary reductions in G that are balanced-budget financed. Transfers increase to clear the government budget constraint and maintain debt constant. Eventually, the economy transitions back to the initial SRCE.

We delegate the formal definition of a transition equilibrium to Appendix C. The main difference compared to the steady state is that we need an additional state variable, time, t, in the dynamic programming problem of households. The policy functions and prices will be time dependent. The numerical solution of the model involves guessing on paths for all the variables that will depend on time and then solving this maximization problem backward, after which the guesses are updated. The solution method is similar to that used in Brinca et al. (2016) and Krusell and Smith (1999).

5 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. Section D in the appendix contains a table that summarizes the values for the parameters that are calibrated outside of the model.

Wages

The wage profile over the life cycle (13) is calibrated directly from the data. We run the following regression, using data from the Luxembourg Income and Wealth Study:

$$\ln(w_i) = \ln(w) + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + \varepsilon_i \tag{21}$$

where j is the age of individual i.

To estimate parameters ρ and σ_ϵ we use PSID yearly data (1968-1997) and run equation (21). We then use the residuals of the equation to estimate both parameters for a yearly periodicity. To transform the parameters from yearly to quarterly, we raise ρ to $\frac{1}{4}$ and divide σ_ϵ by 4. σ_a is chosen using SMM to match the variance of $\ln(w)$.

Preferences

We set the Frisch elasticity of labor supply to 1, as in Trabandt and Uhlig (2011), a much used number number in the literature. The utility from bequests, disutility of work, and the three discount factors (φ, χ, β_1, β_2, β_3) are among the parameters calibrated to match key moments in the data. The corresponding moments are the ratio of wealth owned by households in the age cohort 75-80 years old relative to an average household, the share of hours worked, and three quartiles of the wealth distribution, respectively.

Taxes and Social Security

We use the labor income tax function of Benabou (2002) to capture the progressivity of both the tax schedule and direct government transfers. We use the estimates of Holter et al. (2019), who estimate the parameters θ_0 and θ_1 for the US.[14]

For the social security rates, we assume no progressivity. Both of the social security tax rates, the one paid by the employer and the one paid by the employee, are set to 7.65%, using the value from the bracket covering most incomes. Finally, consumption and capital tax rates are set to 5% and 36%, respectively, as in Trabandt and Uhlig (2011).

Following Hagedorn et al. (2016), we set transfers g to be 7% of GDP. θ_0 is set so that labor 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 bequest motive, discount factors, borrowing limit, disutility from working, and variance of permanent ability. The SMM is set so that it minimizes the following loss function:

$$L(\varphi, \beta_1, \beta_2, \beta_3, b, \chi, \sigma_a) = ||M_m - M_d|| \tag{22}$$

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

We use seven data moments to choose seven parameters, so the system is exactly identified. The seven moments we select in the data are (i) the ratio of wealth owned by households in the 75-80-year-old age cohort relative to an average household, (ii) the share of hours worked, (iii-v) the three quartiles of the wealth distribution, (vi) the variance of log wages, and (vii) the capital-to-output ratio. Table 7 presents the calibrated parameters, and Table 6 presents the calibration fit.

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

Table 6: Calibration Fit

Data moment	Description	Source	Data value	Model value
75-80/all	Share of wealth, households aged 75-80	LWS	1.513	1.513
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	-0.009, 0.000, 0.124

Table 7: Parameters Calibrated Endogenously

Parameter	Value	Description
Preferences		
φ	21.26	Bequest utility
$\beta_1, \beta_2, \beta_3$	0.999, 0.987, 0.951	Discount factors
χ	11.1	Disutility of work
Technology		
b	0.90	Borrowing limit
σ_a	0.695	Variance of ability

6 Quantitative Results

In this section, we use the calibrated model as a laboratory to study the effects of fiscal contractions of different sizes. We start by studying permanent debt consolidations: transitions where the debt level at the final steady state is different (lower) than the debt level at the initial steady state. We then analyze other types of fiscal contractions: permanent and temporary reductions in G — under different financing regimes — but where the economy returns to the initial debt level.

6.1 Permanent Debt Consolidations

We start by considering the experiment that most closely resembles real-world consolidation experiences: permanent fiscal consolidations. 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 its new steady-state 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 7 plots the fiscal multiplier (on impact) depending on the size of the initial G variation. The multiplier is monotonically increasing in the shock: it is larger for smaller decreases in G (i.e., smaller consolidations) and smaller for larger decreases in G (larger consolidations). In other words, the effects of G on Y are nonlinear: the larger the fiscal consolidation, the smaller the impact on output.

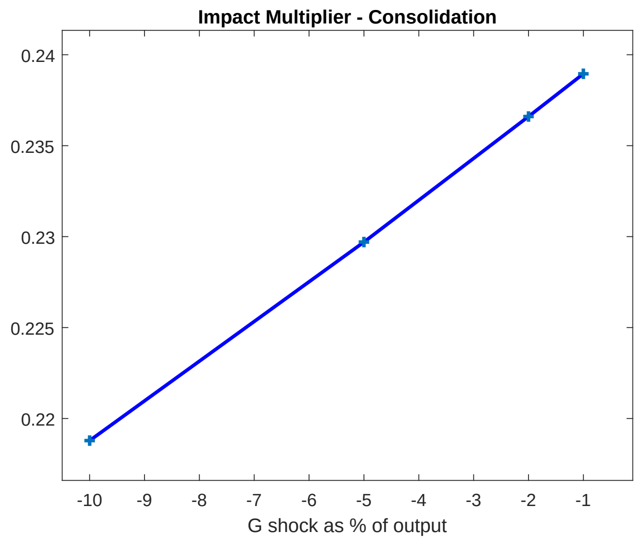

Figure 7: This figure plots the fiscal multiplier for consolidation experiments as a function of the size of the variation in G (as a % of GDP).

Figures 8 and 9 shed light on the mechanism at the heart of this paper that generates this nonlinearity. Figure 8 plots the % of agents at the borrowing constraint one year after the shock, as a function of the size of the consolidation. The mass of constrained agents is increasing in the size of the consolidation: larger consolidations involve larger future reductions in public debt. This generates not only a positive wealth effect, as future lumpsum transfers (in 30 periods) 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 off capital. As agents internalize these positive wealth and income effects, they find it optimal to borrow more today. Thus larger consolidations induce more agents to move towards the constraint in the short run.

Figure 9 illustrates why these changes in the percentage of constrained agents matter for aggregate dynamics. This figure plots the labor supply response as a function of the level of assets for three consolidations of different sizes (1%, 5%, and 10% of GDP).

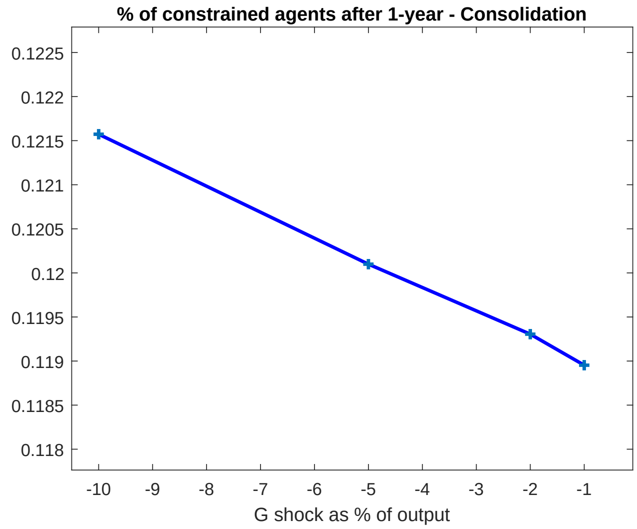

Figure 8: Government spending variation and percentage of constrained agents: on the x-axis we have the variation in G as a percentage of GDP and on the y-axis we have the percentage of credit constrained agents in the period following the shock. The percentage of credit constrained agents is decreasing in the shock.

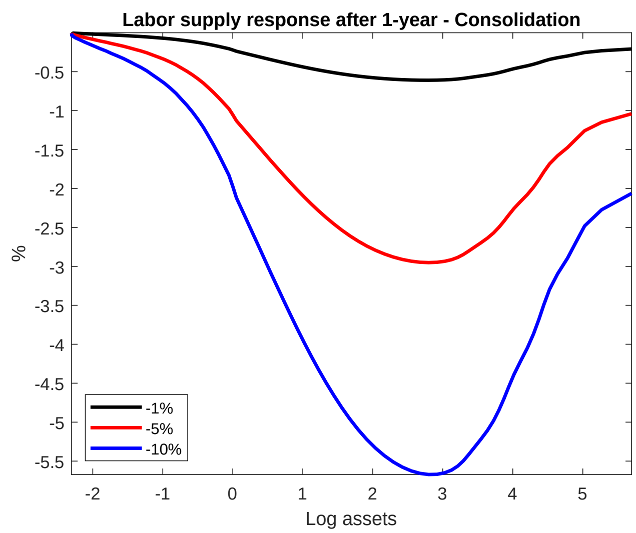

Figure 9: Government spending variation and relative labor supply response: this graph plots the labor supply response relative to the stationary steady state as a function of the initial level of assets for a permanent spending shock financed with deficits.

Notice that the labor supply of constrained and low-wealth agents responds by less than that of wealthier agents. 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 fiscal consolidations in the short run, regardless of their size. Wealthy agents perceive a more positive wealth effect from larger fiscal consolidation, hence reduce their labor supply by more. Larger consolidations move the

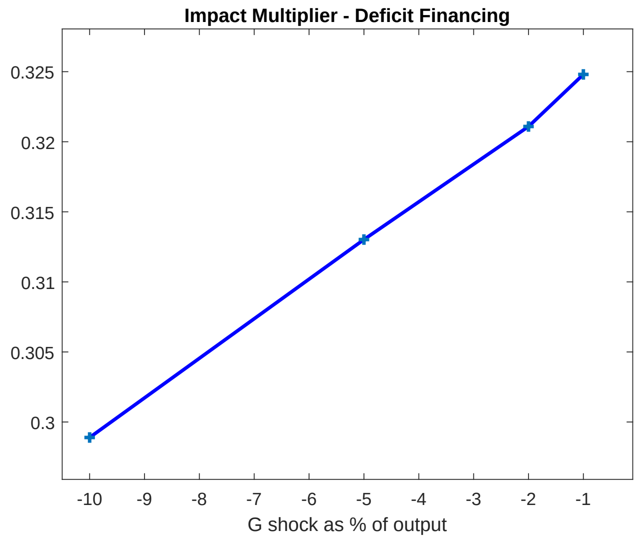

Figure 10: This figure plots the fiscal multiplier as a function of the size of the variation in G (as a % of GDP).

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. In other words, the elasticity of aggregate labor supply to fiscal shocks is decreasing in the size of the fiscal consolidation shock (increasing in the change in government spending). The same pattern translates to the fiscal multiplier as well.

The reason that the labor supply response by wealth is U-shaped is the life cycle. The very wealthiest agents are those who are close to retirement. For these agents it matters less if future wages will be higher because they will not be working in the future.

6.2 *Permanent Fiscal Shocks*

The mechanism that explains why the fiscal multiplier is increasing in the fiscal shock (decreasing in the size of the consolidation) is robust to other types of fiscal consolidation and policy regimes. We now consider the case of a permanent decrease in G financed with temporary changes in public debt, which is then paid for with permanent decreases in transfers, as these elicit the strongest (and more easily interpretable) effects.[15]

[15] To be more specific, the experiment is the following: G falls permanently starting at $t = 1$, taxes and transfers remain unchanged for the first 30 periods and public debt absorbs all variation, transfers then adjust for 50 periods in order to bring public debt back to its original level, and the economy then converges to its new SRCE.

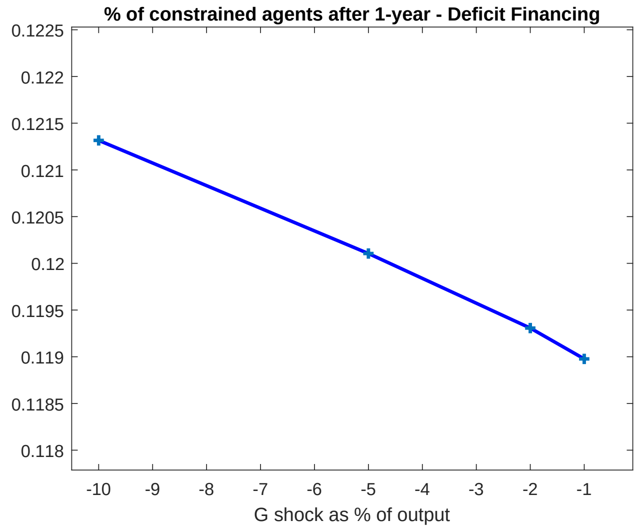

Figure 11: Government spending variation and percentage of constrained agents: on the x-axis we have the variation in G as a percentage of GDP and on the y-axis we have the percentage of credit constrained agents in the period following the shock. The percentage of credit constrained agents is decreasing in the shock.

Figure 10 plots the fiscal multiplier (on impact) as a function of the size of the change in G: again, the fiscal multiplier is monotonically increasing in G, being smaller for larger reductions of G. Figures 11 and 12 show that the same basic mechanism is at work: Figure 11 shows, again, that the mass of constrained agents in the short run is increasing in the size of the shock for the reasons explained before. This increase in future income induces agents to borrow more, which makes their labor supply less responsive to the shock itself. This reduces the relative movement in aggregate labor supply and hence the relative effect on GDP (the fiscal multiplier).

6.3 *Temporary Fiscal Shocks*

We now consider the case of temporary fiscal contractions: sequences of shocks to G that result in the same original SRCE in the long run. We show that the same basic logic applies to this case. Additionally, we consider two types of financing regimes: (i) deficit financing (consolidations), 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 during the entire transition.

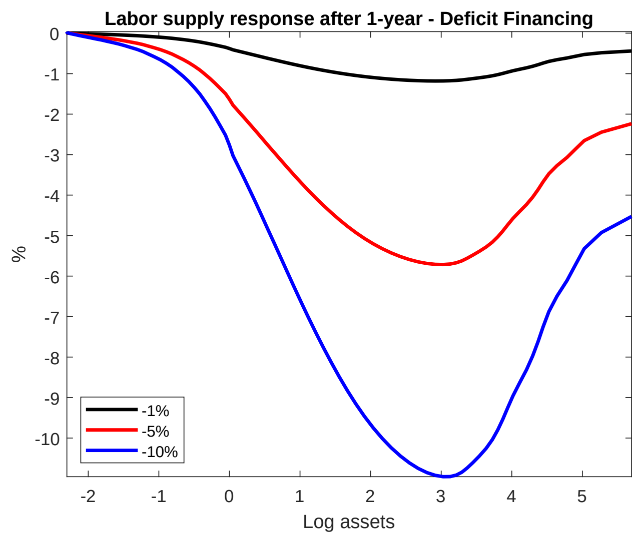

Figure 12: Government spending variation and relative labor supply response: this graph plots the labor supply response relative to the stationary steady state as a function of the initial level of assets for a permanent spending shock financed with deficits.

Path of the Shocks

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

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

where ρ_G is assumed to be 0.9 at a quarterly frequency, consistent with the estimates of Nakamura and Steinsson (2014) for military procurement spending.

Deficit Financing

Figure 13 shows the multiplier as a function of the size of the shock for the case of deficit financing: the overall pattern of monotonicity is unchanged. The main differences are the magnitudes: since the shock is no longer permanent, it no longer causes a permanent increase in wages, therefore leading to more-muted effects on lifetime income and resulting in smaller movements in aggregate labor supply on impact. The left panel plots the impact multipliers (measured the quarter after the shock), while the right panel plots the 1-year integral multipliers. The latter are necessarily smaller in magnitude, as the present discounted value of the fiscal shock becomes smaller as time passes, resulting in smaller movements of labor supply. The qualitative relationship between the multiplier and G is, however, preserved.

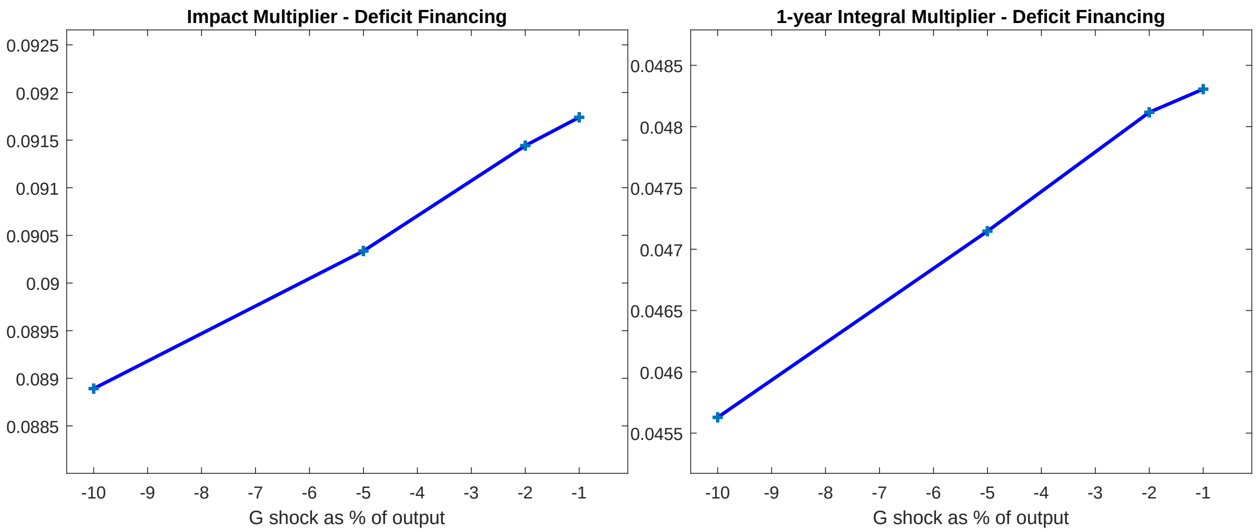

Figure 13: Fiscal multiplier as a function of ε_t^G (the initial impulse), deficit financing. The left panel presents impact multipliers (one quarter after the shock), the right panel presents the 1-year integral multipliers.

Figures 14 and 15 confirm that the basic mechanism still applies. Deficit-financed temporary fiscal consolidations cause an increase in the mass of constrained agents that is increasing in the *absolute* 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 larger the shock, the larger the mass of agents that are constrained and

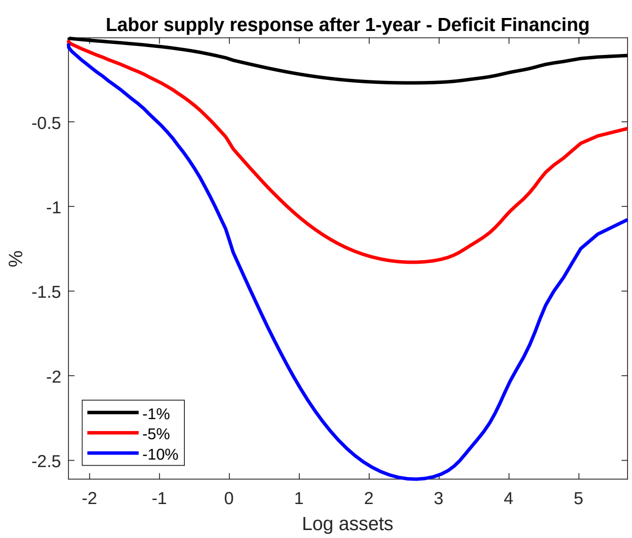

Figure 14: (Relative) labor supply response to different changes in G over the asset distribution.

the more muted the responses of the aggregate labor supply and GDP become.

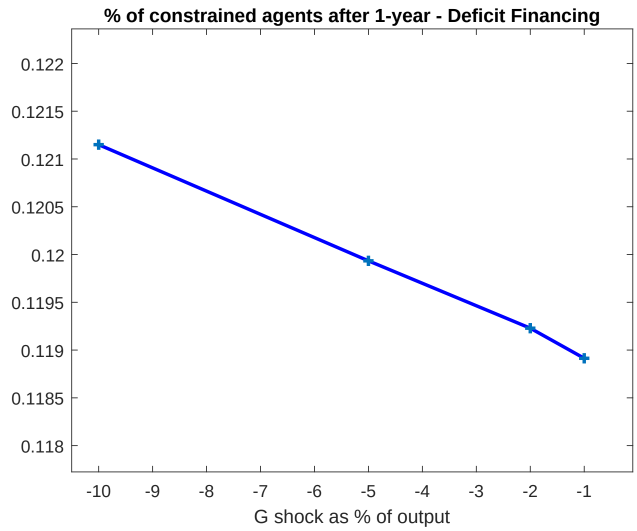

Figure 15: Percentage of agents at the borrowing constraint, deficit financing, one year after the shock, for different levels of the shock to G.

Balanced-Budget

Figure 16 plots the same measures of the fiscal multiplier for the case where the government runs a balanced budget and thus increases transfers when G decreases (so as to keep the level of debt constant). The qualitative results are identical, but the sizes of the multipliers are much larger with balanced budget. Again the nonlinearity arises because constrained agents have a lower EIS and because of shifts in the wealth distribution. This time around it is, however, the constrained agents that respond more strongly to the shock and a larger shock leads to less (not more) constrained agents. Balanced-budget interventions affect the income of agents contemporaneously, and constrained agents who are not forward looking consume more of this extra income today (they have a higher MPC) and enjoy more leisure today as well.

Figure 17 displays the labor supply responses by wealth and the size of the fiscal contraction. These labor supply responses behave in the manner that we would expect, with constrained agents greatly contracting their labor supply in response to a negative shock (increase in transfers). These labor supply responses can be combined with the movements in the distribution presented in Figure 18 to deliver our result: the mass

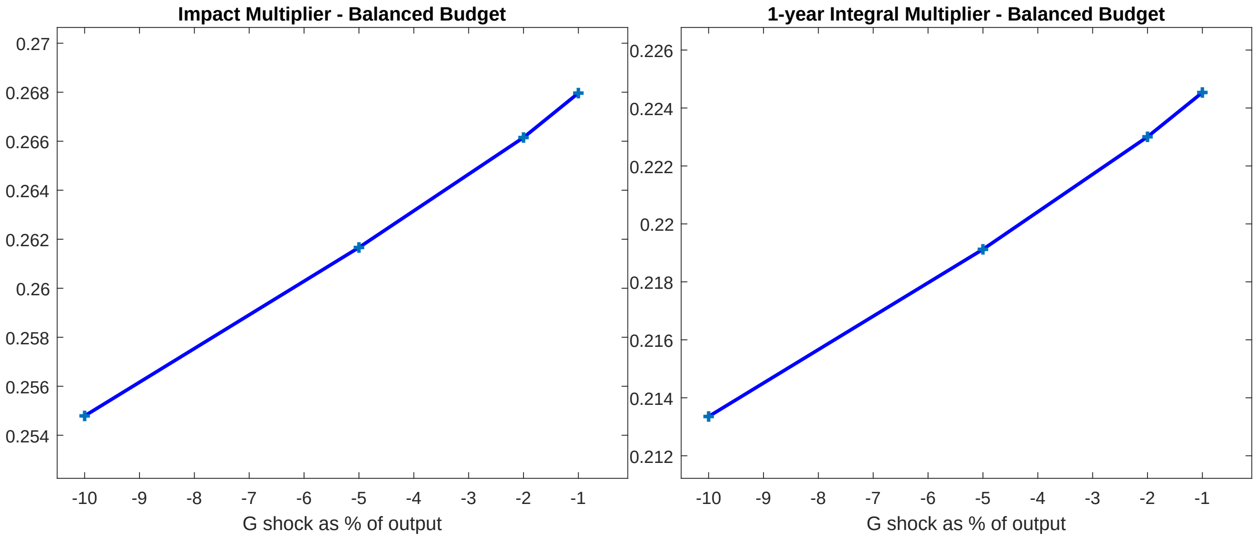

Figure 16: Fiscal multiplier as a function of ε_t^G (the initial impulse), balanced budget financing. The left panel presents impact multipliers (one quarter after the shock), the right panel presents the 1-year integral multipliers.

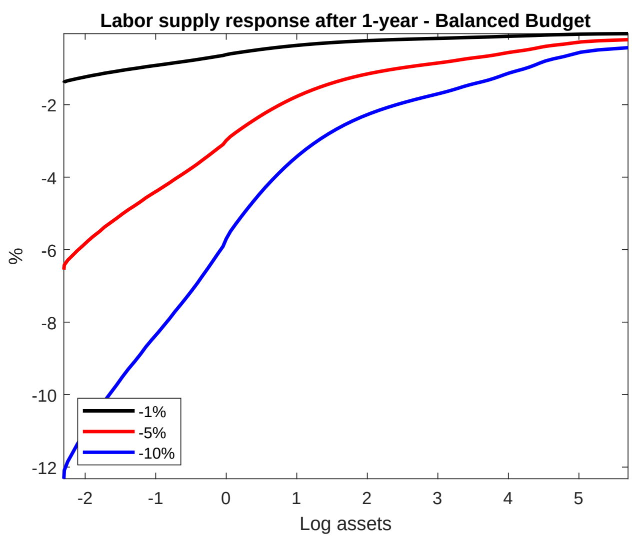

Figure 17: (Relative) labor supply response to different changes in G over the asset distribution, balanced budget.

of constrained agents is increasing in the size of the shock. A negative fiscal shock is financed by a contemporary increase in transfers: this moves agents away from the constraint that were close to it. In this case, agents at the constraint respond more in terms of the labor supply. So, once again, larger shocks are moving the mass of the distribution away from regions where the labor supply response is strongest. This means that the aggregate labor supply response is decreasing in the size of the shock, and so is the multiplier.

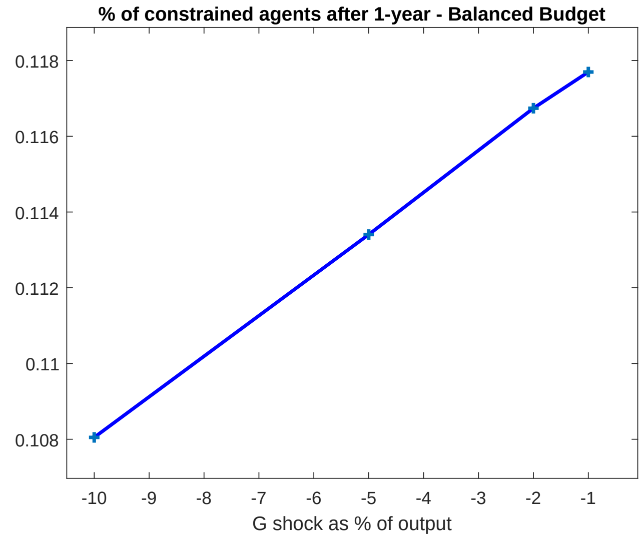

Figure 18: Percentage of agents at the borrowing constraint one year after the shock, balanced budget, for different levels of the shock to G.

Thus balanced-budget fiscal contractions deliver the same qualitative result but through a slightly different mechanism that still hinges on the relationship between movements in the wealth distribution and the EIS of labor across the wealth distribution. One should note that the multipliers in this class of models tend to be lower than what is typically found in empirical exercises. Our case is no exception, for both the level and degree of nonlinearity of multipliers. Our results reinforce the need for future research to focus on amplification mechanisms that can bridge such a gap, especially in models with capital and empirically plausible monetary rules.

7 Micro Evidence of 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 tax-financed shock shifts the wealth distribution to the right. 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 debt-financed shock, on the other hand, shifts the distribution to the left, 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 size of the shock (decreasing in the absolute size).

A number of papers have documented that the EIS is increasing in wealth, see Vissing-Jørgensen (2002) for example for the relationship between wealth and the EIS of consumption and, most notably in our context, Domeij and Floden (2006) for the relationship between wealth and the EIS of labor. We now 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, which contains data on wealth and hours worked, with the data on government spending shocks from Ramey and Zubairy (2018). 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. Let $G_t \equiv g_t + g_{t-1}$, the sum of these shocks.

Table (8) provide an overview of the dataset constructed. We report the aggregate statistics for the fiscal shocks, G_t, and the variations in debt, ΔB, as well as statistics for the microdata on the change in hours worked, $\Delta \ln$ hours worked, 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 for changes in hours worked is zero, with the top quartile having increases above 10% and the bottom one decreases above 13%. We also have in our sample changes in government debt of different sizes, with the median being 1% and the standard deviation above 4, which provides a good

Table 8: Descriptive Statistics

	p25	p50	p75	sd
$\Delta \ln$ hours worked	-0.13	0.00	0.10	(1.96)
ΔB	-0.17	1.05	2.39	(4.42)
G_t	-2.16	0.52	2.00	(4.98)
Net wealth	2,019	36,000	152,680	(512,553)

environment to test how different financing regimes affect the response of hours worked to fiscal shocks. To test this, we estimate 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. Note that fiscal shocks in this exercise can be positive or negative (recall that Section 6 only considers fiscal contractions).

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. 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. In Appendix F, we show that these results are robust to pooling all households in a single regression; interacting the fiscal shock and debt terms with household wealth levels and are also robust to different splits of the sample by net wealth.

Table 9: *G* shock, labor supply response, total 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	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

8 Conclusion

In this paper, we contribute to the analysis of the aggregate effects of government spending shocks by providing empirical evidence showing that larger negative shocks result in smaller effects on output. Using data on fiscal consolidation shocks across 15 OECD countries, we find that fiscal multipliers are increasing in the underlying fiscal shock (decreasing in the absolute size). A different methodology and dataset corroborates this relationship across different time periods and fiscal shocks.

After showing that a standard representative-agent DSGE model cannot replicate this empirical pattern, we develop a life cycle, overlapping-generations model with heterogeneous agents and uninsurable idiosyncratic income risk. We show that such a model calibrated to the US can reproduce the empirical response of output to fiscal shocks of different sizes. We show 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. This pattern is also robust to the financing regime: both tax-financed and deficit-financed fiscal shocks generate the same relationship between multipliers and underlying shocks, albeit via a slightly different mechanism.

Finally, we empirically validate the proposed mechanism by combining micro data from the PSID with identified policy shocks and showing that the response of labor supply is decreasing in wealth for tax-financed fiscal shocks but increasing in wealth for deficit-financed 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 a first step to understanding how the size of fiscal shocks can have different aggregate implications depending on the distributional features of the economy. The mechanism that we illustrate may appear quantitatively small, however, there may be other models where the same mechanism could generate larger effects, for example, if wealthier consumers can also be borrowing constrained as in Kaplan and Violante (2014). This would allow 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. In future research, and in the spirit of Kaplan et al. (2018), we intend to study in greater detail the effects of the empirical joint distribution between marginal propensities to work and consume for the sign and size dependence of fiscal policy shocks.

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A Additional empirical evidence

A.1 IMF Shocks

$$\Delta y_{i,t} = \alpha_i + \sum_{i=0}^{3} \beta_{1,t-i} e^u_{i,t-i} + \sum_{i=0}^{3} \beta_{2,t-i} (e^u_{i,t-i})^2 + \sum_{i=0}^{3} \beta_{3,t-i} e^a_{i,t-i} + \sum_{i=0}^{3} \beta_{4,t-i} (e^a_{i,t-i})^2 + \alpha_i + \gamma_t + \epsilon_{it} \tag{23}$$

Table 10: Nonlinear effects of fiscal unanticipated and announced consolidation shocks, including three lags of each shock.

	β_1	β_2	β_3	β_4
t	-0.645***	0.186***	-0.109	-0.051
	(0.164)	(0.042)	(0.232)	(0.083)
$t-1$	-1.176***	0.163***	-0.561**	0.193
	(0.183)	(0.043)	(0.237)	(0.122)
$t-2$	-0.240	0.102**	0.257	-0.092
	(0.183)	(0.043)	(0.225)	(0.149)
$t-3$	-0.803***	0.255***	-0.122	-0.152
	(0.189)	(0.054)	(0.220)	(0.168)
Observations		510		
Number of countries		15		

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

$$\begin{aligned} \Delta y_{i,t} =& \alpha_i + \sum_{i=0}^{3} \beta_{1,t-i} e^u_{i,t-i} + \sum_{i=0}^{3} \beta_{2,t-i} (e^u_{i,t-i})^2 + \sum_{i=0}^{3} \beta_{3,t-i} e^a_{i,t-i} \\ &+ \sum_{i=0}^{3} \beta_{4,t-i} (e^a_{i,t-i})^2 + \sum_{i=1}^{3} \delta_i e^a_{i,t+i,0} + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{24}$$

$$\begin{aligned} \Delta y_{i,t} =& \sum_{i=0}^{3} \beta_{1,t-i} e^u_{i,t} + \sum_{i=0}^{3} \beta_{2,t-i} (e^u_{i,t})^2 + \sum_{i=0}^{3} \beta_{3,t-i} e^a_{i,t} + \sum_{i=0}^{3} \beta_{4,t-i} (e^a_{i,t})^2 + \sum_{i=0}^{3} \beta_{5,t-i} r^u_{i,t} \\ &+ \sum_{i=0}^{3} \beta_{6,t-i} (r^u_{i,t})^2 + \sum_{i=0}^{3} \beta_{7,t-i} r^a_{i,t} + \sum_{i=0}^{3} \beta_{8,t-i} (r^a_{i,t})^2 + \sum_{i=1}^{3} \delta_i e^a_{i,t+i,0} + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{25}$$

Table 11: Non-linear effects of fiscal unanticipated and announced consolidation shocks, including three lags of each shock and controlling for announced shocks at t that will be implemented over the next three years.

	β_1	β_2	β_3	β_4
t	-0.473***	0.148***	-0.130	-0.087
	(0.156)	(0.041)	(0.221)	(0.084)
$t-1$	-0.848***	0.126***	-0.306	0.158
	(0.159)	(0.042)	(0.233)	(0.117)
$t-2$	-0.347**	0.151***	0.284	-0.134
	(0.160)	(0.042)	(0.227)	(0.137)
$t-3$	-0.631***	0.189***	-0.234	-0.083
	(0.172)	(0.054)	(0.222)	(0.152)
Observations	510			
Number of countries	15			

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

Table 12: Non-linear effects of fiscal unanticipated expenditure and revenue consolidation shocks, including three lags of each shock.

	β_1	β_2	β_5	β_6
t	-0.669*	0.178	-1.484***	0.731***
	(0.354)	(0.211)	(0.342)	(0.163)
$t-1$	-1.146***	0.452**	-1.592***	0.417**
	(0.365)	(0.212)	(0.339)	(0.172)
$t-2$	-0.081	0.204	1.022***	0.317*
	(0.355)	(0.204)	(0.321)	(0.177)
$t-3$	-1.600***	0.651***	-1.127***	0.626***
	(0.362)	(0.218)	(0.327)	(0.186)
Observations	510			
Number of countries	15			

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

Table 13: Non-linear effects of fiscal consolidation shocks.

VARIABLES	(1) Benchmark
β_1	-0.593***
	(0.106)
β_2	0.202***
	(0.033)
Observations	510
Number of countries	15

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

A.1.1 1991-2014 period including Germany

Table 14: Non-linear effects of fiscal unanticipated and announced consolidation shocks.

Variables	Benchmark
β_1	-0.302**
	(0.125)
β_2	0.141***
	(0.031)
β_3	-0.163
	(0.126)
β_4	-0.017
	(0.052)
Observations	510
Number of country1	15

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

Table 15: Non-linear effects of fiscal unanticipated expenditure and revenue consolidation shocks, including three lags of each shock.

	β_1	β_2	β_5	β_6
t	-0.177	-0.210	-1.347***	0.748***
	(0.183)	(0.128)	(0.190)	(0.094)
$t-1$	-1.203***	0.655***	-0.341	0.209
	(0.198)	(0.139)	(0.225)	(0.146)
$t-2$	-0.911***	0.024	-0.579***	0.911***
	(0.219)	(0.156)	(0.203)	(0.138)
$t-3$	-1.707***	0.875***	-0.043	0.356**
	(0.224)	(0.146)	(0.200)	(0.152)
Observations		510		
Number of countries		15		

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

A.2 US Historical Data

Table 16: Linear and quadratic coefficients for impact, 1, 2, 3 and 4-year horizons for both Blanchard and Perotti and news shocks in the same specification when considering the post Korean war sample and Barnichon and Matthes strategy to identify the BP shocks controlling for government debt.

	Positive shocks		Negative shocks	
	Linear	Quadratic	Linear	Quadratic
Impact	2.059	-1.210	-0.945	4.741
	(3.483)	(7.686)	(2.967)	(6.842)
1 year	-2.342	1.854	-1.623	1.614
	(7.291)	(4.059)	(4.816)	(2.647)
2 year	-9.793	2.962	-16.448	4.980
	(8.821)	(2.406)	(9.909)	(2.699)
3 year	-16.490	3.237	-32.428	6.318
	(8.836)	(1.586)	(15.973)	(2.934)
4 year	-16.626	2.479	-40.020	5.818
	(8.452)	(1.127)	(17.818)	(2.455)

Table 17: Linear and quadratic coefficients for impact, 1, 2, 3 and 4-year horizons for both Blanchard and Perotti and news shocks in the same specification when considering the entire sample from 1889 to 2015 and Barnichon and Matthes strategy to identify the BP shocks.

	Positive shocks		Negative shocks	
	Linear	Quadratic	Linear	Quadratic
Impact	0.699	-0.735	0.259	0.387
	(0.340)	(0.436)	(0.264)	(0.327)
1 year	1.429	-0.360	0.517	0.050
	(0.984)	(0.339)	(0.354)	(0.101)
2 year	1.903	-0.247	0.766	0.006
	(0.556)	(0.100)	(0.405)	(0.072)
3 year	1.602	-0.104	0.764	0.012
	(0.397)	(0.051)	(0.592)	(0.081)
4 year	1.720	-0.081	0.485	0.050
	(0.434)	(0.040)	(1.285)	(0.150)

Table 18: Linear and quadratic coefficients for impact, 1, 2, 3 and 4-year horizons for both Blanchard and Perotti and news shocks in the same specification when considering the post Korean war sample and Ramey's strategy to identify the BP shocks.

	Positive shocks		Negative shocks	
	Linear	Quadratic	Linear	Quadratic
Impact	7.316	-7.312	-4.198	6.229
	(8.311)	(9.847)	(2.818)	(3.150)
1 year	3.455	-1.505	-7.307	4.841
	(5.815)	(3.428)	(5.167)	(2.964)
2 year	-2.221	0.800	-14.119	4.287
	(4.886)	(1.392)	(11.812)	(3.458)
3 year	-5.694	1.198	-9.631	1.964
	(4.529)	(0.862)	(10.378)	(2.036)
4 year	-7.359	1.156	-9.446	1.470
	(5.137)	(0.724)	(12.143)	(1.775)

B Details of Representative agent Models

B.1 Real Business Cycle Model

Set-up and Equilibrium

The set-up follows closely that of Cooley and Prescott (1995). A representative household solves

$$\max_{\{C_t,N_t,K_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\nu}}{1+\nu} \right\}$$

s.t.

$$C_t + K_t + B_t = (1-\tau) w_t N_t + (1+r_t^k) K_{t-1} + R_t B_{t-1} - T_t$$

where C_t is consumption, N_t is hours worked, K_t is capital, w_t is the real wage, r_t^k is the rate of return on capital, B_t is holdings of public debt, R_t is the return on public debt, and T_t is a lump sum tax/transfer from the government. The optimality conditions for

Table 19: Linear and quadratic coefficients for impact, 1, 2, 3 and 4-year horizons for only the Blanchard and Perotti shocks when considering the post Korean war sample and Barnichon and Matthes strategy to identify the BP shocks.

	Positive shocks		Negative shocks	
	Linear	Quadratic	Linear	Quadratic
Impact	2.978	-4.507	4.588	-7.842
	(2.831)	(6.189)	(8.974)	(20.630)
1 year	-4.896	3.363	-1.465	1.486
	(5.542)	(3.150)	(10.781)	(6.143)
2 year	-13.307	4.034	-18.190	5.539
	(6.981)	(1.961)	(14.094)	(3.977)
3 year	-18.144	3.606	-30.246	6.017
	(6.997)	(1.294)	(13.100)	(2.490)
4 year	-18.567	2.771	-30.814	4.563
	(6.479)	(0.887)	(14.116)	(1.994)

the household are standard:

$$
\begin{aligned}
1 &= \mathbb{E}_t \beta \left(\frac{C_t}{C_{t+1}} \right)^{\sigma} (1 + r^k_{t+1}) \\
1 &= \mathbb{E}_t \beta \left(\frac{C_t}{C_{t+1}} \right)^{\sigma} R_{t+1} \\
\chi C_t^{\sigma} N_t^{\nu} &= w_t (1 - \tau).
\end{aligned}
$$

The representative firm hires capital and labor in spot markets:

$$
\max_{K_{t-1}, N_t} z_t K_{t-1}^{\alpha} N_t^{1-\alpha} - w_t N_t - (r_t^k + \delta) K_{t-1}.
$$

This yields the standard factor choice first-order conditions:

$$
\begin{aligned}
w_t &= (1 - \alpha) z_t \left(\frac{K_{t-1}}{N_t} \right)^{\alpha} \\
r_t^k + \delta &= \alpha z_t \left(\frac{N_t}{K_{t-1}} \right)^{1-\alpha}.
\end{aligned}
$$

Finally, the government's budget constraint is

$$
G_t + R_t B_{t-1} = B_t + \tau w_t N_t + T_t.
$$

Due to Ricardian equivalence, the specific fiscal rule is irrelevant for the value of the fiscal multiplier. The aggregate resource constraint is

$$
C_t + K_t + G_t = z_t K_{t-1}^{\alpha} N_t^{1-\alpha} + (1 - \delta) K_{t-1}.
$$

Calibration

We try to map the calibration of our baseline neoclassical heterogeneous agents model to the representative agent specification as closely as possible. The discount factor is chosen to yield an equilibrium real rate of 1.1% quarterly, $\beta = 0.9891$. Disutility of labor is $\chi = 8.1$, the coefficient of relative risk aversion is $\sigma = 1.2$, the Frisch elasticity of labor supply is $\nu = 1$, the depreciation rate is $\delta = 0.015$, and the capital share is $\alpha = 1/3$. G_{SS} and B_{SS} are chosen to be 20% and 43% of GDP at steady state, respectively.

B.2 New Keynesian model

We extend the basic RBC model with investment with the standard New Keynesian ingredients. We assume that production is now done by two sectors: a perfectly competitive final goods sector that produces final goods by aggregating a continuum of intermediate varieties in a Dixit-Stiglitz fashion. These firms solve a problem of the type

$$\max_{Y_t(i)} P_t \left[\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} \mathrm{d}i \right]^{\frac{\varepsilon}{\varepsilon-1}} - \int_0^1 P_t(i) Y_t(i) \mathrm{d}i.$$

This solution generates a demand curve for each variety:

$$Y_t(i) = \left[\frac{P_t(i)}{P_t} \right]^{-\varepsilon} Y_t$$

where ε is the elasticity of substitution across varieties. Intermediate goods producers are monopolistic competitors and hire labor and capital in spot markets. Let $P_t(i)$ denote the price of the intermediate variety sold by firm i. These firms face quadratic costs of adjusting their prices à la Rotemberg. The adjustment costs of price setting for firm i are given by

$$\Xi_t(i) = \frac{\xi}{2} Y_t \left[\frac{P_t(i)}{P_{t-1}(i)} \frac{1}{\Pi} - 1 \right]^2.$$

For simplicity, we assume that these costs scale with total output and it is free to adjust prices to keep track with trend inflation Π.

The firm's value in nominal terms is

$$P_t V_t[P_{t-1}(i); X_t] = \max_{P_t(i), Y_t(i), K_t(i), L_t(i)} P_t(i)Y_t(i) - P_t w_t L_t(i) - P_t(r_t + \delta)K_t(i) - P_t \Xi_t(i)$$
$$+ \mathbb{E}_t \frac{\Lambda_{t,t+1}}{\Pi_{t+1}} P_{t+1} V_{t+1}[P_t(i); X_{t+1}].$$

subject to the demand curve for variety i and the production function:

$$Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} Y_t$$
$$Y_t(i) = A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha}.$$

where $\frac{\Lambda_{t,t+1}}{\Pi_{t+1}}$ is the relevant stochastic discount factor for discounting the firm's payoffs, adjusted for inflation. The firm's problem can be split into a static cost-minimization component and a dynamic price-setting one. The static problem yields the standard condition for cost minimization:

$$\frac{w_t}{r_t + \delta} = \frac{1-\alpha}{\alpha} \frac{K_t(i)}{L_t(i)}. \tag{26}$$

Combining this condition with the production function allows us to express total costs as a function of output and factor prices only:

$$\begin{aligned} TC_t(i) &= w_t L_t(i) + (r_t + \delta)K_t(i) \\ &= w_t \frac{Y_t(i)}{A_t \left[\frac{w_t}{r_t+\delta}\frac{\alpha}{1-\alpha}\right]^{\alpha}} + (r_t + \delta)\frac{w_t}{r_t + \delta}\frac{\alpha}{1-\alpha}\frac{Y_t(i)}{A_t \left[\frac{w_t}{r_t+\delta}\frac{\alpha}{1-\alpha}\right]^{\alpha}} \\ &= \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t+\delta}{\alpha}\right)^{\alpha}\frac{Y_t(i)}{A_t}. \end{aligned}$$

This expression is now useful to solve the firm's dynamic problem, just in terms of price and output choices:

$$V_t[P_{t-1}(i);X_t] = \max_{P_t(i),Y_t(i)} \frac{P_t(i)}{P_t}Y_t(i) - TC_t(i) - \Xi_t(i) + \mathbb{E}_t\Lambda_{t,t+1}V_{t+1}[P_t(i);X_{t+1}]$$

subject to the demand function $Y_t(i) = \left[\frac{P_t(i)}{P_t}\right]^{-\varepsilon} Y_t$. We can furthermore replace $Y_t(i)$ for the demand function and solve for $P_t(i)$ only. The first-order condition is then

$$\begin{aligned} &-(\varepsilon-1)P_t(i)^{-\varepsilon}P_t^{\varepsilon-1}Y_t + \varepsilon MC_t P_t(i)^{-\varepsilon-1}P_t^{\varepsilon}Y_t - \xi Y_t\left[\frac{P_t(i)}{P_{t-1}(i)\Pi} - 1\right]\frac{1}{P_{t-1}(i)\Pi} \\ &+\mathbb{E}_t\Lambda_{t,t+1}\xi Y_{t+1}\left[\frac{P_{t+1}(i)}{P_t(i)\Pi} - 1\right]\frac{P_{t+1}(i)}{P_t(i)^2\Pi} = 0 \end{aligned}$$

where marginal costs are

$$MC_t \equiv \frac{\partial TC_t(i)}{\partial Y_t(i)} = \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t+\delta}{\alpha}\right)^{\alpha}\frac{1}{A_t}.$$

We now invoke the symmetric equilibrium assumption to obtain the New Keynesian Phillips curve:

$$[(\varepsilon-1) - \varepsilon MC_t] + \xi\left[\frac{\Pi_t}{\Pi} - 1\right]\frac{\Pi_t}{\Pi} = \mathbb{E}_t\Lambda_{t,t+1}\xi\frac{Y_{t+1}}{Y_t}\left[\frac{\Pi_{t+1}}{\Pi} - 1\right]\frac{\Pi_{t+1}}{\Pi}$$

The central bank sets the nominal interest using a Taylor rule:

$$R_t = R\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\Pi}\left(\frac{Y_t}{Y}\right)^{\phi_Y}$$

where R is some target rate and (Π, Y) are output and inflation benchmarks. The real interest rate is determined via the Fisher Equation:

$$1 + r_t = \frac{R_t}{\Pi_t}.$$

We assume that government debt pays a real return and that all intermediate firm profits are rebated to the representative household.

Calibration

We calibrate all common parameters to the same values as in the RBC model. For the New Keynesian parameters, we use standard values: menu costs are set so that firms change their prices once every three quarters, $\eta = 58.10$; the elasticity of substitution across varieties is $\varepsilon = 6$; and the Taylor rule parameters are $\rho_R = 0.80, \phi_\Pi = 1.50, \phi_Y = 0.5$.

B.3 Investment Adjustment Costs

We introduce quadratic adjustment costs of investment of the type

$$\frac{\Phi}{2} K_{t-1} \left(\frac{I_t}{K_{t-1}} - \delta \right)^2 .$$

This changes the first-order condition for K_t for the representative household:

$$1 + \Phi \left(\frac{K_t}{K_{t-1}} \right) = \beta \mathbb{E}_t \left(\frac{C_t}{C_{t+1}} \right)^{\sigma} \left\{ 1 + r^k_{t+1} + \frac{\Phi}{2} \left[\left(\frac{K_{t+1}}{K_t} \right)^2 - 1 \right] \right\} .$$

Calibration

We choose a standard quarterly value of $\Phi = 12.5$.

B.4 Infinite Capital Adjustment Costs

Figure 19 shows that in the extreme case of infinite adjustment costs, so that capital is fixed throughout the experiment, the level of the multiplier can be raised to match the data; but this is still not enough to generate any meaningful nonlinearities.

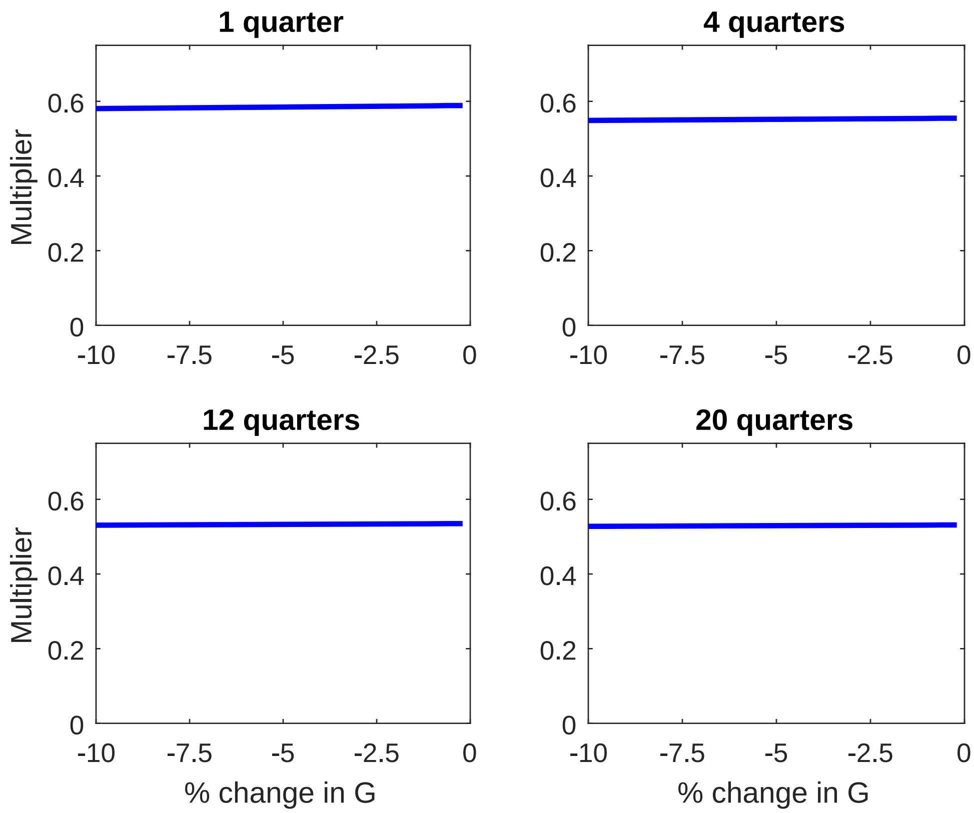

Figure 19: Representative agent, New Keynesian model with infinite adjustment costs of investment: fiscal multipliers as a function of the size of the variation in G, at different horizons.

C 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, $\{g_t, \Psi_t, G_t\}_{t=1}^{t=\infty}$; government debt, $\{B_t\}_{t=1}^{t=\infty}$; inheritance from the dead, $\{\Gamma_t\}_{t=1}^{t=\infty}$; 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 function $V(k, \beta, a, u, j)$ and the policy functions, $c(k, \beta, a, u, j)$, $k'(k, \beta, a, u, j)$, and $n(k, \beta, a, u, j)$ solve the consumers' optimization problem.

2. Markets clear:

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

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

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

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:

$$g_t \int d\Phi_t + G_t + r_t B_t = \int \left(\tau_k r_t (k_t + \Gamma_t) + \tau_c c_t + n_t \tau_l \left(\frac{n_t w_t(a,u,j)}{1 + \tilde{\tau}_{ss}} \right) \right) d\Phi_t + (B_{t+1} - B_t)$$

5. The social security system balances:

$$\Psi_t \int_{j \geq 65} d\Phi_t = \frac{\tilde{\tau}_{ss} + \tau_{ss}}{1 + \tilde{\tau}_{ss}} \left(\int_{j<65} n_t w_t d\Phi_t \right)$$

6. The assets of the dead are uniformly distributed among the living:

$$\Gamma_t \int \omega(j) d\Phi_t = \int (1 - \omega(j))\, k_t d\Phi_t$$

7. The distribution follows an aggregate law of motion:

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

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			
θ_0	0.788	Income tax level	Holter et al. (2019)
θ_1	0.137	Income tax progressivity	Holter et al. (2019)
τ_c	0.047	Consumption tax	Trabandt and Uhlig (2011)
τ_k	0.364	Capital tax	Trabandt and Uhlig (2011)
$\tilde{\tau}_{ss}$	0.077	Social security tax: employer	OECD 2001-2007
τ_{ss}	0.077	Social security tax: employee	OECD 2001-2007
Income profile parameters			
γ_1	0.265	Wage profile	LIS survey
γ_2	-0.005	Wage profile	LIS survey
γ_3	3.6E-05	Wage profile	LIS survey
Macro ratios			
B/Y	1.714	Debt-to-GDP ratio	U.S. Data
G/Y	0.15	Government spending-to-GDP ratio	Budget balance
g/Y	0.07	Transfers-to-GDP ratio	Hagedorn et al. (2016)

E Distribution

Permanent Shock: Consolidations

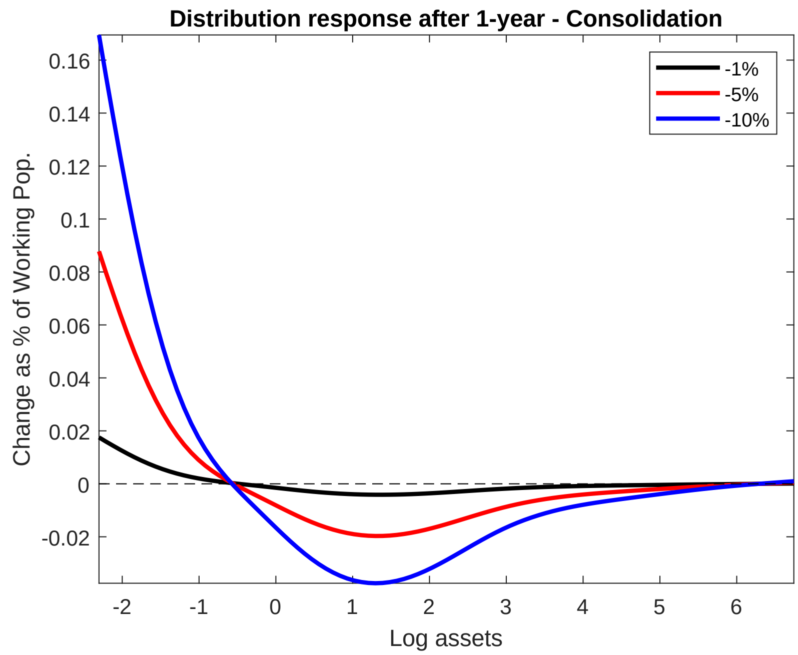

Figure 20: Changes in the distribution in response to a permanent change in G.

Permanent Shock: Deficit Financing

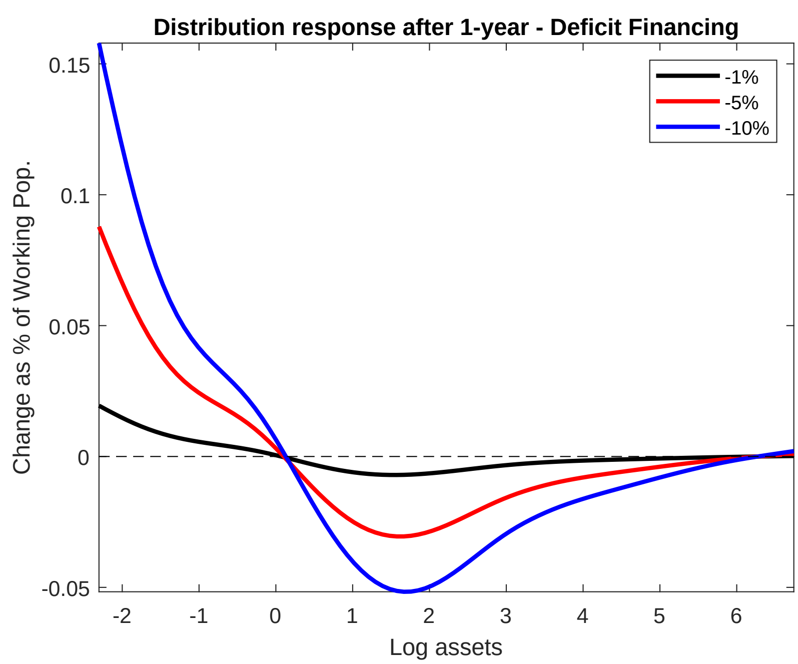

Figure 21: Changes in the distribution in response to a permanent change in G.

Temporary Shock: Deficit Financing

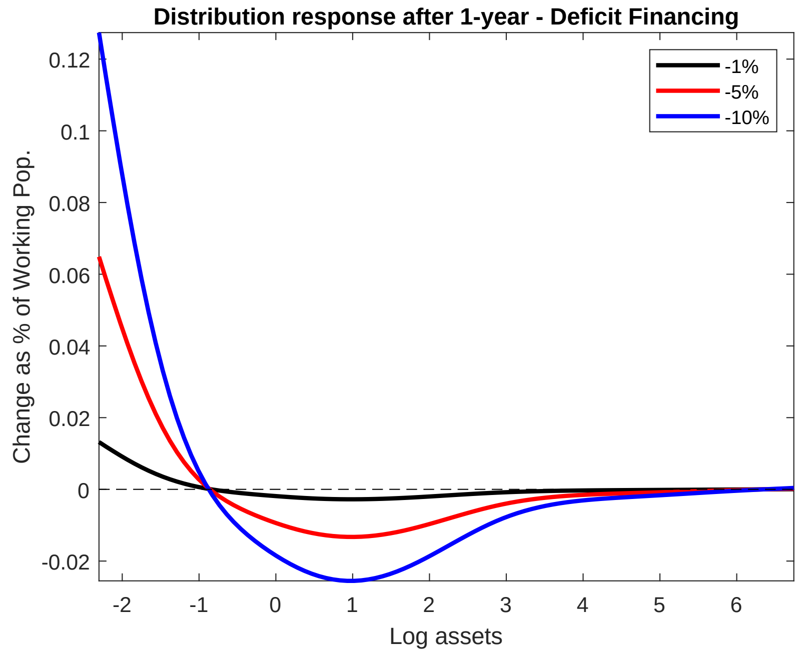

Figure 22: Changes in the distribution in response to a permanent change in G.

Temporary Shock: Balanced Budget

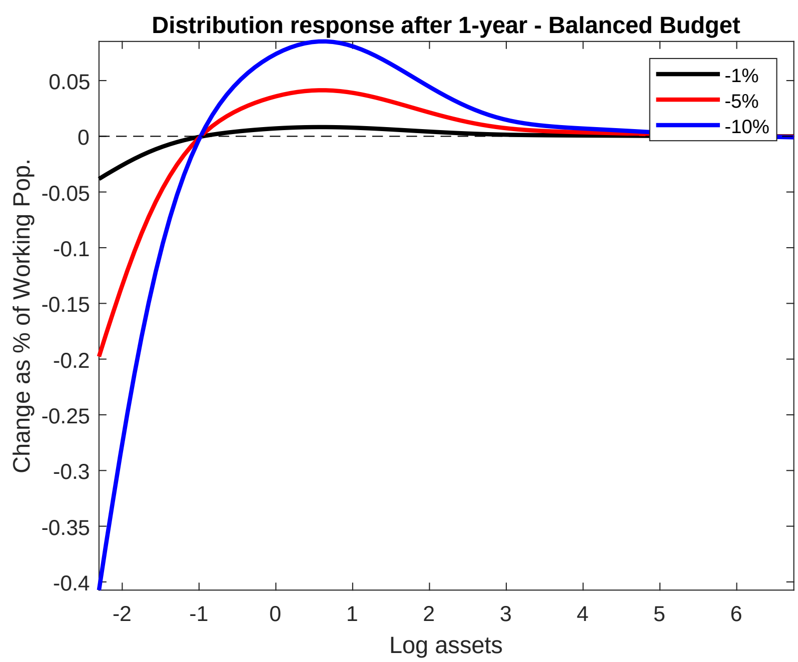

Figure 23: Changes in the distribution in response to a permanent change in G.

F Robustness: Micro Evidence of the Mechanism

Table 20: G shock, labor supply response and financing regime by total wealth. i^y is the annual income of the household.

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

$$\begin{aligned} \ln h_{it} =& \beta_1 G_t + \beta_2 a_t + \beta_3 \Delta B_t + \beta_4 a_t G_t + \beta_5 \Delta B_t G_t + \beta_6 a_t \Delta B_t \\ &+ \beta_7 a_t \Delta B_t G_t + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{27}$$

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

Table 21: G shock, labor supply response, total wealth and financing regime

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

response. This would be consistent with $\beta_5 < 0$.

Results in Table 21 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%.