The Nonlinear Effects of Fiscal Policy*

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Abstract

We argue that the fiscal multiplier of government purchases is *increasing* in the spending shock, in contrast to what is assumed in most of the literature. The fiscal multiplier is largest for large positive government spending shocks and smallest for large contractions in government spending. We empirically document this fact using aggregate data for the US. We find that a neoclassical, life-cycle, incomplete markets model calibrated to match key features of the US 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 size of the fiscal shock, and this holds regardless of whether shocks are deficit- or balanced-budget financed (albeit through different mechanisms). We find evidence of our mechanism in micro-data 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, this movement of fiscal expansions was promptly followed by a period of austerity measures aimed at reducing the size of the resulting high levels of government debt. 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, stage of development, among others.[1]

However, most of the literature treats the effects of government interventions as being *linear*: contractionary and expansionary fiscal policies are assumed to have the same (symmetric) effects, and small and large shocks are assumed to have the same (linear) effects.[2] In this paper, we argue that fiscal multipliers from government spending shocks are *increasing* in the shock. Larger expansions in government spending are associated with larger multipliers, and the converse is also true. We verify this fact empirically, and show that it holds true in a calibrated neoclassical, life-cycle model with incomplete markets and heterogeneous agents.

We begin our analysis by empirically documenting the sign and size dependence of fiscal multipliers in the US, which we show to be increasing in the government expenditure shock. To arrive at this conclusion, we utilize two different datasets and empirical methodologies, based on two leading empirical papers in the area. First, we focus on 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

[1] See for example Auerbach and Gorodnichenko (2012), Ramey and Zubairy (2018), Brinca et al. (2016), Brinca et al. (2017), Hagedorn et al. (2016), Krueger et al. (2016), Basso and Rachedi (2017), Ferriere and Navarro (2014), Ilzetzki et al. (2013), 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 contractions (i.e. tax or expenditure based) can have nonlinear effects.

in military spending as in Ramey (2011b) and the identification assumptions of Blanchard and Perotti (2002). Using Jordà (2005)'s projection method and pooling observations across high and low unemployment periods, the authors find no evidence of a state dependent fiscal multiplier. We instead pool observations across periods with negative and positive fiscal shocks, and find evidence that the fiscal multiplier is quantitatively and statistically different across negative and positive shocks: the 1-year (cumulative) multiplier for positive shocks is 0.56, and 0.20 for negative shocks.

As robustness, we test the external validity of our results by using the fiscal consolidation episodes dataset from Alesina et al. (2015a), which comprises 16 OECD countries over the 1981-2014 period. Using a narrative approach based on Romer and Romer (2010) to identify exogenous fiscal consolidations, we find fiscal multipliers to be decreasing in the size of the consolidation: which is to say that fiscal multipliers are smaller for larger decreases in government spending.

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. (2017). 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 labor supply elasticity of these agents is lower and their work hours are less responsive to contemporaneous and future changes in aggregate variables such as factor prices.

We study how the economy responds to different changes in government spending, ranging from large fiscal contractions to large fiscal expansions. An increase in government spending, financed by debt, generates a negative future income effect, as future taxes need to be raised. This effect is compounded by the crowding out of private capital: as the stock of capital falls, real wages also fall, reducing expected lifetime income (especially for agents with lower savings). This negative shock to future income induces increased savings today, thus reducing the mass of agents at the borrowing constraint. Since unconstrained agents have a higher labor supply elasticity, aggregate labor supply expands more, leading to larger fiscal multipliers. Conversely, government spending contractions reduce precautionary motives and raise the mass of agents who are the constraint. These agents' labor supply responds less to the shock, leading to smaller fiscal multipliers. The larger shock, the larger the overall change in the distribution of wealth, which explains the size dependence.[3]

We show that balanced-budget fiscal expansions and contractions result in the same pattern of sign and size dependence, but via a different (but related) mechanism. Consider first the case of a fiscal expansion that is financed by a contemporary increase in taxes (so that debt is constant): the contemporary negative income effect elicits a much larger labor supply response by constrained agents. This negative income effect also brings to the constraint many agents who were close to it. This leftwards shift therefore increases the aggregate labor supply response, resulting in a larger response of output and fiscal multiplier. Conversely, a balance-budget fiscal contraction results in a contemporary decrease in taxes that moves agents away from the constraint. Since the agents who would reduce their labor supply the most are those at the constraint, this reduces the overall response of labor supply, leading to a smaller 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 income shocks depends on wealth and how this relationship depends on the timing of the shock. We establish that for current income shocks, wealth-poor agents display a stronger labor supply response, with the opposite being true for future income shocks. This validates the model mechanics regarding the two different types of financing: for shocks that are financed through contemporary taxes/transfers, the labor supply response is strongest for poorer agents, while wealthier agents respond the most to fiscal shocks that

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

are financed through deficits.

The rest of the paper is organized as follows: Section 2 presents the empirical results on the aggregate non-linearity of fiscal multipliers. Section 3 argues that standard representative agent models can match the levels, but not the nonlinear patterns that we find in the data. Section 4 introduces the main quantitative model, and Section 5 describes the our calibration strategy. Section 7 presents the results from the quantitative model and in Section 8 we empirically test and validate the mechanisms using the PSID data. Section 9 concludes.

2 Empirical Analysis

In this section, we use aggregate time-series data to study the sign and size dependence of fiscal multipliers. The main analysis employs the historical dataset of Ramey and Zubairy (2018) for the US and the Local Projection Method of Jordà (2005) to show that a positive government spending shock yields larger multipliers than a negative shock of the same magnitude. We also show that the fiscal multiplier depends not only on the sign but also on the size of the shock. Finally, we argue for the external validity of our findings by showing that they are also present in the Alesina et al. (2015a) dataset of consolidation episodes in OECD countries.

2.1 US historical data

To compare the multipliers across positive and negative fiscal shocks, a sufficiently large span of observations for both types of shocks is needed. Using US quarterly historical data addresses this problem, as it provides us with enough observations for both shocks.[4] Additionally, historical 20th century data spans many periods of expansion and recession, as well as different regimes for fiscal and monetary policy.

We employ 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

[4]255 observations for positive fiscal shocks and 249 observations for negative ones.

includes real GDP, GDP deflator, government purchases, federal government receipts, population, unemployment rate, interest rates and defense news.

To identify exogenous government spending shocks, Ramey and Zubairy (2018) use two different approaches: (i) the defense news series proposed by Ramey (2011b), which consists of exogenous variations in government spending linked to political and military events that are identified using a narrative approach, and that are plausibly independent from the state of the economy; and (ii) shocks based on the identification hypothesis of Blanchard and Perotti (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 are more relevant in the long run (as news happen several quarters before the spending actually occurs).

Figure 1 plots the time series for both shocks. Large variations in the 1910s, 1940s, and 1950s reflect defense spending with the two World Wars 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.

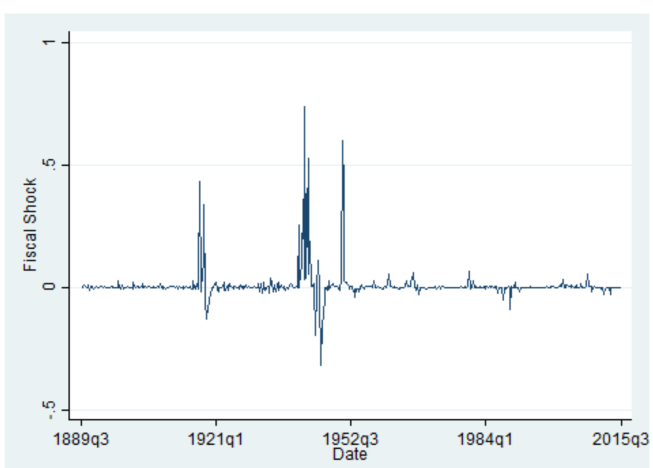

Figure 1: Fiscal shock as a percentage of real GDP

It is instructive to start with a non-parametric approach and look for signs of a nonlinear relationship between output and government spending in the data. Figure 2 shows the 1 quarter cumulative output response in the y-axis, and 1 quarter cumulative government spending in the x-axis, both normalized by trend GDP. The red line is a fitted quadratic polynomial: this line is increasing, which implies that the fiscal multiplier is *positive*; moreover, the line is *convex*, suggesting that output increases by relatively more for larger shocks to government spending. This convexity arises from a positive quadratic term, which is both quantitatively large (0.49), but also statistically significant at the 1% level.[5]

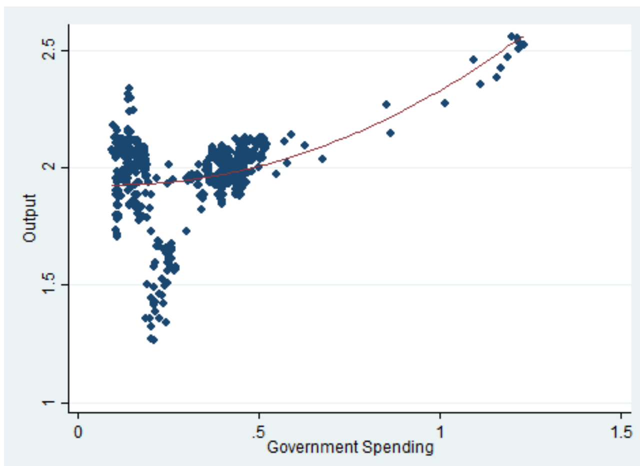

Figure 2: 1 quarter cumulative real output in the y-axis and 1 quarter cumulative real government spending in the x-axis, both as percentage of trend GDP. The red line represents the quadratic fitted polynomial between the two variables. The correlation between output and the first order term of government spending is 0.44 (p-value 0.00) and with the second order term of government spending is 0.49 (p-value 0.00).

2.1.1 Testing for Sign-Dependence

To formally test for potential asymmetries between positive and negative fiscal shocks, we use the same methodology as Ramey and Zubairy (2018), which is based on the Local Projection Method of Jordà (2005). This consists of estimating the following equation for different time horizons h

[5] Appendix A.1 presents the same figure at the 4 and 8 quarter horizons.

$$y_{t+h} = I_{t-1}[\alpha_{\text{pos},h} + \Psi_{\text{pos},h}(L)z_{t-1} + \beta_{\text{pos},h}\text{shock}_t]$$
$$+(1 - I_{t-1})[\alpha_{\text{neg},h} + \Psi_{\text{neg},h}(L)z_{t-1} + \beta_{\text{neg},h}\text{shock}_t] + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, ... \tag{1}$$

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 news variable to control for serial correlation. $\Psi_h(L)$ is a polynomial of order 4 in the lag operator and shock_t is the exogenous shock, which consists of the defense news variable and the Blanchard-Perotti spending shock. I is a dummy variable that is equal to one when $\text{shock}_t \geq 0$.

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.[6] 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,

$$\sum_{j=0}^{h} y_{t+j} = I_{t-1}[\delta_{\text{pos},h} + \phi_{\text{pos},h}(L)z_{t-1} + m_{\text{pos},h}\sum_{j=0}^{h} g_{t+j}]+ \tag{2}$$
$$(1 - I_{t-1})[\delta_{\text{neg},h} + \phi_{\text{neg},h}(L)z_{t-1} + m_{\text{neg},h}\sum_{j=0}^{h} g_{t+j}] + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, ...$$

where shock_t is used as an instrument to $\sum_{j=0}^{h} g_{t+j}$, which is the sum of the government spending from t to $t + h$. This way, $m_{\text{pos},h}$ and $m_{\text{neg},h}$ can be directly interpreted as the cumulative multiplier at horizon h for either regime (positive or negative shocks).

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

Estimation results for specification (2) are presented in Table 1; these results show that the two multipliers are quantitatively different, with the multiplier for positive fiscal shocks larger than the multiplier for negative shocks. Ramey and Zubairy (2018) argue that the Blanchard-Perotti shocks may be anticipated, and this can raise concerns of instrument relevance. To test if the multipliers are also statistically different across positive and negative fiscal shocks, we use Anderson et al. (1949) (AR) statistics, which is robust to weak instruments. As it is possible to see in the last column in table 1 the instruments are not only quantitatively but also statistically different.[7]

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	0.20	0.13	0.44	0.14
	(0.17)	(0.33)	(0.14)	
1 year cumulative multiplier	0.27	0.20	0.56	0.13
	(0.14)	(0.26)	(0.17)	
2 year cumulative multiplier	0.45	0.30	0.66	0.06
	(0.10)	(0.24)	(0.11)	
3 year cumulative multiplier	0.56	0.55	0.72	0.05
	(0.09)	(0.16)	(0.09)	
4 year cumulative multiplier	0.58	0.68	0.73	0.07
	(0.09)	(0.12)	(0.08)	

Table 1: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks. The AR statistic measures whether the negative and positive shock multipliers are statistically different.

2.1.2 Testing for Size-Dependence

The previous exercise shows that positive fiscal spending shocks generate larger output effects than negative ones, but is not sufficient to say anything about the effects of shocks with the same sign but different sizes. We proceed to investigate the size-dependence of the fiscal

[7] Barnichon and Matthes (2017) present results opposite to ours, with their estimates of the multiplier being larger for contractions than for expansions of government spending. This is related to different choices of methodology and instruments. First, Barnichon and Matthes (2017) do not combine defense news and Blanchard-Perotti shocks. As Ramey and Zubairy (2018) argue, the defense news variable fails to capture short run dynamics, while the Blanchard-Perotti identification hypothesis fails to capture the long run dynamics, and so it becomes important to use both instruments at the same time to accurately capture both short and long run dynamics. Second, when using the Blanchard-Perotti identification hypothesis, the authors deviate from what Ramey and Zubairy (2018) propose, by first estimating a VAR to identify the shock and then including the shock in the Local Projection regression, while also including lagged control variables. As Ramey and Zubairy (2018) highlight, the Blanchard-Perotti shock is identified as the part of government expenditure not explained by lagged control variables. Including these lagged control variables in a regression with current government spending is enough to correctly identify the Blanchard-Perotti shock.

multiplier. We start by extending specification (2) with quadratic terms for both fiscal expansions and contractions

$$\sum_{j=0}^{h} y_{t+j} = I_{t-1}\left[\delta_{\text{pos},h} + \phi_{\text{pos},h}(L) z_{t-1} + m_{\text{pos},h}\sum_{j=0}^{h} g_{t+j} + m_{2\text{pos},h}\left(\sum_{j=0}^{h} g_{t+j}\right)^2\right] + \tag{3}$$

$$(1 - I_{t-1})\left[\delta_{\text{neg},h} + \phi_{\text{neg},h}(L) z_{t-1} + m_{\text{neg},h}\sum_{j=0}^{h} g_{t+j} + m_{2\text{neg},h}\left(\sum_{j=0}^{h} g_{t+j}\right)^2\right] + \epsilon_{t+h}, \text{ for } h = 0, 1, 2, \ldots$$

If the effects of fiscal policy are size-dependent, coefficients $m_{2\text{pos},h}$ and $m_{2\text{neg},h}$ should be statistically different from zero. Table 2 reports the estimation results: in the short run, nonlinearities are stronger for fiscal expansions than for contractions, with the quadratic coefficient for fiscal expansions being statistically different from zero and indicating that the fiscal multiplier is largest for large expansions.

	$m_{\text{pos},h}$	$m_{\text{pos},h}$	$m_{\text{neg},h}$	$m_{2\text{neg},h}$
Impact	0.33	0.17	0.15	0.03
	(0.12)	(0.07)	(0.33)	(0.07)
1 year	0.27	0.14	0.32	-0.02
	(0.12)	(0.07)	(0.32)	(0.06)
2 years	0.08	0.13	0.32	-0.01
	(0.31)	(0.08)	(0.40)	(0.08)
3 years	-0.65	0.18	-0.44	0.17
	(0.63)	(0.09)	(0.76)	(0.13)
4 years	-1.36	0.21	-1.31	0.24
	(0.91)	(0.09)	(0.93)	(0.11)

Table 2: Linear and quadratic terms for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks.

Note that the inclusion of these quadratic terms means that $m_{i,h}$ can no longer be interpreted as a multiplier. Due to size dependence, there is no longer such thing as "the" fiscal multiplier. An estimate for the marginal fiscal multiplier can be obtained as $\hat{m}_{i,h} + 2 \times \hat{m}_{2i,h} \times \sum_{j=0}^{h} g_{t+j}$ for $i = \text{pos}, \text{neg}$. Table 3 reports the multipliers for the average fiscal shock, as well as the average $\sum_{j=0}^{h} g_{t+j}$ in a fiscal expansion plus one standard deviation, and the average $\sum_{j=0}^{h} g_{t+j}$ in a fiscal contraction minus one standard deviation. These estimated multipliers are, once again, larger for expansions than for contractions at short horizons. In the context of a fiscal expansion, raising $\sum_{j=0}^{h} g_{t+j}$ by one standard deviation, increases the cumulative multiplier by 19% on impact. During a fiscal contraction, reducing $\sum_{j=0}^{h} g_{t+j}$ by one standard deviation only decreases the multiplier by 7%, on average.

	Average negative - st.dev.	Average negative	Average positive	Average positive + st.dev.
Impact mult.	0.15	0.16	0.40	0.47
1 year cum. mult.	0.32	0.30	0.40	0.57
2 year cum. mult.	0.32	0.31	0.29	0.57
3 year cum. mult.	-0.50	-0.09	-0.22	0.32
4 year cum. mult.	-1.45	-0.08	-0.71	0.07

Table 3: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks.

An alternative way to illustrate this size-dependence is to calculate the fiscal multiplier for each observation in our sample, using the estimates in Table 2, and plot these estimates against the size of the respective fiscal shocks. This is done in Figure 3: the asymmetry is very clear, as multiplier estimates for negative spending shocks are much lower than those associated with positive spending shocks (about 0.2 vs. 0.5 on average). Size dependence has an interesting pattern that reflects our earlier estimates: the slope is very small (but positive) for negative spending shocks, and much steeper for positive ones. The range of multipliers for positive shocks is $[0.26, 0.75]$, and $[0.16, 0.22]$ for negative ones.[8]

An alternative test of size dependence involves including of a quadratic term in a linear specification similar to equation (2), without pooling observations across periods of fiscal expansions and contractions. The link between the sign and the size of the shock and the fiscal multiplier holds under this alternative approach. Results are robust to pooling observations above and below the median positive or the median negative shocks, with the fiscal multiplier being largest for large expansions and smallest for large contractions. All these robustness checks are reported in Appendix A.1, in Tables 14 and 15.

[8] Figures 19 - 21 in Appendix A.1 show the same relation between fiscal shocks and multipliers at the 1, 2, and 3-year horizons. While for those horizons the multiplier is always increasing with the shock, independently of the shock being positive of negative, the slope is always smaller for negative shocks.

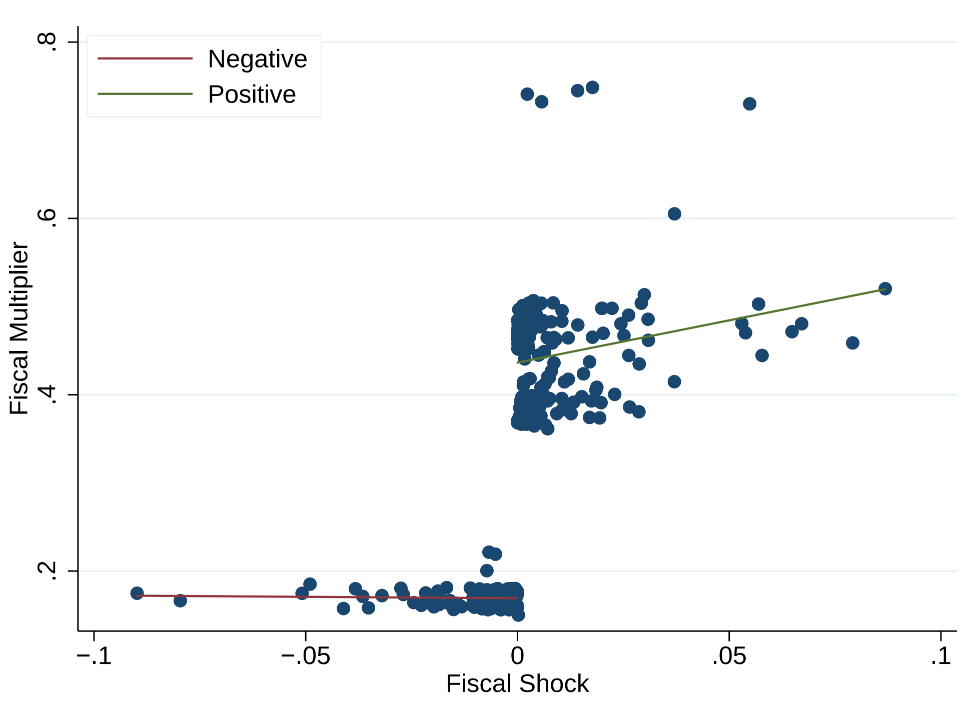

Figure 3: Impact multiplier vs Fiscal shock: On the y-axis we have the impact multiplier and on the x-axis we have the size of the fiscal shock. For negative shocks the correlation is -0.04 (P-value 0.56) while for positive shocks is 0.20 (P-value 0.02).

2.1.3 Robustness and Other Tests

Our results may be sensitive to the choice of specification and sample. To assuage these concerns, we perform several robustness checks and the results results can be found in Appendix A.1. In particular, we show that our results hold even when excluding World War II, as well as considering only a post 1947 sample. We also show that our results are robust including additional controls, or the number of lags for the controls.

We also test for nonlinear effects of fiscal policy on other macroeconomic variables: consumption and investment. There is a large literature on the effects of fiscal shocks on different components of private expenditure, i.e. Ramey (2012), Blanchard and Perotti (2002), Ramey (2011a). While there is a consensus in the literature that government spending crowds out investment, the effects on consumption are less consensual. We use the Federal Reserve Economic Data (FRED) series for nominal consumption and investment, starting in 1947 and estimate equation (3) with private consumption and private investment as left-hand side variables. Results for consumption and investment (Tables 18 and 20 in Appendix A.1 respectively) indicate that, at all horizons, the multipliers are consistently larger for fiscal expansions than contractions and that these multipliers are largest for large expansions and smallest for large contractions. Notice also that while the multiplier for consumption is positive on impact, becoming negative at the end of year 1, the multiplier for investment is always negative, which is consistent with the consensus on the literature.

We also test whether our results hold in a specification where we do not pool observations across fiscal expansion and contraction episodes, and simply include a quadratic term. These results (Tables 19 and 21 in Appendix A.1) are in line with the previous ones: the consumption multiplier is positive on impact and then becomes negative and investment multiplier always negative, with multipliers being increasing on the size of the shock.

Finally, we test if our results hold for different thresholds for pooling observations. Results from pooling observations across positive and negative shocks show the multiplier to be increasing on the size of the shock. This would suggest that, independently of the threshold chosen for polling observations, we should find multipliers larger for shocks above the threshold. Figures 22 and 23 show the results hold across different thresholds used, with larger shocks yielding larger multipliers.

2.2 IMF shocks

In this section we provide supporting evidence that the nonlinearities of the fiscal multiplier are not only related to the sign of the shock but also to the absolute variation. In particular, we show that larger fiscal consolidations (i.e., more negative spending shocks) are associated with smaller multipliers. This is shown in the context of the Alesina et al. (2015a) annual dataset of fiscal consolidation episodes, which includes 16 OECD countries and ranges from 1981 to 2014.[9]

[9] The dataset includes Australia, Austria, Belgium, Canada, Germany, Denmark, Spain, Finland, France, Japan, United Kingdom, US, Ireland, Italy, Portugal and Sweden.

Alesina et al. (2015a) expand the original dataset of Devries et al. (2011) with exogenous fiscal consolidations episodes, known as IMF shocks. Devries 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 Devries et al. (2011), Alesina et al. (2015a) use the methodological innovation introduced by Alesina et al. (2015b), who alert for the fact that a fiscal adjustment is rather a multi-year plan than an isolated change and consequently it results in policies that are both unexpected and others 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, and expected revenue changes stemming from tax code revisions. Moreover, fiscal consolidations that were not implemented are not included in the dataset and so all fiscal consolidation episodes that are included are assumed to be fully credible.

We estimate the following specification,

$$\Delta y_{i,t} = \alpha_i + \beta_1 e^u_{i,t} + \beta_2 (e^u_{i,t})^2 + \beta_3 e^a_{i,t} + \beta_4 (e^a_{i,t})^2 \tag{4}$$

where $\Delta y_{i,t}$ is the output growth rate in country i and year t, $e^u_{i,t}$ is the unanticipated fiscal consolidation shock and $e^a_{i,t}$ is the anticipated fiscal consolidation shock. We include squared terms to capture the nonlinear effects of fiscal shocks. We follow Alesina et al. (2015a) and estimate the equation using Seemingly Unrelated Regressions (SUR), imposing cross-country restrictions on the β coefficients.

Results are presented in Table 4 and validate our hypothesis that the nonlinear effects of fiscal shocks are not only related to the sign of the shock, but also to the size. The coefficients associated with the linear terms of both announced and unexpected fiscal consolidations are negative, indicating that fiscal consolidations lead to a decrease in output. However, the coefficients of interest, β_2 and β_4, have a positive sign, meaning that the larger the consolidation, the smaller is the effect on output and, hence, the fiscal multiplier (even though only the coefficient associated with the squared term of announced fiscal consolidations is statistically significant). This coefficient is not only statistically significant but also economically meaningful, as an increase in one standard deviation of announced consolidations leads to a decrease of 80% in the fiscal multiplier.

Variables	Benchmark
β_1	-0.004**
	(0.002)
β_2	0.001
	(0.001)
β_3	-0.024***
	(0.002)
β_4	0.007***
	(0.001)
*** p<0.01, ** p<0.05, * p<0.1	

Table 4: Non-linear effects of fiscal consolidation shocks.

3 Nonlinear Effects of Fiscal Policy in Representative Agent Environments

We are interested in understanding what mechanisms generate the nonlinearities and asymmetries 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 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 present 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

[10]The main deviations from the cited benchmark are: separable preferences in consumption and leisure, and no trend growth for TFP.

given horizon h,

$$\mathcal{M}_h = \frac{\sum_{i=0}^{h} \prod_{j=0}^{i} R_j^{-1}(Y_i - Y_{SS})}{\sum_{i=0}^{h} \prod_{j=0}^{i} R_j^{-1}(G_i - G_{SS})} \tag{5}$$

for $h = 0$, this becomes the traditional definition of the multiplier measured at impact.

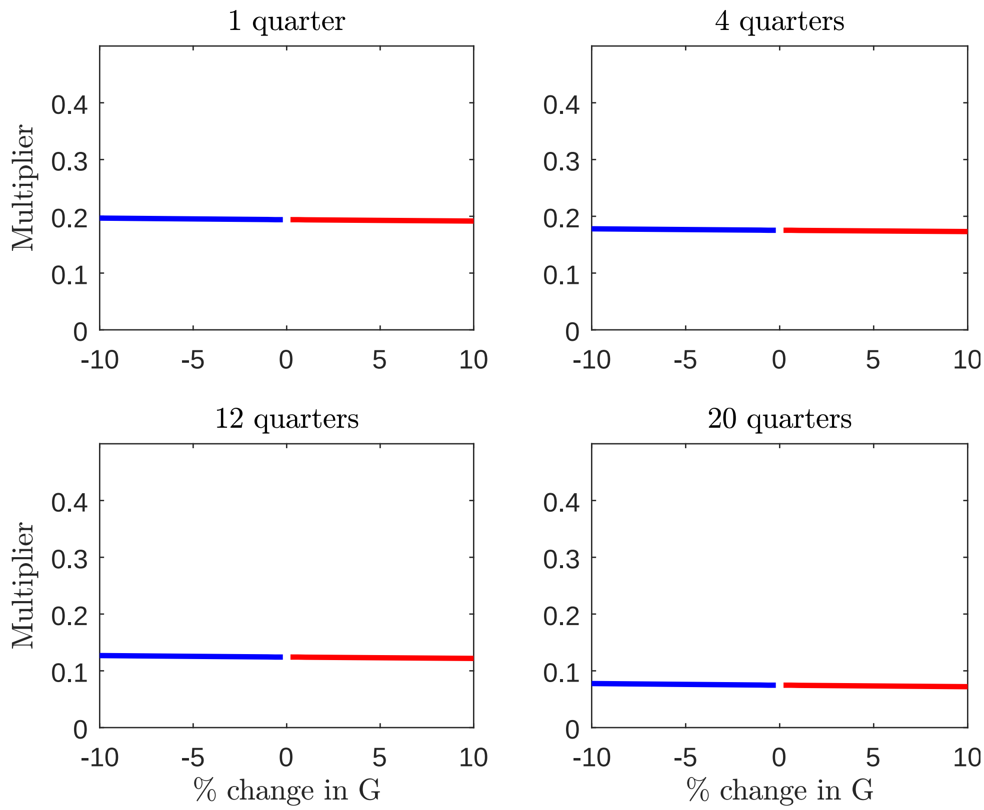

Figure 4: Representative Agent, RBC Model: fiscal multipliers as a function of the size of the variation in G, at different horizons. The blue line corresponds to G contractions, while the red line represents G expansions.

The figure shows that, as it is well know, 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 nonlinearities or asymmetries that we find in the data. In fact, the model predicts the multiplier to be slightly *decreasing* with the change in G, violating the asymmetric 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: again, multipliers are low and do not vary with the size or sign 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 sign and 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 in such a way that is 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 DSGE models. Adjustment

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

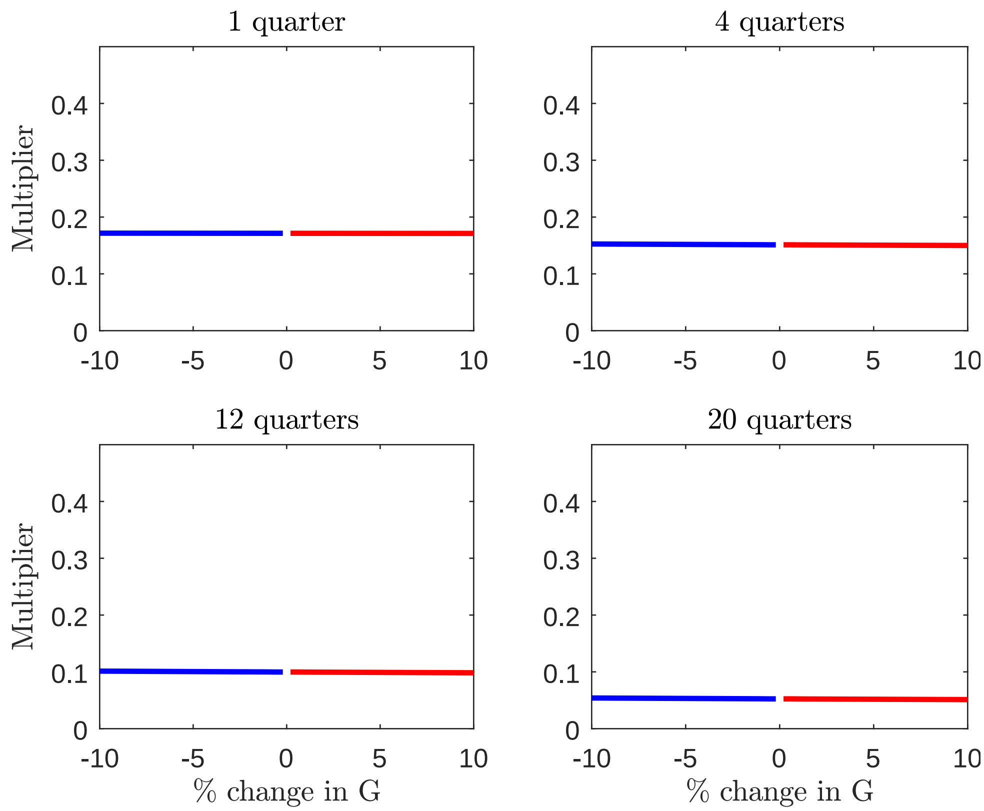

Figure 5: Representative Agent, New Keynesian Model: fiscal multipliers as a function of the size of the variation in G, at different horizons. The blue line corresponds to G contractions, while the red line represents G expansions.

costs of investment are able to generate empirically plausible fiscal multipliers while maintaining standard assumptions for monetary policy.

Figure 6 repeats the baseline experiment by introducing adjustment costs of investment in the New Keynesian specification. It shows that, while raising multipliers, adjustment costs of investment are not sufficient to generate empirically plausible levels for the multipliers or for the nonlinearities. Importantly, however, they help generate the correct asymmetry: fiscal multipliers now become slightly increasing in the shock to G, but this is quantitatively very small.

An increase in government spending affects the supply of the two factors of production with opposing effects: on one hand, real interests 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 fiscal multipliers. Still, none of this is sufficient

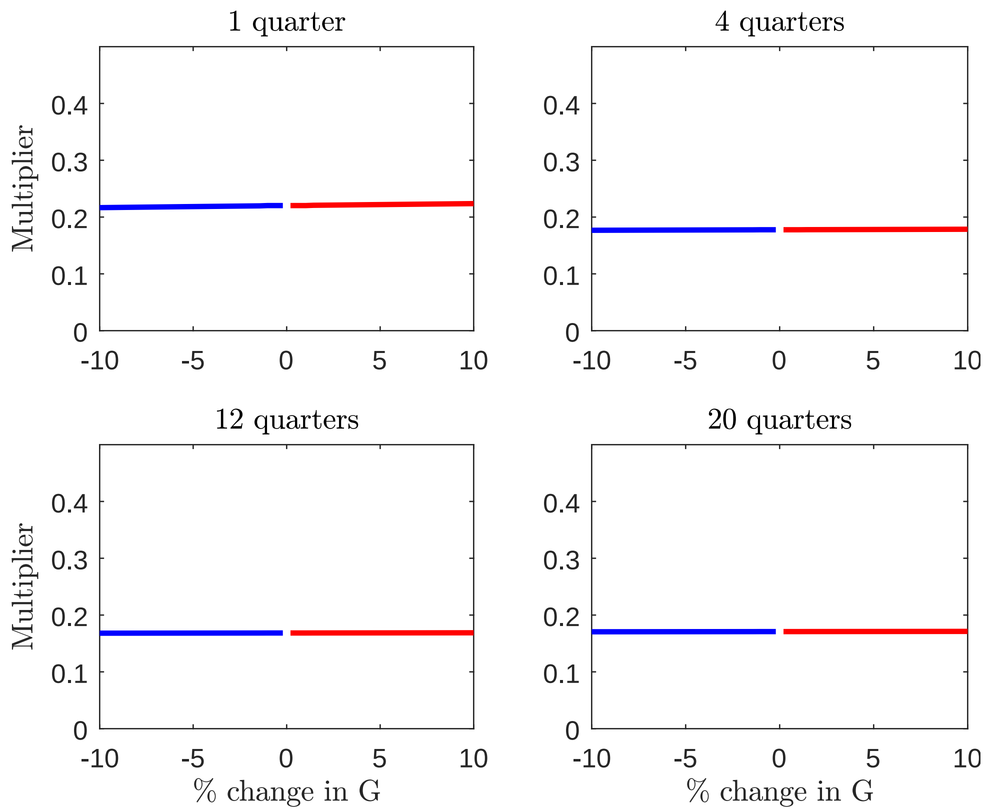

Figure 6: Representative Agent, New Keynesian Model with Adjustment Costs of Investment: fiscal multipliers as a function of the size of the variation in G, at different horizons. The blue line corresponds to G contractions, while the red line represents G expansions.

to match either the levels or the patterns that are detected in the data.[12]

4 Heterogeneous Agents Model

In the previous sections, we present empirical evidence that the macroeconomic effects of fiscal spending shocks depend both on the *size* and *sign* of the shock. In this section, we present a quantitative model that allows us to rationalize these findings. The model follows closely Brinca et al. (2016) and Brinca et al. (2017).

[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.

Technology

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

$$Y_t(K_t, L_t) = K_t^{\alpha} [L_t]^{1-\alpha} \tag{6}$$

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

$$K_{t+1} = (1-\delta)K_t + I_t \tag{7}$$

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,

$$\Pi_t = Y_t - w_t L_t - (r_t + \delta)K_t. \tag{8}$$

Under a competitive equilibrium, factor prices are paid their marginal products,

$$w_t = \frac{\partial Y_t}{\partial L_t} = (1-\alpha)\left(\frac{K_t}{L_t}\right)^{\alpha} \tag{9}$$

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

Demographics

The economy is populated by J overlapping generations of households. Peterman and Sager (2016) highlight the importance of having a life-cycle economic when assessing the effects of government debt. 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 so households work for 180 quarters (45 years). We assume no population growth and normalize the size of each new cohort to 1. $\omega(j) = 1 - \pi(j)$ defines the age-dependent probability of surviving; applying the law of large numbers, this means that the mass of retired agents at 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 that are assigned at birth, persistent idiosyncratic productivity shocks, asset holdings, and discount factors that 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 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 value these bequests in their utility in order to better match the data on retired household wealth.

Labor Income

The wage received by an household depends on three different factors that determine the number of labor efficiency units each household is endowed in each period: age j, permanent ability $a \sim N(0, \sigma_a^2)$, and an idiosyncratic productivity shock u, which follows an AR(1) process:

$$u' = \rho u + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon^2) \tag{11}$$

Labor income per hour worked depends on the wage rate per efficiency unit of labor w; this income is given by

$$w_i(j, a, u) = w e^{\gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + a + u} \tag{12}$$

$\gamma_i, i = 1, 2, 3$ are calibrated directly from the data to capture the age profile of labor income.

Preferences

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

$$U(c, n) = \frac{c^{1-\sigma}}{1-\sigma} - \chi \frac{n^{1+\eta}}{1+\eta} \tag{13}$$

The utility function for retired households also depends on bequests,

$$D(k) = \varphi \log(k) \tag{14}$$

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 over consumption τ_c, and capital income τ_k. Labor income taxes follow a non-linear schedule as in Benabou (2002):

$$\tau(y) = 1 - \theta_0 y^{-\theta_1} \tag{15}$$

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, public debt interest expenses rB_t, and lump sum transfers g_t.

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

$$g\left(45 + \sum_{j \geq 65} \Omega_j\right) = R - G - rB, \tag{16}$$

$$\Psi\left(\sum_{j \geq 65} \Omega_j\right) = R^{ss}. \tag{17}$$

Recursive Formulation of the Household Problem

In a given period, a household is defined by her 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 utility. The problem can be written recursively as:

$$V(k,\beta,a,u,j) = \max_{c,k',n}\left[U(c,n) + \beta\mathbb{E}_{u'}\left[V(k',\beta,a,u',j+1)\right]\right]$$

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

$$\begin{aligned} c(1+\tau_c) + k' &= (k+\Gamma)\left(1+r(1-\tau_k)\right) + g + Y^L \\ Y^L &= \frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}}\left(1-\tau_{ss}-\tau_l\left(\frac{nw(j,a,u)}{1+\tilde{\tau}_{ss}}\right)\right) \\ n \in [0,1], &\quad k' \geq -b, \quad c > 0 \end{aligned} \tag{18}$$

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

$$V(k,\beta,j) = \max_{c,k'}\left\{U(c,n) + \beta[1-\pi(j)]V(k',\beta,j+1) + \pi(j)D(k')\right\}$$

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

$$\begin{aligned} c(1+\tau_c) + k' &= (k+\Gamma)\left[1+r(1-\tau_k)\right] + g + \Psi, \\ k' \geq 0, &\quad c > 0 \end{aligned} \tag{19}$$

Stationary Recursive Competitive Equilibrium

Let the distribution over the individual states be denoted $\Phi(k,\beta,a,u,j)$. Then, we can define a stationary recursive competitive equilibrium (SRCE) as

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 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 Experiment and Transition

Our fiscal experiments consist of variations of government spending (G) of different signs and sizes (measures as % of GDP). For permanent shocks, we consider only deficit financing experiments whereby taxes and transfers are unchanged, and public debt changes permanently. For temporary shocks, we consider both deficit financing experiments where taxes and transfers are unchanged for a certain number of periods, and then debt returns to its original level, as well as balanced-budget experiments where debt remains constant. In sum, for permanent changes in G we consider the transition to a new SRCE with a different debt to GDP ratio, while for temporary changes the economy returns to the same SRCE.

We define the equilibrium transition as follows. For a given level of initial capital stock, initial distribution of households and initial taxes, respectively K_0, Φ_0 and $\{\tau_l, \tau_c, \tau_k, \tau_{ss}, \tilde{\tau}_{ss}\}_{t=1}^{t=\infty}$, a competitive equilibrium is a sequence of individual functions for the household, $\{V_t, c_t, k_t', n_t\}_{t=1}^{t=\infty}$, of 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 of measures $\{\Phi_t\}_{t=1}^{t=\infty}$, such that 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:

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

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

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

3. The factor prices are paid their marginal productivity:

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

4. The government budget balances:

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

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

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

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 standard parameters.

Wages

The wage profile through the life cycle (12) is calibrated directly from the data. We run the following regression, using data from the Luxembourg Income and Wealth Study.

$$\ln(w_i) = \ln(w) + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3 + \varepsilon_i \tag{20}$$

where j is the age of individual i.

To estimate parameters ρ and σ_ϵ we use PSID yearly data and run equation (20). We then use the residuals of the equation to estimate both parameters for an 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 Brinca et al. (2016) and Brinca et al. (2017), an average 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, share of hours worked and the 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 government transfers. To estimate the parameter θ_1 for the US, we use OECD data on labor income taxes and estimate the equation for different family types. We then weight the value of each parameter by the weight of each family type in the overall population.

For the social security rates we assume no progressivity. Both social security tax rates, on behalf of the employer and on behalf of 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 23.3% and 1.55%, 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 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:

$$L(\varphi, \beta_1, \beta_2, \beta_3, b, \chi, \sigma_a) = ||M_m - M_d|| \tag{21}$$

with M_m and M_d being 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 the ratio of wealth owned by households in the age cohort 75-80 years old relative to an average household, (ii) 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 6 presents the calibrated parameters and Table 5 presents the calibration fit.

Table 5: 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-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 6: 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_ϵ	0.695	Variance of ability

6 Intuition: Labor Supply and Credit Constraints

To build intuition on why credit constraints can generate asymmetric effects for fiscal policy shocks, we consider a simplified version of the model described in the previous section where agents are infinitely lived, taxes are lump-sum, and there is no social security and discount factor heterogeneity. Households solve a simplified problem given by

$$
\begin{aligned}
V(s_t^i) &= \max_{c_t^i, k_{t+1}^i, n_t^i} \left[U(c_t^i, n_t^i) + \beta \mathbb{E}_t [V(s_{t+1}^i) | s_t^i] \right] \\
&\text{s.t.} \\
c_t^i + k_{t+1}^i &= k_t^i (1 + r_t) + w_t u_t^i n_t^i - T_t \\
k_{t+1}^i &\geq -\underline{b} \\
s_t^i &= (k_t^i, u_t^i)
\end{aligned}
$$

where u_t^i is some idiosyncratic productivity shock.

In the standard neoclassical model the response of output to changes in government purchases depends only on changes in factor employment: capital and labor. Since capital is fixed in the short-run, the impact multiplier is determined solely by changes in labor supply.[13] We start by decomposing the different channels through which a change in government spending can affect individual labor supply, given individual states s_t^i and the aggregate state is X_t,[14]

Proposition 6.1. *The (total) response of labor supply $n(s_t^i)$ to a change in current govern-*

[13] Athreya et al. (2017) provide an extensive analysis in the context of general equilibrium models with incomplete markets such as this one.

[14] All derivations are in the Appendix.

ment consumption G_t is given by

$$\begin{aligned}\frac{\mathrm{d}n_t^i}{\mathrm{d}G_t} =&[\alpha_1(s_t^i;X_t)+\alpha_2(s_t^i;X_t)\Lambda_1(s_t^i;X_t)(1-\mathbb{1}_t^i)]\frac{\mathrm{d}w_t}{\mathrm{d}G_t}\\ &+\alpha_2(s_t^i;X_t)[1-(1-\mathbb{1}_t^i)\Lambda_2(s_t^i;X_t)]\left(\frac{\mathrm{d}T_t}{\mathrm{d}G_t}-k_t^i\frac{\mathrm{d}r_t}{\mathrm{d}G_t}\right)\\ &+\alpha_2(s_t^i;X_t)(1-\mathbb{1}_t^i)\mathcal{F}(s_t^i;X_t)\end{aligned}$$

where $\mathbb{1}_t^i = 1$ if the individual is constrained at t and zero otherwise; $\alpha_1, \alpha_2, \Lambda_1, \Lambda_2 > 0$ are time-invariant functions of the individual's current states s_t^i and X_t; and $\mathcal{F}$ is a time-invariant function of future changes in wages, interest rates, and taxes.

The labor supply of constrained agents does not respond to future changes in factor prices and taxes contained in $\mathcal{F}$. Since $\alpha_2 > 0$, constrained agents react relatively *less* to changes in current wages, but relatively more to changes in the current non-labor component of income (taxes and interest rates). In other words, constrained agents display a lower labor supply elasticity with respect to both current and future wages. The relative labor supply response between constrained and unconstrained agents will then crucially depend on the mode of financing: balanced budget fiscal expansions, for example, should trigger a relatively larger response by constrained agents, as they involve changes in current taxes.

Proposition 6.2. *The effects of future changes in taxes and factor prices on individual labor supply $\mathcal{F}(s_t^i;X_t)$ can be written recursively as*

$$\begin{aligned}\mathcal{F}(s_t^i;X_t) =& -\Lambda_3(s_t^i;X_t)[1-\Lambda_2(s_{t+1}^i;X_{t+1})]\frac{\mathrm{d}w_{t+1}}{\mathrm{d}G_t}\\ &+[\Lambda_4(s_t^i;X_t)+\Lambda_5(s_t^i;X_t)\Lambda_2(s_{t+1}^i;X_{t+1})k_{t+1}^i]\frac{\mathrm{d}r_{t+1}}{\mathrm{d}G_t}\\ &+\Lambda_5(s_t^i;X_t)[1-\Lambda_2(s_{t+1}^i;X_{t+1})]\frac{\mathrm{d}T_{t+1}}{\mathrm{d}G_t}\\ &+\Lambda_5(s_t^i;X_t)\mathcal{F}(s_{t+1}^i;X_{t+1})\end{aligned}$$

where

$$\Lambda_3(s_t^i; X_t)[1 - \Lambda_2(s_{t+1}^i; X_{t+1})] \geq 0$$
$$\Lambda_5(s_t^i; X_t)[1 - \Lambda_2(s_{t+1}^i; X_{t+1})] \geq 0$$
$$\Lambda_5(s_t^i; X_t) \geq 0$$

The above proposition shows that current labor supply responds positively to increases in future taxes (i.e. unconstrained agents observe the Ricardian Equivalence), and negatively to increases in future wages. Assuming that an increase (decrease) in government spending causes a standard crowding out (in) effect on investment, the capital stock falls (increases), and future wages are lower (higher). This means that the labor supply response on impact for unconstrained agents reflects not only the standard Ricardian effects but also the path of future wages. These two forces are absent from the labor supply response of constrained agents. Therefore, deficit financed fiscal expansions can potentially have a much larger effect on the labor supply for unconstrained agents, who internalize the present discounted value of the fiscal costs as well as of the fall in wages.

This differential response of labor supply between constrained and unconstrained agents is the key mechanism that drives our main results: regardless of the financing scheme, if an *increase* in government purchases changes the mass of constrained agents differently than a *decrease* in spending, we should observed asymmetric effects on aggregate labor supply and, therefore, on output. We can show that the savings function for an individual agent is given by

$$\frac{\mathrm{d}k_{t+1}^i}{\mathrm{d}G_t} = \Lambda_1(s_t^i; X_t)\frac{\mathrm{d}w_t}{\mathrm{d}G_t} + \Lambda_2(s_t^i; X_t)\left(k_t^i \frac{\mathrm{d}r_t}{\mathrm{d}G_t} - \frac{\mathrm{d}T_t}{\mathrm{d}G_t}\right) + \mathcal{F}(s_t^i; X_t)$$

Not surprisingly, savings comove with $\mathcal{F}$: in particular, increases in future taxes or decreases in future wages induce agents to increase their savings. Faced with a deficit-financed fiscal expansion, agents close to their borrowing constraint are induced to save more and, therefore, move away from the constraint. This increases the mass of unconstrained agents and, therefore, the aggregate labor supply elasticity. On the other hand, faced with a decrease in spending, the positive wealth effect induces agents to save less and potentially hit the constraint. This increase in the mass of constrained agents means that labor supply will be much less response, and therefore output moves by less.

Balanced Budget Fiscal Policies The intuition described above applies to the case of deficit financing, when current changes in G are financed with public debt and future taxes. Alternatively, the government could finance current changes in G with contemporaneous changes in T, keeping B constant. This can potentially attenuate the effect as current tax increases induce a relatively larger labor supply response by constrained agents. Still, as long as the rise in spending (and taxes) is persistent, unconstrained agents still react to changes in current taxes (albeit by less), and additionally respond to future changes in taxes and wages.

7 Quantitative Results

In this section, we use the calibrated model as a laboratory to study the effects of changes in G of different signs and sizes. We study both permanent and temporary changes in G, as well as different financing regimes.

7.1 Permanent Fiscal Shocks

We start by considering the case of permanent increases (decreases) in G that are financed with temporary increases (decreases) in public debt, which are then paid for with permanent decreases (increases) in transfers, as these elicit the strongest (and more easily interpretable) effects.[15] Figure 7 plots fiscal multipliers (on impact) as a function of the size of the change in G: the fiscal multiplier is monotonically increasing in G. It is lower for fiscal contractions

[15] To be more specific, the experiment is the following: G rises permanently at $t = 1$; taxes and transfers remain unchanged for the first 20 periods and public debt absorbs all variation; transfers then adjust for 60 periods in order to bring public debt back to its original level, and the economy then converges to its new SRCE.

than for fiscal expansions, and is larger (smaller) for larger fiscal expansions (contractions).

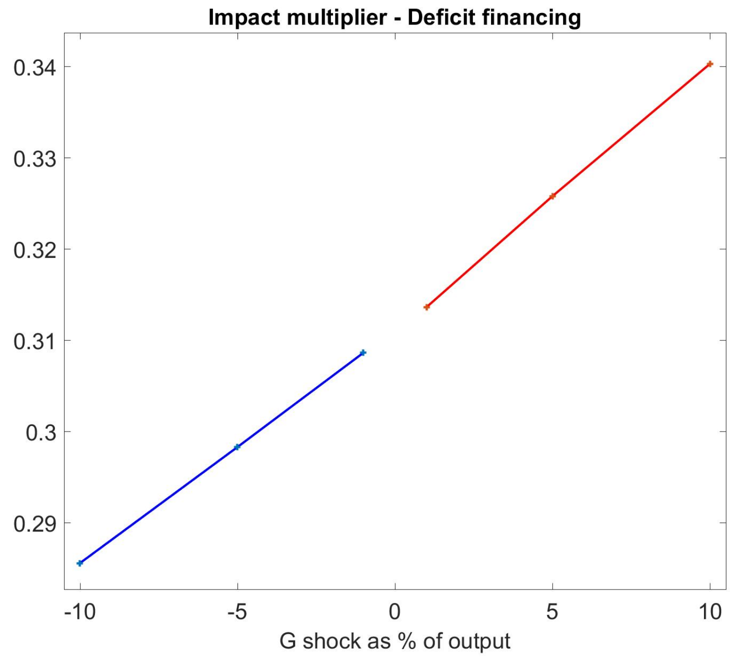

Figure 7: This figure plots the fiscal multiplier as a function of the size of the variation in G (as a % of GDP). The blue line corresponds to G contractions, while the red line represents G expansions.

Figures 8 and 9 help us understand the forces behind the mechanism. Figure 8 plots the percentage of constrained agents the period following the shock as a function of its size. As government spending increases, so does public debt, which crowds out capital. This permanent reduction in the capital stock lowers wages, and thus the lifetime income for most agents in this economy. This reduction in lifetime income leads to a decrease in borrowing, which then leads to less agents being credit constrained. Conversely, a fall in spending leads to a reduction in public debt, which contributes to an increase in the capital stock and higher wages going forward. As lifetime income rises, agents borrow more and the share of credit constrained agents increases. These changes in the mass of constrained agents affect the fiscal multiplier, since the labor supply of constrained agents is less elastic.

Figure 9 presents this relationship: the labor supply response of different types of agents as a function of the increase in G (left panel) or decrease in G (right panel). An increase in G reduces wages going forward; unconstrained agents react strongly to this fall in lifetime

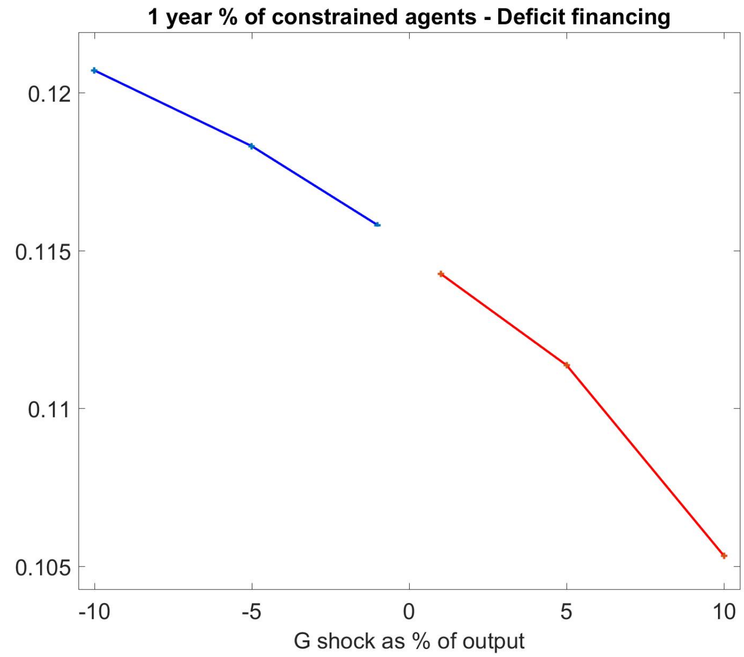

Figure 8: Government spending variation and percentage of constrained agents: In the X-axis we have the variation in G in percentage of GDP and in the Y-axis we have the percentage of credit constrained agents in the period following the shock. Blue line represents G contractions and red G expansions. The percentage of credit constrained agents is decreasing in the shock.

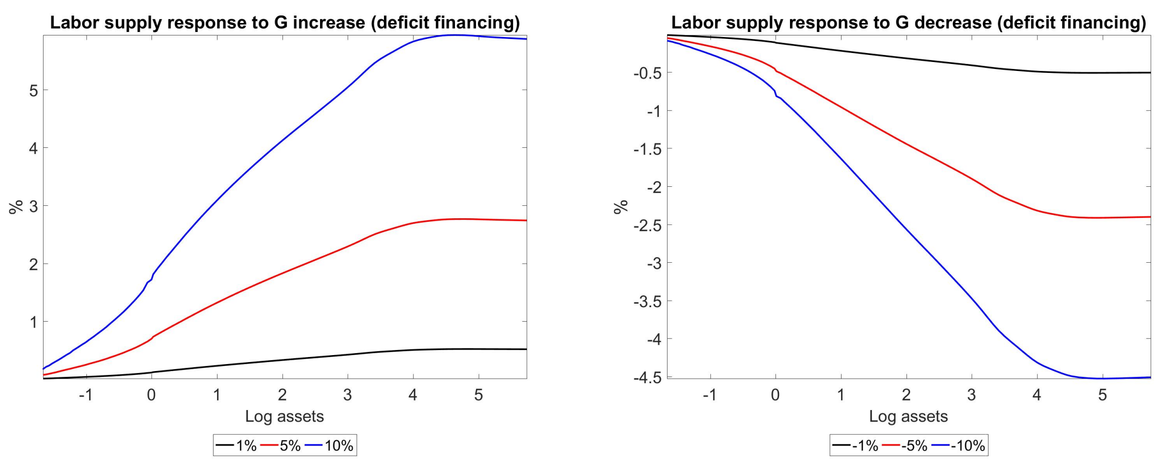

Figure 9: Government spending variation and relative labor supply response: this graph plots the labor supply response relative to the stationary steady state as a function of the initial level of assets for a permanent spending shock financed with deficits. The left panel corresponds to positive changes in G, while the right panel corresponds to negative changes in G.

income and their labor supply expands relatively more in the period of the shock. Constrained agents, on the other hand, do not respond to changes in future income, and their labor supply is only affected by current conditions, consequently responding less. Since more agents become unconstrained when G increases, the effective aggregate labor supply elasticity in the economy increases, leading to a larger output response to fiscal shocks. The same logic applies to fiscal contractions, represented in the right panel: in this case, there is an increase in lifetime income, which leads unconstrained agents to reduce their labor supply today. Constrained agents react only to current wages, and so their labor supply response is more muted. Since more agents become constrained in response to the fiscal contraction, this attenuates the effect of fiscal shocks on GDP: output falls but not by as much as it would expand for an expansion of the same size.

7.2 Temporary Fiscal Shocks

We now consider the more empirically plausible case of temporary fiscal shocks, and show that the same logic goes through. Additionally, we consider two types of financing regimes: (i) deficit financing, where the temporary shock is absorbed by changes in public debt until a certain point in time, after which transfers adjust to ensure that the economy returns to the initial (pre-shock) level of public debt, and (ii) balanced budget financing, in which transfers adjust in such a way to keep public debt constant during the entire transition.

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 10 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 difference are the magnitudes: since the shock is no longer permanent, it no longer causes a permanent decrease in wages, therefore leading to 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 right after the shock), while the right panel plots the one-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.

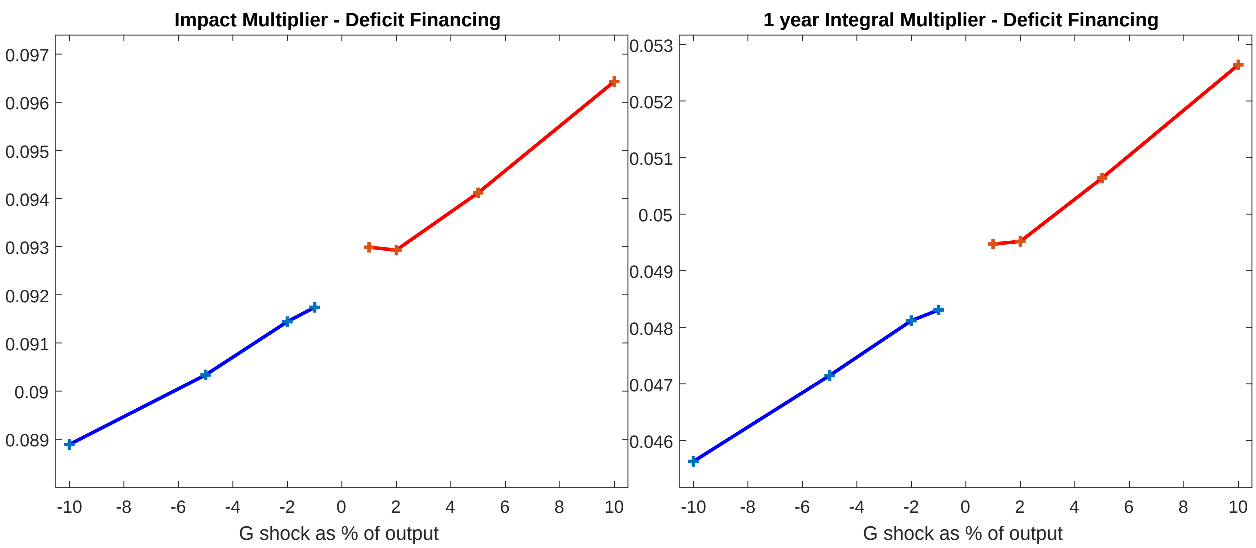

Figure 10: Fiscal multiplier as a function of ε_t^G (the initial impulse), deficit financing. The left panel presents impact multipliers (one quarter after the shock), the right panel presents the 1-year integral multipliers.

Figure 11 illustrates the mechanism behind the effect, by plotting the relative change in labor supply across the asset distribution. The change in labor supply is monotonically increasing (decreasing) both in the level of assets and in the size of the shock (the line starts at the constraint). Positive (negative) fiscal shocks lead to an decrease (increase) of agents at the constraint, which contributes to a greater (lower) elasticity of labor supply with respect to the fiscal shock. The change in the share of agents at the constraint is shown in figure 12: the fiscal shock causes agents to move away from the constraint. Since the fiscal policy is financed with future taxes, and both the responses of the wage and interest rates are backloaded, the labor supply of constrained agents responds much less than that of unconstrained ones.

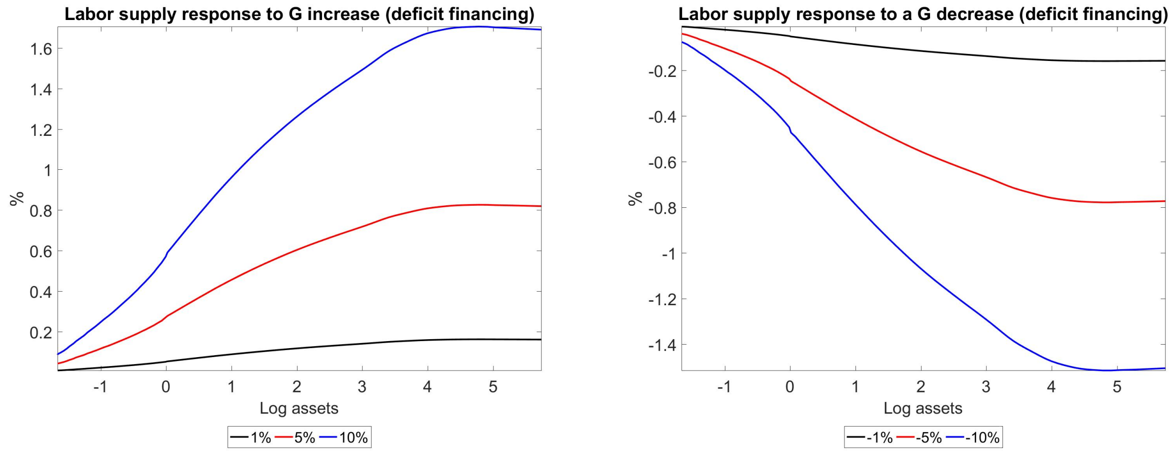

Figure 11: (Relative) labor supply response to different changes in G over the asset distribution. Left panel plots the relative response to increases in G, right panel plots the relative response to decreases in G.

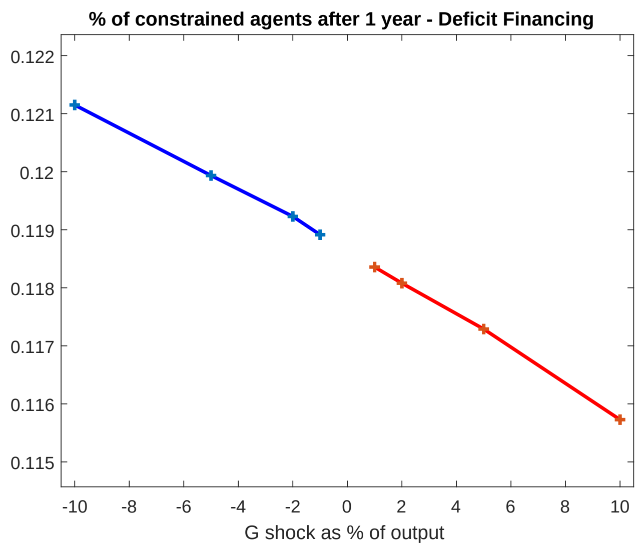

Figure 12: Percentage of agents at the borrowing constraint, deficit financing, one year after the shock, for different levels of the shock to G.

Balanced Budget Figure 13 plots the same measures of the fiscal multiplier for the case where the government runs a balanced budget, and thus decreases (increases) transfers when G increases (decreases). The qualitative results are identical, but the sizes of the multipliers are much larger, and the mechanism is different. This is because balanced budget interventions affect the income of constrained agents contemporaneously, and these agents react very strongly to changes in their current income. On top of the mechanism that we propose, there is a more conventional one: when G increases, not only unconstrained agents react strongly due to changes in future wages, but also constrained agents now expand their labor supply due to rises in current taxes/decreases in current transfers.

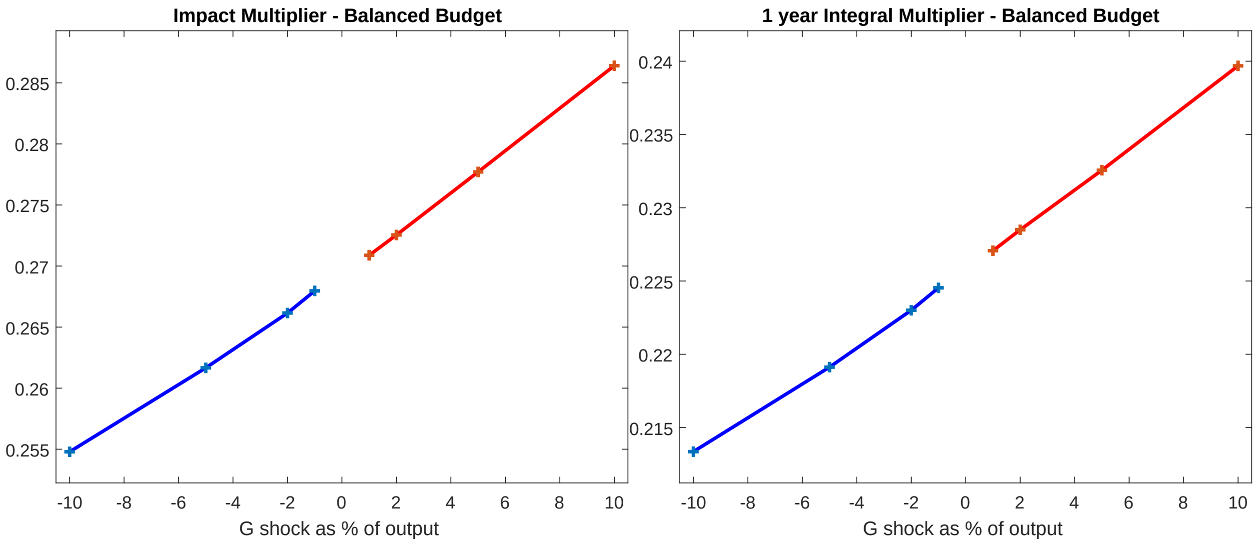

Figure 13: Fiscal multiplier as a function of ε_t^G (the initial impulse), balanced budget financing. The left panel presents impact multipliers (one quarter after the shock), the right panel presents the 1-year integral multipliers.

Since the fiscal shock is financed contemporaneously, constrained agents tend to react relatively more to positive changes in transfers than unconstrained ones, as shown by the labor supply responses in 14. These labor supply responses behave in the manner that we would expect, with constrained agents greatly expanding their labor supply in response to a positive shock (decrease in transfers) and reducing their labor supply much more in response to a negative fiscal shock (increase in transfers). These labor supply responses can be combined with the movements in the distribution presented in 15 to deliver our result: this graph shows that the mass of constrained agents is increasing in the size of the shock. Take a positive fiscal shock, to which constrained agents respond relatively more in expanding their labor supply. This positive shock is financed by a contemporaneous decrease in transfers, which brings to the constraint agents that were already close to it. This increases the mass of constrained agents, who we know respond relatively more to the shock. The logic is the converse for negative fiscal shocks: by raising transfers, the government moves agents away from the constraint, to a part of the distribution where their labor supply response is relatively larger. Since the shock is negative, this results in a relatively smaller fiscal multiplier.

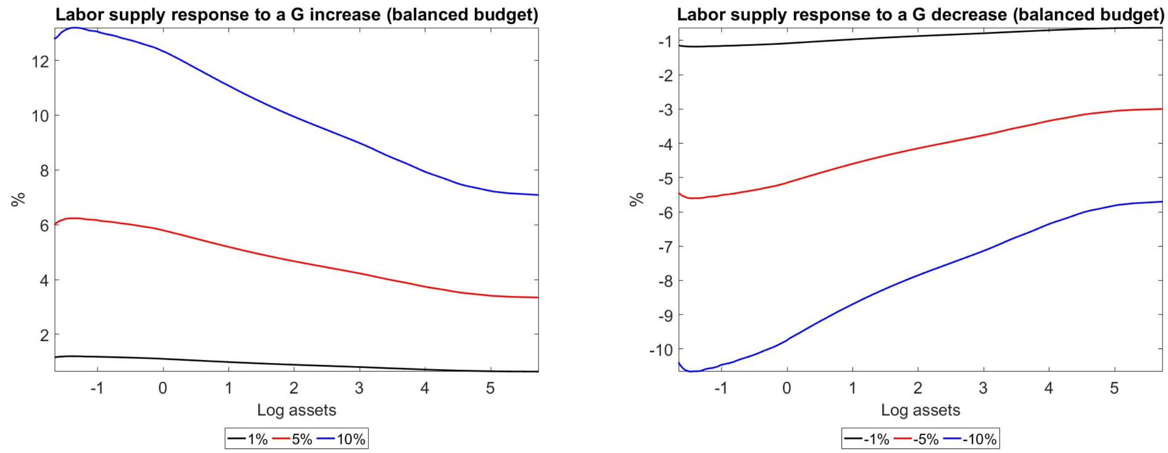

Figure 14: (Relative) labor supply response to different changes in G over the asset distribution, balanced budget. Left panel plots the relative response to increases in G, right panel plots the relative response to decreases in G.

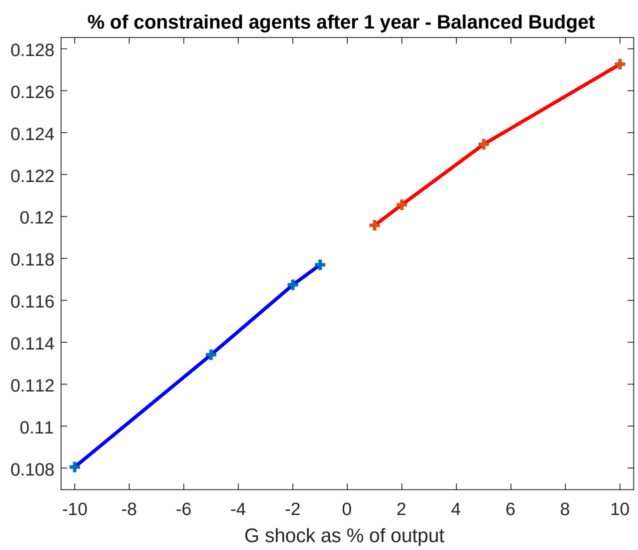

Figure 15: Percentage of agents at the borrowing constraint one year after the shock, balanced budget, for different levels of the shock to G.

Financing Regimes in the Data Empirically we established that nonlinearities are stronger for positive than for negative shocks, with the difference being larger at shorter horizons. Model results indicate that the financing regime matters in a heterogeneous agents model, with balanced budget experiments yielding larger multipliers and stronger nonlinearities. The empirical asymmetry could then potentially be explained by positive and negative fiscal shocks being financed by different fiscal rules.

To test this hypothesis we estimate equation (2) now with tax revenue in percentage of potential GDP as the dependent variable. $m_{pos,h}$ and $m_{neg,h}$ can now be interpreted as the revenue multiplier: how much tax revenue changes in response to each type of shock (conditional on the state of the economy). Figure 16 plots these tax multipliers at different horizons, and suggest that the revenue multiplier is larger for positive fiscal shocks during the first ten periods. This can be interpreted as suggestive evidence that positive fiscal shocks tend to be financed with balanced budgets, while negative fiscal shocks tend to be closer to deficit financing. Our model then predicts that both the level and the nonlinearity should be larger for positive than for negative fiscal shocks, as we find in the data.

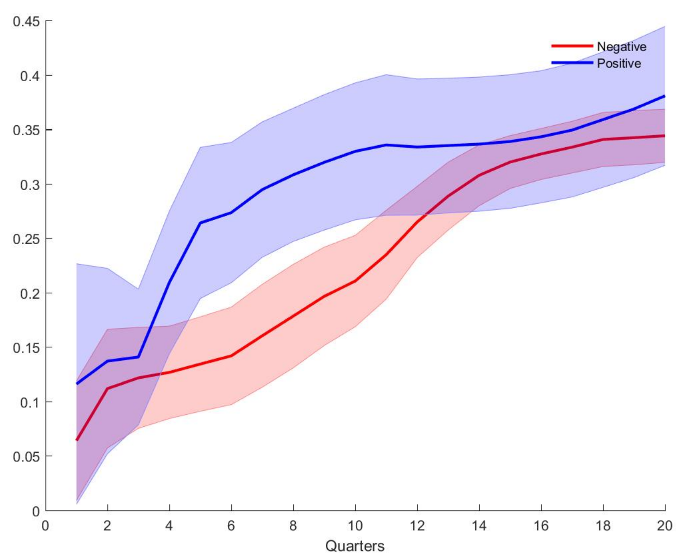

Figure 16: Tax multiplier:

8 Micro Evidence of the Mechanism

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

We use data from the Panel Study on Income Dynamics (PSID) to empirically support the micro mechanisms that we propose above. This dataset allow us to test the mechanism as it combines data on wealth, income, and hours worked. Between 1989 and 1999, the PSID collects data on wealth every five years and after 1999 every two years. Data on income and hours worked is collected every survey year.

The first hypothesis we test is if the response of labor supply depends on wealth, and if this relation is the same for future and current income shocks. Our model results depend on the financing regime to the extent that tax-financed shocks generate current income effects, while debt-financed shocks are associated with future income shocks. We expect constrained agents to respond the most to current income shocks, and the least to future income shocks.

We follow the income shock identification hypothesis of Domeij and Floden (2006), who in turn follow Altonji (1986), and use the one-year lag of both the reported hourly wage rate w^{**} – only available for hourly rated workers – and its percentage change as instruments for the percentage variation in the implied hourly wage rate w^{*}, measured as the household head's total labor income and divided by total hours worked. We then interact the instrumented variable with standardized total wealth a, defined as the net value of all assets, to see how the labor supply elasticity depends on wealth. To test the elasticity to both current and income shocks we estimate the following two specifications

$$\ln h_{it} = \beta_1 \Delta \ln w^*_{it} + \beta_2 a_{it} + \beta_3 a_{it} \Delta \ln w^*_{it} + \alpha_i + \gamma_t + \epsilon_{it} \tag{22}$$

$$\ln h_{it} = \beta_1 \Delta \ln w^*_{it+4} + \beta_2 a_{it} + \beta_3 a_{it} \Delta \ln w^*_{it+4} + \alpha_i + \gamma_t + \epsilon_{it} \tag{23}$$

where h is total number of hours worked in year t by the head of household i, α_i are household fixed effects and γ_t are year fixed effects. Results are reported in Table 7. While hours worked increase with an rise in current wage, they decrease with a future increase in wage. Moreover, the relation between the labor supply elasticity and wealth is the opposite for current and future income shocks: while the elasticity is increasing in wealth for future income shocks, it is decreasing for current income shocks. Quantitatively, a wealth increase of one standard deviation decreases the labor supply elasticity to current shocks by 18.6% and increases the elasticity to future shocks by 10.6%.

	Current Income Shock		Future Income Shock	
VARIABLES	(1)	(2)	(3)	(4)
β_1	1.205***	0.915***	-4.327***	-4.194***
	(0.358)	(0.274)	(1.142)	(1.025)
β_2		-0.031**		-0.021
		(0.014)		(0.035)
β_3		-0.170***		0.443*
		(0.062)		(0.230)
Observations	53,383	53,383	38,905	38,905
Number of ID	12,769	12,769	10,165	10,165

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

Table 7: Labor supply elasticity, total wealth, current and future income shocks

We now proceed to test whether the dependence of labor supply responses on wealth and the timing of income shocks depends at all on the implied financing regime for fiscal shocks. We identify fiscal shocks as in Section 2.1 using quarterly data, and then sum these shocks over a two 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. We then estimate the following equation

$$\begin{aligned} \ln h_{it} = & \beta_1 G_t + \beta_2 a_t + \beta_3 \Delta B_t + \beta_4 a_t G_t + \beta_5 \Delta B_t G_t + \beta_6 a_t \Delta B_t \\ & + \beta_7 a_t \Delta B_t G_t + \alpha_i + \gamma_t + \epsilon_{it} \end{aligned} \tag{24}$$

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

Results in Table 8 show that the coefficient signs are all in line with what we would expect, thus validating the model mechanism. For a 1% fiscal spending shock, when debt is not changing, an increase of wealth by one standard deviation decreases the labor supply response by 94.5%. If debt increases by 1%, the response of an household with zero wealth decreases by 45.2%, while a household with wealth equal to one standard deviation increases its labor supply response by 800%.[16]

9 Conclusion

In this paper, we contribute to the analysis of the aggregate effects of government spending shocks by providing empirical evidence that their macroeconomic effects depend both on the sign and size of these shocks. Using historical data for the US, we find that fiscal multipliers

[16] For robustness, we test whether splitting the sample into above and below median wealth households produces similar results. Results in Table 22 show that households with wealth below the median respond more to shocks if debt does not change, while households with wealth above the median respond more to shocks financed through debt.

VARIABLES	(1) G Shock	(2) G Shock	(3) G Shock	(4) G Shock
β_1	0.327	0.068**	0.166	0.073**
	(0.244)	(0.030)	(0.182)	(0.031)
β_2			3.423*	1.262*
			(1.920)	(0.699)
β_3		0.873***		0.647**
		(0.325)		(0.328)
β_4			-0.173*	-0.069*
			(0.096)	(0.037)
β_5		-0.044***		-0.033**
		(0.016)		(0.016)
β_6				-0.650
				(0.453)
β_7				0.032
				(0.022)
Observations	81,678	81,678	81,678	81,678
Number of ID	17,670	17,670	17,670	17,670

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

Table 8: G shock, labor supply response, total wealth and financing regime

are increasing on the sign and size of the underlying fiscal shock. A different methodology and dataset corroborate this relationship in the context of fiscal consolidations in OECD countries.

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 signs and sizes. We show that the response of labor supply across the wealth distribution, along with the response of this very same distribution, are crucial to generate the 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 different mechanism.

Finally, we empirically validate the proposed mechanism by combining micro data from the PSID with identified policy shocks, and showing that the positive response of labor supply is decreasing in wealth for tax-financed fiscal shocks, but increasing in wealth for deficit-financed fiscal shocks.

We see this paper as a first step to understanding how the size and sign of fiscal shocks can have different aggregate implications depending on the distributional features of the economy. In this paper, we focused essentially on the role of heterogeneous marginal propensities to work for 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 US historical data

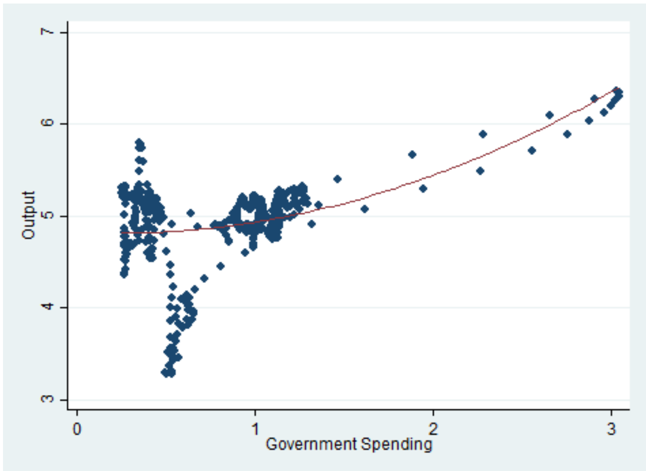

Figure 17: 1 year cumulative real output in the y-axis and 1 year cumulative real government spending in the x-axis, both as percentage of trend GDP. The red line represents the quadratic fitted polynomial between the two variables. The correlation between output and the first order term of government spending is 0.45 (p-value 0.00) and with the second order term of government spending is 0.50 (p-value 0.00).

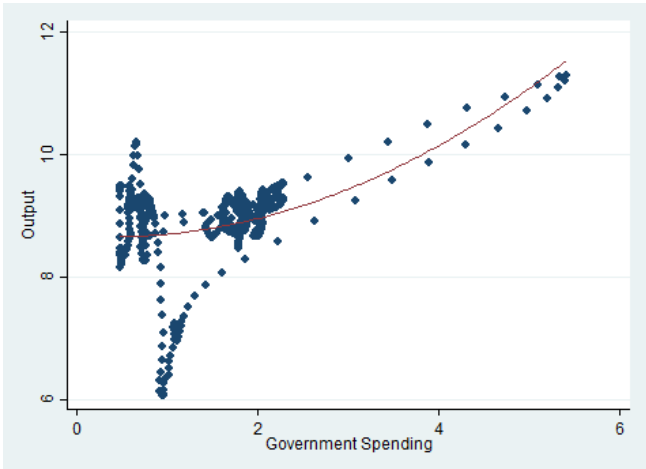

Figure 18: 2 years cumulative real output in the y-axis and 2 years cumulative real government spending in the x-axis, both as percentage of trend GDP. The red line represents the quadratic fitted polynomial between the two variables. The correlation between output and the first order term of government spending is 0.45 (p-value 0.00) and with the second order term of government spending is 0.50 (p-value 0.00).

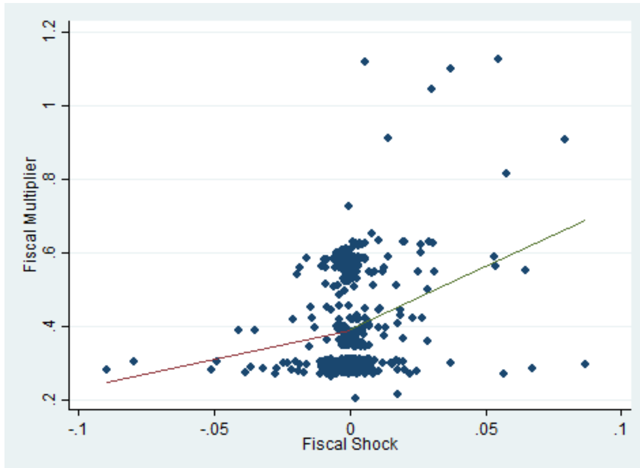

Figure 19: 1 year cumulative multiplier vs Fiscal shock: On the y-axis we have the 1 year cumulative multiplier and on the x-axis we have the size of the fiscal shock. For negative shocks the correlation is 0.14 (P-value 0.03) while for positive shocks is 0.28 (P-value 0.00).

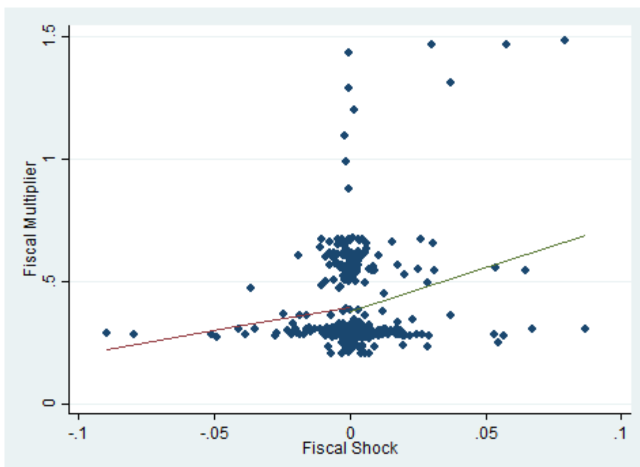

Figure 20: 2 year cumulative multiplier vs Fiscal shock: On the y-axis we have the 2 year cumulative multiplier and on the x-axis we have the size of the fiscal shock. For negative shocks the correlation is 0.12 (P-value 0.07) while for positive shocks is 0.25 (P-value 0.00).

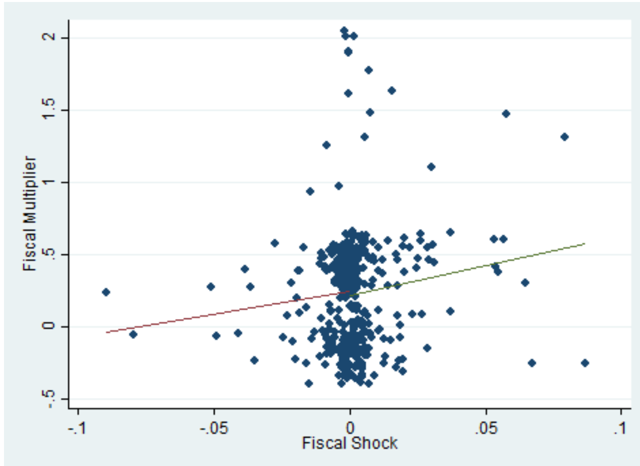

Figure 21: 3 year cumulative multiplier vs Fiscal shock: On the y-axis we have the 3 year cumulative multiplier and on the x-axis we have the size of the fiscal shock. For negative shocks the correlation is 0.08 (P-value 0.19) while for positive shocks is 0.15 (P-value 0.03).

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	0.22	0.18	0.41	AR = 0.34
	(0.15)	(0.33)	(0.14)	
1 year cumulative multiplier	0.28	0.30	0.54	AR = 0.26
	(0.13)	(0.21)	(0.17)	
2 year cumulative multiplier	0.45	0.42	0.65	AR = 0.13
	(0.09)	(0.17)	(0.12)	
3 year cumulative multiplier	0.54	0.61	0.73	AR = 0.10
	(0.08)	(0.12)	(0.11)	
4 year cumulative multiplier	0.56	0.70	0.72	AR = 0.09
	(0.09)	(0.09)	(0.11)	

Table 9: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks in a specification without controlling for tax revenue.

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	0.23	0.05	0.44	AR = 0.24
	(0.15)	(0.29)	(0.16)	
1 year cumulative multiplier	0.30	0.11	0.57	AR = 0.13
	(0.12)	(0.25)	(0.18)	
2 year cumulative multiplier	0.48	0.30	0.67	AR = 0.05
	(0.19)	(0.23)	(0.11)	
3 year cumulative multiplier	0.58	0.53	0.73	AR = 0.05
	(0.07)	(0.15)	(0.09)	
4 year cumulative multiplier	0.60	0.67	0.73	AR = 0.06
	(0.07)	(0.11)	(0.08)	

Table 10: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks in a specification controlling for the government debt to GDP ratio.

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	0.32	0.03	0.59	AR = 0.12
	(0.12)	(0.23)	(0.12)	
1 year cumulative multiplier	0.35	0.11	0.66	AR = 0.18
	(0.11)	(0.21)	(0.14)	
2 year cumulative multiplier	0.52	0.29	0.70	AR = 0.21
	(0.11)	(0.23)	(0.08)	
3 year cumulative multiplier	0.60	0.56	0.72	AR = 0.21
	(0.10)	(0.16)	(0.07)	
4 year cumulative multiplier	0.61	0.65	0.70	AR = 0.20
	(0.10)	(0.11)	(0.07)	

Table 11: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks, considering 8 lags for the control variables.

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	-0.07	-0.66	0.54	AR = 0.15
	(0.12)	(0.22)	(0.20)	
1 year cumulative multiplier	-0.00	-0.45	0.69	AR = 0.16
	(0.12)	(0.36)	(0.30)	
2 year cumulative multiplier	0.19	-0.13	0.87	AR = 0.26
	(0.15)	(0.30)	(0.24)	
3 year cumulative multiplier	0.22	-0.12	0.92	AR = 0.24
	(0.20)	(0.33)	(0.27)	
4 year cumulative multiplier	0.06	-0.34	0.68	AR = 0.15
	(0.23)	(0.39)	(0.28)	

Table 12: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks, omitting the world war II period.

	Linear	Negative shocks	Positive shocks	AR P-value
Impact	0.60	0.71	0.99	AR = 0.40
	(0.34)	(0.40)	(0.37)	
1 year cumulative multiplier	0.33	0.52	0.68	AR = 0.66
	(0.31)	(0.52)	(0.40)	
2 year cumulative multiplier	0.35	0.35	0.54	AR = 0.76
	(0.25)	(0.49)	(0.36)	
3 year cumulative multiplier	0.57	0.20	0.78	AR = 0.80
	(0.24)	(0.63)	(0.35)	
4 year cumulative multiplier	0.60	0.09	0.92	AR = 0.74
	(0.27)	(0.70)	(0.37)	

Table 13: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks, considering only the post 1948 period.

	Linear	Quadratic term
Impact	0.13	0.06
	(0.16)	(0.04)
1 year	0.14	0.04
	(0.19)	(0.04)
2 years	0.14	0.06
	(0.29)	(0.05)
3 years	-0.29	0.011
	(0.50)	(0.06)
4 years	-0.91	0.015
	(0.72)	(0.007)

Table 14: Linear and quadratic term for 1, 2, 3 and 4 year horizons for fiscal shocks.

	Average - st.dev.	Average	Average + st.dev.
Impact	0.14	0.17	0.19
1 year cum. mult.	0.18	0.21	0.25
2 year cum. mult.	0.23	0.32	0.42
3 year cum. mult.	-0.05	0.20	0.46
4 year cum. mult.	-0.46	-0.02	0.41

Table 15: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for average G, one standard deviation above and below, for the specification with a quadratic term.

	Linear	Below threshold	Above threshold	AR P-value
Impact multiplier	0.20	0.22	0.12	AR = 0.17
	(0.17)	(0.17)	(0.59)	
1 year cumulative multiplier	0.27	0.28	0.39	AR = 0.19
	(0.14)	(0.15)	(0.59)	
2 year cumulative multiplier	0.45	0.46	0.55	AR = 0.16
	(0.10)	(0.11)	(0.31)	
3 year cumulative multiplier	0.56	0.56	0.63	AR = 0.15
	(0.09)	(0.09)	(0.16)	
4 year cumulative multiplier	0.58	0.59	0.32	AR = 0.22
	(0.09)	(0.10)	(0.13)	

Table 16: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for fiscal shocks above and below the median negative shock.

	Linear	Below threshold	Above threshold	AR P-value
Impact multiplier	0.20	0.12	0.44	AR = 0.22
	(0.17)	(0.35)	(0.15)	
1 year cumulative multiplier	0.27	0.19	0.54	AR = 0.18
	(0.14)	(0.29)	(0.19)	
2 year cumulative multiplier	0.45	0.28	0.66	AR = 0.12
	(0.10)	(0.28)	(0.11)	
3 year cumulative multiplier	0.56	0.46	0.72	AR = 0.12
	(0.09)	(0.21)	(0.08)	
4 year cumulative multiplier	0.58	0.60	0.71	AR = 0.18
	(0.09)	(0.16)	(0.07)	

Table 17: Impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for fiscal shocks above and below the median positive shock.

	Average negative - st.dev.	Average negative	Average positive	Average positive + st.dev.
Impact mult.	-0.07	0.09	0.13	0.26
1 year cum. mult.	-0.36	-0.21	-0.29	-0.12
2 year cum. mult.	-0.89	-0.62	-0.72	-0.26
3 year cum. mult.	-2.12	-1.36	-0.76	-0.18
4 year cum. mult.	-4.55	-2.80	-0.59	-0.17

Table 18: Consumption impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks.

	Average - st.dev.	Average	Average + st.dev.
Impact	0.11	0.21	0.31
1 year cum. mult.	-0.20	-0.12	-0.03
2 year cum. mult.	-0.54	-0.31	-0.08
3 year cum. mult.	-0.48	-0.23	0.02
4 year cum. mult.	-0.42	-0.22	-0.01

Table 19: Consumption impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for average G, one standard deviation above and below, for the specification with a quadratic term.

	Average negative - st.dev.	Average negative	Average positive	Average positive + st.dev.
Impact mult.	-1.87	-1.12	-0.47	-0.39
1 year cum. mult.	-3.40	-2.09	0.09	-0.31
2 year cum. mult.	-5.05	-3.19	-0.58	-0.49
3 year cum. mult.	-8.46	-5.26	-1.84	-0.47
4 year cum. mult.	-15.50	-9.34	-3.93	-0.72

Table 20: Investment impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for positive and negative fiscal shocks.

	Average - st.dev.	Average	Average + st.dev.
Impact	-0.82	-0.61	-0.39
1 year cum. mult.	-0.73	-0.59	-0.44
2 year cum. mult.	-1.06	-0.65	-0.25
3 year cum. mult.	-2.35	-1.01	0.33
4 year cum. mult.	-4.79	-1.90	0.99

Table 21: Investment impact and cumulative multipliers for 1, 2, 3 and 4 year horizons for average G, one standard deviation above and below, for the specification with a quadratic term.

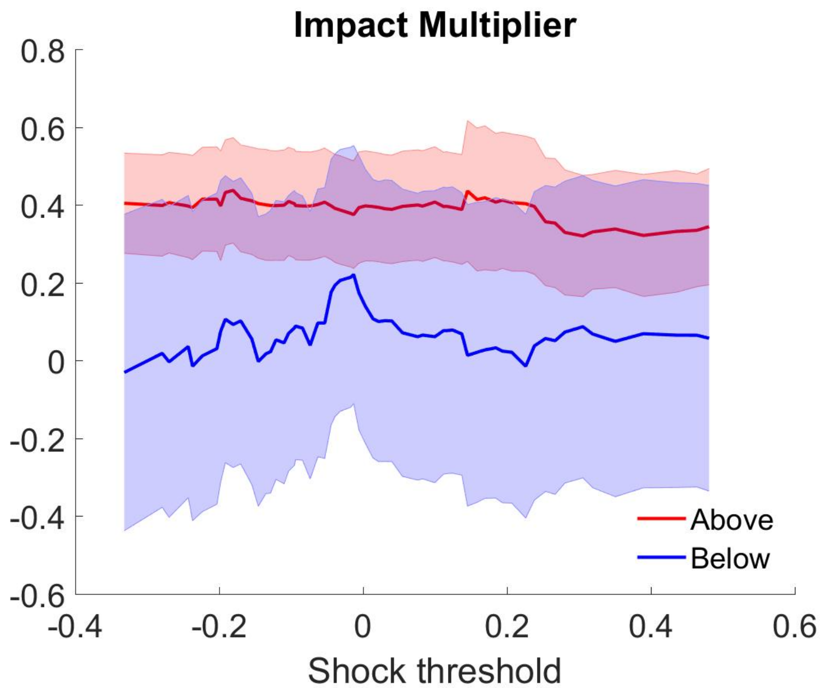

Figure 22: Average impact multiplier on the y-axis and shock threshold in percentage of GDP on the x-axis. The red line represents the average fiscal multiplier for shocks above the threshold and the blue line the average fiscal multiplier for shocks below the threshold. Results from specification (3) for different pooling of the sample

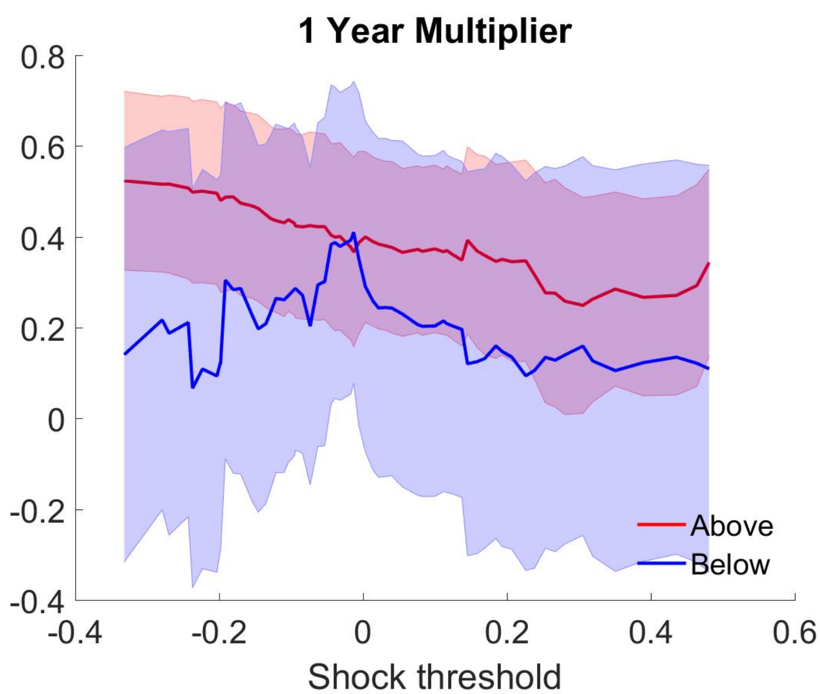

Figure 23: Average 1 year cumulative multiplier on the y-axis and shock threshold in percentage of GDP on the x-axis. The red line represents the average fiscal multiplier for shocks above the threshold and the blue line the average fiscal multiplier for shocks below the threshold. Results from specification (3) for different pooling of the sample.

B Details on 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 are hours worked, K_t is capital, w_t is the real wage, r_t^k is the rate of return on capital, B_t are 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 the household are standard

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

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,

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

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 $\delta = 0.015$; 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 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 generate 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 intermediate variety sold by firm i. These firms face quadratic costs of adjusting their prices a 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

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

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,

$$\frac{w_t}{r_t + \delta} = \frac{1-\alpha}{\alpha} \frac{K_t(i)}{L_t(i)} \tag{25}$$

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 is useful to now 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 FOC 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 $\varepsilon = 6$; 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 24 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.

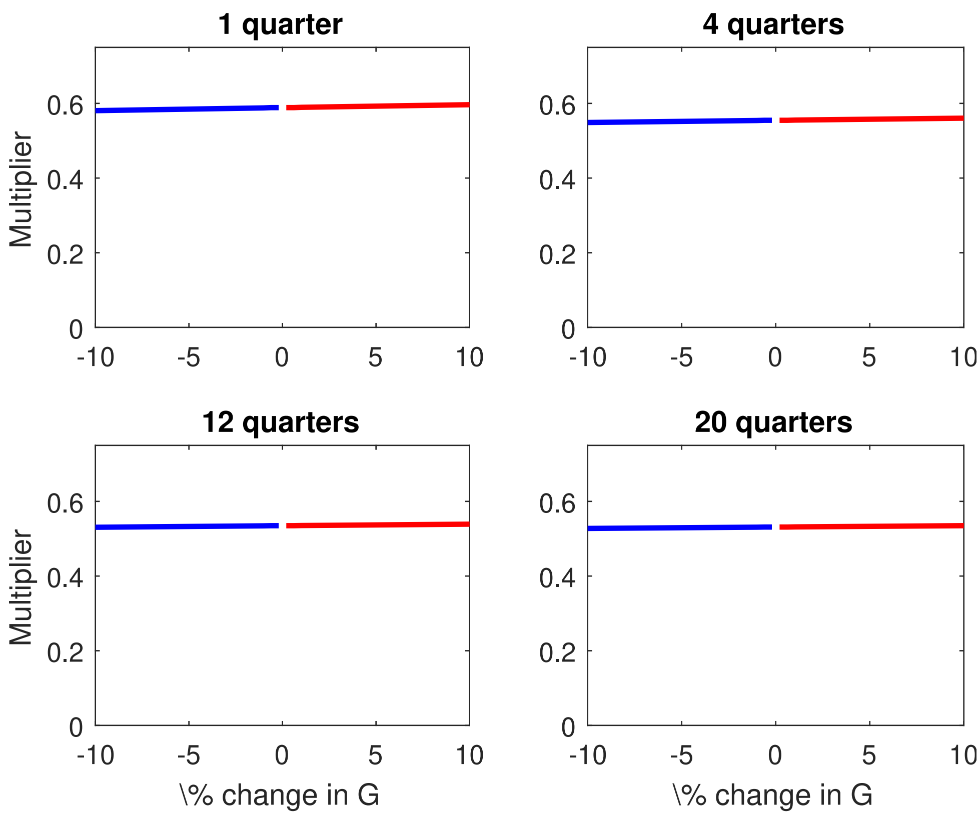

Figure 24: Representative Agent, New Keynesian Model with Infinite Adjustment Costs of Investment: fiscal multipliers as a function of the size of the variation in G, at different horizons. The blue line corresponds to G contractions, while the red line represents G expansions.

C Derivations for Section 6

The solution to the household problem is standard, where λ_t^i is the Lagrange multiplier on the borrowing constraint

$$
\begin{aligned}
(c_t^i)^\sigma (n_t^i)^\eta &= u_t^i w_t \\
(c_t^i)^{-\sigma} &= \beta \mathbb{E}_t (1 + r_{t+1})) c_{t+1}^i)^{-\sigma} + \lambda_t^i \\
c_t^i + k_{t+1}^i &= k_t^i (1 + r_t) + w_t u_t^i n_t^i - T_t \\
k_{t+1}^i &\geq -\underline{b} \perp \lambda_t^i \geq 0
\end{aligned}
$$

Combining the labor supply FOC with the budget constraint allows us to derive the response of labor supply to a change in G_t,

$$
\frac{\mathrm{d}n_t^i}{\mathrm{d}G_t} = \alpha_1(s_t^i; X_t) \frac{\mathrm{d}w_t}{\mathrm{d}G_t} + \alpha_2(s_t^i; X_t) \left[(1 - \mathbb{1}_t^i) \frac{\mathrm{d}k_{t+1}^i}{\mathrm{d}G_t} + \frac{\mathrm{d}T_t}{\mathrm{d}G_t} - k_t^i \frac{\mathrm{d}r_t}{\mathrm{d}G_t} \right] \tag{26}
$$

where

$$
\begin{aligned}
\alpha_1(s_t^i; X_t) &= \frac{\frac{n_t^i}{\eta w_t}}{1 + \frac{\sigma}{\eta} \frac{w_t n_t^i u_t^i}{c_t^i}} \left(1 - \sigma \frac{w_t n_t^i u_t^i}{c_t^i} \right) \\
\alpha_2(s_t^i; X_t) &= \frac{\frac{n_t^i}{\eta w_t}}{1 + \frac{\sigma}{\eta} \frac{w_t n_t^i u_t^i}{c_t^i}} \sigma \frac{w_t}{c_t^i}
\end{aligned}
$$

For constrained agents $\frac{\mathrm{d}k_{t+1}^i}{\mathrm{d}G_t} = 0$, but not for unconstrained ones. To determine the response of the savings policy to changes in G_t, we can combine the Euler equation with the budget constraint

$$
\begin{aligned}
\frac{\mathrm{d}k_{t+1}^i}{\mathrm{d}G_t} =& \Lambda_1(s_t^i; X_t) \frac{\mathrm{d}w_t}{\mathrm{d}G_t} + \Lambda_2(s_t^i; X_t) \left(k_t^i \frac{\mathrm{d}r_t}{\mathrm{d}G_t} - \frac{\mathrm{d}T_t}{\mathrm{d}G_t} \right) \\
& - \mathbb{E}_t \Lambda_3(s_t^i; X_t) \frac{\mathrm{d}w_{t+1}}{\mathrm{d}G_t} + \mathbb{E}_t \Lambda_4(s_t^i; X_t) \frac{\mathrm{d}r_{t+1}}{\mathrm{d}G_t} + \mathbb{E}_t \Lambda_5(s_t^i; X_t) \left(\frac{\mathrm{d}T_{t+1}}{\mathrm{d}G_t} + \frac{\mathrm{d}k_{t+2}^i}{\mathrm{d}G_t} \right)
\end{aligned}
$$

with

$$
\begin{aligned}
\kappa(s_t^i;X_t) &= \left[\frac{1-\alpha_2(s_t^i;X_t)u_t^i w_t}{c_t^i} + \mathbb{E}_t\beta\left(\frac{c_t^i}{c_{t+1}^i}\right)^{\sigma}(1+r_{t+1})^2\frac{1-\alpha_2(s_{t+1}^i;X_{t+1})u_{t+1}^i w_{t+1}}{c_{t+1}^i}\right] \\
\Lambda_1(s_t^i;X_t) &= \kappa(s_t^i;X_t)^{-1}\frac{u_t^i(\alpha_1(s_t^i;X_t)w_t+n_t^i)}{c_t^i} \\
\Lambda_2(s_t^i;X_t) &= \kappa(s_t^i;X_t)^{-1}\frac{1-\alpha_2(s_t^i;X_t)u_t^i w_t}{c_t^i} \\
\Lambda_3(s_t^i;X_t) &= \kappa(s_t^i;X_t)^{-1}\beta\left(\frac{c_t^i}{c_{t+1}^i}\right)^{\sigma}(1+r_{t+1})\frac{u_{t+1}^i(\alpha_1(s_{t+1}^i;X_{t+1})w_{t+1}+n_{t+1}^i)}{c_{t+1}^i} \\
\Lambda_4(s_t^i;X_t) &= \kappa(s_t^i;X_t)^{-1}\beta\left(\frac{c_t^i}{c_{t+1}^i}\right)^{\sigma}\left[1/\sigma-(1+r_{t+1})k_{t+1}^i\frac{1-\alpha_2(s_{t+1}^i;X_{t+1})u_{t+1}^i w_{t+1}}{c_{t+1}^i}\right] \\
\Lambda_5(s_t^i;X_t) &= \kappa(s_t^i;X_t)^{-1}\beta\left(\frac{c_t^i}{c_{t+1}^i}\right)^{\sigma}(1+r_{t+1})\frac{1-\alpha_2(s_{t+1}^i;X_{t+1})u_{t+1}^i w_{t+1}}{c_{t+1}^i}
\end{aligned}
$$

We can rewrite this expression as

$$
\frac{\mathrm{d}k_{t+1}^i}{\mathrm{d}G_t} = \Lambda_1(s_t^i;X_t)\frac{\mathrm{d}w_t}{\mathrm{d}G_t} + \Lambda_2(s_t^i;X_t)\left(k_t^i\frac{\mathrm{d}r_t}{\mathrm{d}G_t} - \frac{\mathrm{d}T_t}{\mathrm{d}G_t}\right) + \mathcal{F}(s_t^i;X_t) \tag{27}
$$

where $\mathcal{F}(s_t^i;X_t)$ takes into account all changes in future factor prices and taxes. Combining 26 with 27 yields the expression in Proposition 2.1:

$$
\begin{aligned}
\frac{\mathrm{d}n_t^i}{\mathrm{d}G_t} =& [\alpha_1(s_t^i)+\alpha_2(s_t^i)\Lambda_1(s_t^i)(1-\mathbb{1}_t^i)]\frac{\mathrm{d}w_t}{\mathrm{d}G_t} \\
&+\alpha_2(s_t^i)[1-(1-\mathbb{1}_t^i)\Lambda_2(s_t^i)]\left(\frac{\mathrm{d}T_t}{\mathrm{d}G_t} - k_t^i\frac{\mathrm{d}r_t}{\mathrm{d}G_t}\right) \\
&+\alpha_2(s_t^i)(1-\mathbb{1}_t^i)\mathcal{F}(s_t^i;X_t)
\end{aligned}
$$

The comparative statics are immediate from signing $\alpha_1,\alpha_2,\Lambda_1,\Lambda_2$.

We can write $\mathcal{F}(s_t^i;X_t)$ recursively as

$$\begin{aligned}\mathcal{F}(s_t^i;X_t) = &-\overbrace{\Lambda_3(s_t^i;X_t)[1-\Lambda_2(s_{t+1}^i;X_{t+1})]}^{\geq 0}\frac{\mathrm{d}w_{t+1}}{\mathrm{d}G_t}\\ &+[\Lambda_4(s_t^i;X_t)+\Lambda_5(s_t^i;X_t)\Lambda_2(s_{t+1}^i;X_{t+1})k_{t+1}^i]\frac{\mathrm{d}r_{t+1}}{\mathrm{d}G_t}\\ &+\overbrace{\Lambda_5(s_t^i;X_t)[1-\Lambda_2(s_{t+1}^i;X_{t+1})]}^{\geq 0}\frac{\mathrm{d}T_{t+1}}{\mathrm{d}G_t}\\ &+\Lambda_5(s_t^i;X_t)\mathcal{F}(s_{t+1}^i;X_{t+1})\end{aligned}$$

It is possible to show that

$$k_{t+1}^i < 0 \Rightarrow [\Lambda_4(s_t^i;X_t)+\Lambda_5(s_t^i;X_t)\Lambda_2(s_{t+1}^i;X_{t+1})k_{t+1}^i] > 0$$

In which case we can show that $\mathcal{F}(s_t^i;X_t)\geq 0$ for

$$\frac{\mathrm{d}r_{t+j}}{\mathrm{d}G_t}\geq 0\ ,\ \frac{\mathrm{d}w_{t+j}}{\mathrm{d}G_t}\leq 0\ \text{,and}\ \frac{\mathrm{d}T_{t+j}}{\mathrm{d}G_t}\geq 0, \forall j\geq 0$$

C.1 Derivation of the Firm's Problem with Nominal Rigidities

In the baseline model, firms are not responsible for the investment decision, they simply choose factors statically. This means that it is possible to split the firm's problem into a static one (factor choice/cost minimization) and a dynamic one (price setting/output choice). It is easier to set up the firm's problem recursively. The firm's value in nominal terms is

$$\begin{aligned}P_tV_t[P_{t-1}(i);X_t] = \max_{P_t(i),Y_t(i),K_t(i),L_t(i)} & P_t(i)Y_t(i) - P_tw_tL_t(i) - P_t(r_t+\delta)K_t(i) - P_t\Xi_t(i)\\ &+\mathbb{E}_t\frac{\Lambda_{t,t+1}}{\Pi_{t+1}}P_{t+1}V_{t+1}[P_t(i);X_{t+1}]\end{aligned}$$

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 by inflation (as we are discounting nominal payoffs). We first solve the static problem, which is to minimize costs given a desired level of production. This solves the factor choice problem and generates the expression for total costs,

$$\min_{L_t(i), K_t(i)} w_t L_t(i) + (r_t + \delta) K_t(i)$$

subject to $Y_t(i) \leq A_t K_t(i)^{\alpha} L_t(i)^{1-\alpha}$. Letting λ_t be the Lagrange multiplier on the production constraint, the FOC's are

$$w_t = \lambda_t A_t (1-\alpha) K_t(i)^{\alpha} L_t(i)^{-\alpha}$$

$$r_t + \delta = \lambda_t A_t \alpha K_t(i)^{\alpha-1} L_t(i)^{1-\alpha}$$

We can combine them to generate the standard condition for cost minimization,

$$\frac{w_t}{r_t + \delta} = \frac{1-\alpha}{\alpha} \frac{K_t(i)}{L_t(i)} \tag{28}$$

From this condition, we can derive an expression for total costs that is useful to solve the dynamic problem. Notice that it allows us to write the optimal choice of capital as a function of labor and factor prices, $K_t(i) = \frac{w_t}{r_t+\delta} \frac{\alpha}{1-\alpha} L_t(i)$. We can replace for capital in the production function to write

$$Y_t(i) = A_t\left[\frac{w_t}{r_t+\delta}\frac{\alpha}{1-\alpha}L_t(i)\right]^{\alpha} L_t(i)^{1-\alpha} = A_t\left[\frac{w_t}{r_t+\delta}\frac{\alpha}{1-\alpha}\right]^{\alpha} L_t(i)$$

This means that we can write

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

Thus allowing us to write total (real) costs as a function of desired production $Y_t(i)$ and factor prices,

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

We can now replace this expression in the firm's value function and solve a problem just in terms of total prices and output choices (now expressed in real terms),

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

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 FOC 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

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

While this equation seems complicated, we now make a simplifying assumption: except for $P_{t-1}(i)$, all firms are otherwise identical as their factor choice is static. If all firms start with the same chosen price level, their choice for a current price level will also be identical.

Aggregate Supply Equilibrium Conditions The set of equilibrium conditions is then

$$
\begin{aligned}
\frac{r_t+\delta}{w_t}&=\frac{\alpha}{1-\alpha}\frac{L_t}{K_t}\\
MC_t&=\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t+\delta}{\alpha}\right)^{\alpha}\frac{1}{A_t}\\
[(\varepsilon-1)-\varepsilon MC_t]+\xi\left(\frac{\Pi_t}{\Pi}-1\right)\frac{\Pi_t}{\Pi}&=\mathbb{E}_t\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}\xi\left(\frac{\Pi_{t+1}}{\Pi}-1\right)\frac{\Pi_{t+1}}{\Pi}
\end{aligned}
$$

D Parameters

Parameter	Value	Description	Source
Preferences			
η	1	Inverse Frisch Elasticity	Trabandt and Uhlig (2011)
σ	1.2	Risk aversion parameter	Literature
Technology			
α	0.33	Capital share of output	Literature
δ	0.015	Capital depreciation rate	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	
θ_1	0.137	Income tax progressivity	OECD
τ_c	0.047	Consumption tax	Trabandt and Uhlig (2011)
τ_k	0.364	Capital tax	Trabandt and Uhlig (2011)
$\tilde{\tau}_s s$	0.077	Social security tax: employer	OECD 2001-2007
$\tau_s s$	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	US Data
G/Y	0.15	Government spending to GDP ratio	US Data
g/Y	0.07	Transfers to GDP ratio	Hagedorn et al. (2016)

E Robustness: Micro evidence of the mechanism

$$\ln h_t = c + \beta_1 \sum_{i=0}^{1} g_{t-i} + \beta_2 \Delta B_t + \beta_3 \Delta B_t \sum_{i=0}^{1} g_{t-i} + \alpha_i + \gamma_t + \epsilon_t \tag{29}$$

VARIABLES	(1) Below Median Wealth	(2) Above Median Wealth
β_1	0.095*	0.070*
	(0.055)	(0.038)
β_2	1.035*	0.533
	(0.560)	(0.381)
β_3	-0.052*	-0.027
	(0.027)	(0.018)
Constant	-1.886*	-1.519**
	(1.055)	(0.733)
Observations	37,712	43,947
Number of ID	12,661	10,563

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

Table 22: G shock, labor supply response and financing regime by total wealth