The Young, the Old, and the Government: Demographics and Fiscal Multipliers*

Henrique S. Basso
Banco de España

Omar Rachedi
Banco de España

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Abstract

We document that government spending multipliers depend on the age structure of the population. Using the variation in military spending and birth rates across U.S. states, we show that local fiscal multipliers increase with the share of young people in total population. We rationalize this fact with a parsimonious life-cycle open-economy New Keynesian model with age-specific differences in labor supply and demand, and credit market imperfections. The model explains 87% of the relationship between local fiscal multipliers and demographics, and implies that the U.S. population aging between 1980 and 2015 caused a 38% drop in national government consumption spending multipliers.

Key Words: Life-cycle, Population Aging, Government Consumption Spending.

JEL Classification Codes: E30, E62, J11.

*Addresses: henrique.basso@bde.es and omar.rachedi@bde.es. The views expressed in this paper are those of the authors and do not necessarily represent the views of the Banco de España or the Eurosystem. We thank Florian Bilbiie, Jesus Fernandez-Villaverde, Yuriy Gorodnichenko, Basile Grassi, Alexandre Janiak, Matthias Kredler, Dirk Krueger, Alexander Ludwig, Alisdair McKay, Claudio Michelacci, Nicola Pavoni, William Peterman, Emiliano Santoro, Ctirad Slavik, Harald Uhlig, Ernesto Villanueva, Minchul Yum, and presentation participants at the Pontificia Universidad Catolica de Chile, University of Copenhagen, Bank of Canada, Federal Reserve Bank of New York, Stony Brook University, CEFER at the Bank of Lithuania, CERGE-EI, Universidad Carlos III de Madrid, University of Glasgow, University of Oxford, Banco de Portugal, Latvijas Banka, the RES Conference in Bristol, the IBEO Workshop in Alghero, the CEF Conference in New York, the EEA-ESEM Meeting in Lisbon, the Money Macro and Finance Conference in London, the Macro Banking and Finance Workshop in Milan, the ESCB Research Cluster Workshop on "Medium and long-run challenges for Europe", the SAEe Meeting in Barcelona, the Workshop on Fiscal Policy in EMU: The Way Ahead in Frankfurt, the Conference on Theories and Methods in Macroeconomics in Paris, the CEPR Conference on "Growth and Inequality: Long-Term Effects of Short-Term Policies" in Tel Aviv, the Bristol Macro Workshop, the World Bank-Banco de España Conference on "Output Fluctuations and Long-Term Growth" in Madrid, the Portuguese Economic Journal Conference in Lisbon, the Conference on "Growth and Business Cycle in Theory and Practice" in Manchester, and the LuBraMacro Workshop in Aveiro for useful comments and suggestions.

1 Introduction

Every time a government considers a plan of fiscal stimulus or fiscal consolidation, there is a strong debate among policymakers, journalists, and economists on the effectiveness of such a policy. This effectiveness is often summarized by the size of the fiscal multiplier, which measures how much output expands following a rise in government spending. Nevertheless, fiscal multipliers are not constant structural parameters, but rather they depend on the characteristics of the economy.

This paper sheds light on a novel determinant of the size of the government consumption spending multiplier: the age structure of the economy. We study a panel of output, military spending, and demographic characteristics across U.S. states and document that local fiscal multipliers rise with the share of young people in total population. We show that a parsimonious life-cycle open-economy New Keynesian model with credit market imperfections and age-specific differences in labor supply and demand explains 87% of the link between local fiscal multipliers and demographics. The model implies that the aging of the U.S. population between 1980 and 2015 caused a 38% drop in national government spending multipliers.

We focus on the differences across U.S. states to uncover the causal effect of demographics on fiscal multipliers. The identification comes from the cross-state variation in the share of young people in total population. As states' age structure can respond to government spending shocks through migration flows, we exploit the heterogeneity in fertility across U.S. states and instrument the share of young people with lagged birth rates. Then, we identify the government spending shocks by leveraging the heterogeneity in the geographical distribution of government military spending, as in Nakamura and Steinsson (2014). Our identification approach is further corroborated by the lack of correlation across states between the geographical distribution of military spending and the age structure.

In our benchmark regression, the size of fiscal multipliers depends positively on the share of young people (aged 20 - 29) in total population: increasing the share of young people by 1% above the average share across U.S. states raises the local output fiscal multiplier by 3.1%, from 1.51 up to 1.56. These estimates imply an inter-quantile range of output fiscal multipliers across U.S. states that varies between 1.2 and 1.7. We run a comprehensive battery of robustness checks and find that the age sensitivity of local fiscal multipliers is always highly economically and statistically significant. In particular, we show that the age-sensitivity of local fiscal multipliers holds above and beyond any effect that differences across states in the unemployment rates, the Gini indexes of labor earnings, and the sectoral compositions of value added - among other variables - have on the propagation of military spending on output.

To rationalize the link between demographics and fiscal multipliers, we build a life-cycle open-economy New Keynesian model with age-specific differences in labor supply and labor demand, and credit market imperfections. We consider a staggered price setting model with two countries that belong to a monetary union. The household sector has a life-cycle structure, whereby individuals face three stages of life: young, mature, and old. Following Gertler (1999), we define a framework in which the optimal choices of the individuals within each age group aggregate linearly. Although this approach reduces the relevance of differences *within* age groups, it allows us to emphasize the heterogeneity *across* age groups and incorporate nominal rigidities and open economy interactions into a tractable environment. In this way, our model extends a standard two-country New Keynesian economy with a rich life-cycle structure.

The model features age-specific differences in both labor supply and labor demand. On the one hand, the labor supply elasticity varies exogenously across the three age groups. In the empirically relevant case, young and old workers have a higher labor supply elasticity than mature workers. On the other hand, we follow Jaimovich et al. (2013) and posit that the production function is characterized by capital-experience complementarity. The demand of experience labor is relatively more persistent over the cycle as it is tied to the stock of capital. Instead, young labor is less complementary to capital, and thus its demand is relatively more volatile. These two mechanisms allow the model to be consistent with the high volatility of hours worked and hourly wages of young workers observed in the data (e.g., Rios-Rull, 1996; Gomme et al., 2005; Jaimovich and Siu, 2009).

We also consider credit market imperfections. Households can trade capital and bonds but cannot perfectly smooth consumption because markets are incomplete. In the baseline model, we restrict further households' borrowing capacity with an ad-hoc constraint which does not allow any borrowing at all. Since young households face a hump-shaped labor income over the life-cycle, they want to borrow and smooth lifetime consumption. Yet, credit market imperfections limit the consumption smoothing and boost the marginal propensity to consume of young households well above the one of mature households, as it is in the data.[1]

In the model, young households are then characterized by very elastic employment outcomes and a relatively high marginal propensity to consume. Consequently, as the proportion of young workers increases, a government consumption spending shock triggers a larger response of both labor and consumption, implying a larger output fiscal multiplier.

In the quantitative analysis, the model explains almost entirely the size of fiscal multipliers and 87% of the link between fiscal multipliers and demographics: increasing the share of young people by 1% above the average share across U.S. states raises the local output fiscal multiplier by 2.7%, from 1.46 up to 1.50. We then measure the contribution of the different mechanisms of the model to this result. We find that the ad-hoc borrowing constraint and incomplete credit markets account each one for 30% of the age sensitivity of local multipliers, whereas the age-specific

[1]Young households have a number of characteristics associated with a higher marginal propensity to consume. For instance, young households own much less liquid assets than older households and the marginal propensity to consume depends negatively on the amount of liquid assets (Kaplan et *al.*, 2014; Misra and Surico, 2014).

labor demand through the capital-experience complementarity accounts for 33% of it. Instead, the age-specific labor supply elasticities play a minor role and explain only the remaining 7%.

Focusing on regional data allows us to leverage local heterogeneity to identify fiscal multipliers and their sensitivity to demographics. Yet, the effectiveness of fiscal policy should also be evaluated at the national level, taking account of all general equilibrium mechanisms.[2] Since our theoretical model is consistent with the empirical evidence on local multipliers, it represents an ideal laboratory to study the evolution of national fiscal multipliers in light of the progressive aging of the U.S. population. The model implies that the drop in the share of young people from 1980 to 2015 caused a 38% reduction in the size of the national output fiscal multiplier. Since most advanced economies are experiencing a gradual population aging, the model suggests that over time fiscal stimulus through government consumption spending could become a relatively less effective tool to spur economy activity.[3]

This paper is related to the literature that focuses on the implications of demographics for long-run trends (Krueger and Ludwig, 2007; Aksoy et *al.*, 2019; Carvalho et *al.*, 2016), and short-term fluctuations (Jaimovich and Siu, 2009; Wong, 2018). The implications of demographics for the aggregate effects of fiscal policy have been highlighted by Anderson et *al.* (2016), Janiak and Santos-Monteiro (2016), and Ferraro and Fiori (2019). Our paper differs from this strand of the literature on two main dimensions. First, we focus on the elasticity of output to fiscal shocks. Following Nakamura and Steinsson (2014) and Chodorow-Reich (2019), we exploit the heterogeneity across U.S. states and estimate the causal effect of demo-

[2]Nakamura and Steinsson (2014) and Chodorow-Reich (2019) show that local fiscal multipliers consider the local impact of federally financed policies and wash out any monetary policy response to government spending. Both features make local multipliers larger than national ones. On the other hand, local multipliers are dampened by expenditure switching and import leakage effects that do not take place at the national level.

[3]This result refers to the effectiveness of fiscal policy in normal times. The literature has highlighted cases in which fiscal multipliers are very high, e.g., when the economy is at zero lower bound (Christiano et al., 2011; Woodford, 2011) or there is slack in the economy (Auerbach and Gorodnichenko, 2012; Rendahl, 2016).

graphics on fiscal multipliers.[4] Second, we build a quantitative model that can be used as a laboratory to measure the effects of changes in the age structure of the economy on fiscal multipliers.

2 Empirical Evidence

This section shows that local fiscal multipliers depend on demographics: fiscal multipliers are larger in states with higher shares of young people in total population.

We study a panel of output, government military spending, and demographic characteristics across U.S. states. To estimate the effect of government spending on output - and how this effect depends on the age structure of each state - we use the variation across U.S. states in both military buildups and birth rates. This procedure identifies the *local fiscal multiplier*, which is a federally-financed open-economy relative multiplier. This multiplier estimates the response of output in a specific state (say, California) relative to the response of output of all the other U.S. states when the federal government spends one extra dollar in California, and this dollar is financed by taxing individuals in all U.S. states.

2.1 Data

We build a data set of government military spending, output, and demographic characteristics across the 50 U.S. states and the District of Columbia at the annual frequency from 1967 until 2015.

We complement the data on the geographical distribution of military spending of Nakamura and Steinsson (2014) with information from the Statistical Abstract of the U.S. Census Bureau and the website usaspending.org of the U.S. Office of

[4] Anderson et *al.* (2016) and Ferraro and Fiori (2019) exploit the variation across age groups at the national level and derive the responses of consumption and unemployment to tax shocks identified with the narrative approach of Romer and Romer (2010). Instead, we leverage the variation at a relatively more disaggregated level, by looking at the variation at the age group-state level.

Management and Budget. The data cover any procurement of the U.S. Department of Defense above 10,000$ up to 1983, and above 25,000$ from 1983 on.

State output is the state GDP series of the Bureau of Economic Analysis (BEA). State employment is taken from the Current Employment Statistics of the Bureau of Labor Statistics (BLS). The data on state population and births rates are from the Census Bureau. The data on births rates are from 1930 onwards. The birth rates of Alaska and Hawaii are available only from 1960 onwards. The data on the state demographic structure by age, race, and sex are from the Survey of Epidemiology and End Results of the National Cancer Institutes.

2.2 Econometric Specification

We estimate the causal effect of demographics on local output fiscal multipliers using the following panel regression:

$$\frac{Y_{i,t} - Y_{i,t-2}}{Y_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} + \gamma \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} \left(D_{i,t} - \bar{D}\right) + \zeta D_{i,t} + \epsilon_{i,t} \quad (1)$$

where $Y_{i,t}$ denotes per capita output in state i at time t, $G_{i,t}$ refers to per capita federal military spending allocated to state i at time t, $D_{i,t}$ is the log-share of young people over total population in state i at time t multiplied by 100, $\bar{D} = \sum_i \sum_t \frac{D_{i,t}}{n_i n_t}$ is the average log-share of young people,[5] and n_i denotes the number of states and n_t the number of years in the sample. The parameter α_i is a state fixed effect, and δ_t denotes time fixed effects. The fixed effects capture any state-specific trend in output, government spending, and demographics, and control for aggregate shocks, such as variations in the national monetary policy stance.[6]

[5]The demeaning of the share of young people allows us to interpret β as the local fiscal multiplier on a state with the average share of young people, but has no effect on the estimation of the age sensitivity γ.

[6]Following Nakamura and Steinsson (2014), we consider two-year changes in output and government spending to capture in a parsimonious way the dynamic effects of fiscal policy. Appendix A.3 shows that controlling for dynamics by adding lag terms of both output and government spending does not alter our conclusions. The same applies if we control for state-specific time trends. Appendix A.4 shows that results do not change if we consider a one-year impact multiplier, a four-year impact multiplier, and a two-year cumulative fiscal multiplier

In the baseline regression we consider the share of young people as the ratio of 20-29 years old white males over the total population of white males. We focus on the white male population to avoid that the different trends across U.S. states in the labor participation of female workers and workers of other racial groups could be confounding factors that spuriously drive the effect of changes in the age structure of the population on the size of local fiscal multipliers. In the robustness checks, we show that our results do not change if we consider either all males or the entire population of 20-29 years old individuals.

In Equation (1) the coefficient β denotes the local output fiscal multiplier: it defines the dollar increase in per-capita output following a one dollar increase in per-capita federal government spending in a state with the average share of young people. The parameter γ is associated to our regressor of interest, which is the interaction between changes in federal government spending and the share of young people in total population. This parameter defines how fiscal multipliers vary with the age structure of a state: when the share of young people rises by 1% above the average, the fiscal multiplier increases from β up to $\beta + \gamma$.

We also estimate the effect of government spending on state employment rate with a similar regression, in which the dependent variable is the growth rate of state employment rate $E_{i,t}$:

$$\frac{E_{i,t} - E_{i,t-2}}{E_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} + \gamma \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} \left(D_{i,t} - \bar{D}\right) + \zeta D_{i,t} + \epsilon_{i,t}. \quad (2)$$

We identify government spending shocks following the approach of Nakamura and Steinsson (2014), which exploits the heterogeneous sensitivity of states' military procurements to an increase in federal military spending.[7,8] This IV strategy implies

rather than a two-year impact fiscal multiplier. Finally, we show that the use of Driscoll and Kray (1998) standard errors does not alter the level of statistical significance of our estimates.

[7]E.g., federal military spending as a fraction of national GDP dropped by 1.5% following the U.S. withdrawal from Vietnam. The withdrawal had large heterogeneous effects across U.S. states: in California federal military procurements as a fraction of the state GDP decreased by 2.5%, while Illinois experienced a drop of just 1%.

[8]The use of military spending to estimate national fiscal multipliers follows the work of Barro (1981), Barro

a first stage regression in which per capita state military procurement (as a fraction of per capita state GDP) is regressed against the product of per capita national military spending (as a fraction of per capita national GDP) and state fixed effects:

$$\frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} = \alpha_i + \delta_t + \eta_i \frac{G_t - G_{t-2}}{Y_{t-2}} + \varphi X_{i,t} + \epsilon_{i,t} \tag{3}$$

where $X_{i,t}$ includes the instruments for both the share of young people and its interaction with the changes in government spending. The coefficient η_i captures the heterogeneous exposure of each state to a rise in federal military spending. This first stage allows us to capture the systematic fixed state-level sensitivity to changes in federal spending, which by construction is orthogonal to any variation in either the political process or the local business cycle that may alter the allocation of spending across states. Furthermore, from 2000 to 2015 the correlation between state-level measures of federal military purchases and the spending of local and state governments is 0.24, suggesting that the bulk of the variation in the allocation of military spending is not driven by state-specific dynamics.[9]

Then, we evaluate whether the effects of government spending shocks on output and employment depend on states' age structure. The panel dimension of the data is crucial to identify the link between demographics and fiscal multipliers. Since our baseline regression features state and time fixed effects, the identification comes from the cross-state variation - and its changes over time - in the share of young people in total population. At any point in time, there is a large dispersion across states in the share of young people. For instance, in 2015 the share of young people

and Redlick (2011), and Ramey (2011), among many others. This strand of the literature considers national military spending as exogenous. The implicit assumption is that the U.S. do not embark in a war because national output is low. Our instrument relies on a much weaker exogeneity restriction: we posit that the U.S. do not embark in a war because the output of a specific state is lower than the output of all other states.

[9]We estimate local multipliers by leveraging the variation in military procurements to explicitly rule out the components of government spending that relate to public wage bill, transfers, and the provision of public services. In this way, our estimates can hardly be due to the fact that households in young states are more likely to be transfer recipients. This claim is further corroborated by the low correlation between state-level measures of military purchases and the spending of local and state government.

ranges between the 11.9% of Maine and the 22.6% of D.C. Moreover, the relative ranking across states has been changing over time. As an example, in 1980 New York had the fourth lowest share of young people in the U.S. Yet, in 2015 the share of young people of New York has become the tenth highest in the U.S.

States' age structure would not be exogenous to government spending shocks if they trigger migration flows. To avoid any concern on the endogeneity of demographics, we follow Shimer (2001) and instrument the share of young people with lagged birth rates.[10] This IV strategy allows us to identify the causal effect of states' age structure on fiscal multipliers. In our baseline specification, we instrument the share of young people with 20-30 year lagged birth rates: we use the average birth rate between 1940 and 1950 to instrument the share of young people in 1970.[11] Finally, including the share of young people independently from the interaction with government spending – through the presence of the term $\zeta D_{i,t}$ in Equations (1) and (2) – allows us to control for the potential direct channel whereby changes in the age-structure of population and fertility rates affect per-capita output. In this way, the interaction term captures any effect through which demographics shape the output effects of government spending that hold above and beyond the direct impact that demographics have on per-capita GDP.

2.3 Results

Table 1 reports the results of the benchmark regressions estimated using instrumental variables for both military spending and the share of young workers.

Column (1) refers to the regression in which the dependent variable is the change in output per capita. The first entry shows that the local output fiscal multiplier for a state with an average share of young people (e.g., Massachusetts and Nevada) is

[10] Appendix A.7 shows that lagged birth rates explain the bulk of the variability of the age structure of the population across states and time.

[11] The birth rates for Alaska and Hawaii start in 1960. The results do not change if we consider either an unbalanced panel of birth rates, or we use 10 year lagged birth rates for Alaska and Hawaii.

Table 1: Response to a Government Expenditure Shock across U.S. States

	(1) Output per Capita	(2) Employment Rate
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.511***	1.095***
	(0.406)	(0.215)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times \left(D_{i,t} - \bar{D}\right)$	0.047***	0.034***
	(0.016)	(0.011)
$D_{i,t}$	0.002***	0.001
	(0.001)	(0.001)
First-Stage F Statistic	13.21	11.96
R^2	0.374	0.621
N. Observations	2374	2374

Note: The table reports the estimates of a panel IV regression across U.S. states using data from 1967 to 2015 at an annual frequency. In regression (1) the dependent variable is the change in output per capita. In regression (2) the dependent variable is the change in employment rate. The independent variables are the change in per capita state government spending (as a fraction of per capita state GDP), $\left(G_{i,t} - G_{i,t-2}\right)/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita state government spending (as a fraction of per capita state GDP) and the log-share of young people, $\left[\left(G_{i,t} - G_{i,t-2}\right)/Y_{i,t-2}\right] \times \left(D_{i,t} - \bar{D}\right)$. In both regressions, changes in per capita state government spending (as a fraction of per capita state GDP) are instrumented with the product of state fixed effects and the change in per capita national government spending (as a fraction of per capita national GDP). The share of young people is instrumented with 20-30 year lagged birth rates. We include time and state fixed effects in all regressions. Robust standard errors clustered at the state level are reported in brackets. *** indicates statistical significance at the 1%.

statistically significant at the 1% level and equals 1.51. This result implies that – in a state with the average share of young people in total population – one additional dollar of per-capita federal military spending raises per-capita output by 1.51 dollars.[12] Also the estimated value of the parameter γ associated with the interaction term is highly statistically significant, with a p-value of 0.005. The value of the estimated parameter points out that the effect of demographics on local output fis-

[12]Dupor and Guerrero (2017) show that including the years of the Korean war yields an estimate of the local fiscal multiplier which is not statistically different from zero. This result hinges on two particular years, 1953 and 1954. In the robustness checks, we show that although the level of local multipliers may vary across specifications, the age sensitivity barely changes.

cal multipliers is also highly economically significant: increasing the share of young people by 1% above the average raises output fiscal multipliers by 3.1%, from 1.51 up to 1.56. These estimates imply an inter-quantile range of output fiscal multipliers across U.S. states that varies between the values of 1.2 in Ohio and 1.7 in Arizona. Column (2) displays the results of the regression in which the dependent variable is the change in the employment rate. For a state with an average share of young people, the local employment fiscal multiplier equals 1.10. Demographics affect also the local employment fiscal multiplier: increasing the share of young people by 1% in absolute terms above the average raises employment fiscal multipliers by 3.1%, from 1.10 up to 1.13. Finally, the high values associated with the Kleibergen-Paap Wald statistic in both regressions – which are also higher than the values of the partial F-statistic in Nakamura and Steinsson (2014) – corroborate the validity of our instrumenting strategy.

To assess whether the age sensitivity of local fiscal multipliers hinges on a particular econometric specification, we run a comprehensive battery of robustness checks. Table 2 reports the first of alternative specifications for the estimates of both the local output fiscal multiplier (Panel A) and the local employment fiscal multiplier (Panel B). In either case, the first column displays the results of the baseline regression. The following columns show the results for the OLS regression, the "partial" IV regression in which we instrument state government spending but we do not instrument the share of young people, an IV regression in which we use a different measure of young people (those aged 15-29)[13], and an IV regression in which we use a different measure of birth rates (25 years lagged birth rates). Finally, we estimate the fiscal multipliers in regressions in which the share of young people is computed over the entire male population and the overall population, rather than using only the white male population.

[13] The age sensitivity of local fiscal multipliers is always highly statistically significant even in case we consider different definitions of young people, such as individuals between 20 and 34 years old, or individuals between 15 and 34 years old. The results are available upon request.

Table 2: Response of Output & Employment Rate to Government Shocks - Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Baseline	Baseline	No IV Birth Rates	Share Age 15-29	Birth Rates 25 Year Lag	All Men	Men & Women
	IV	OLS	"Partial" IV	IV	IV	IV	IV
Panel A. Response of Output							
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.511***	0.109	1.515***	1.251***	1.451***	1.664***	1.613***
	(0.409)	(0.112)	(0.468)	(0.394)	(0.396)	(0.432)	(0.435)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t}-\bar{D})$	0.047***	0.011*	0.067**	0.051**	0.051***	0.066**	0.060**
	(0.017)	(0.006)	(0.028)	(0.024)	(0.017)	(0.028)	(0.025)
$D_{i,t}$	0.002***	0.002***	0.002***	0.003***	0.001	0.002**	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.374	0.390	0.330	0.382	0.411	0.362	0.364
N. Observations	2374	2397	2397	2374	2366	2374	2374
Panel B. Response of Employment Rate							
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.095***	0.180**	1.046***	0.959***	1.097***	1.091***	1.075***
	(0.215)	(0.076)	(0.236)	(0.210)	(0.210)	(0.226)	(0.220)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t}-\bar{D})$	0.034***	0.001	0.025**	0.038**	0.035***	0.038**	0.039**
	(0.011)	(0.005)	(0.010)	(0.016)	(0.010)	(0.017)	(0.016)
$D_{i,t}$	0.001	0.001	0.001	0.001**	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.621	0.635	0.590	0.627	0.627	0.625	0.624
N. Observations	2374	2397	2397	2374	2366	2374	2374

Note: The table reports the estimates of panel regressions across U.S. states from 1967 to 2015 at an annual frequency. In Panel A the dependent variable is the change in output per capita. In Panel B the dependent variable is the change in the employment rate. If not stated otherwise, the independent variables are the change in per capita state government spending (as a fraction of per capita state GDP), $(G_{i,t}-G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita state government spending (as a fraction of per capita state GDP) and the log-share of young people, $[(G_{i,t}-G_{i,t-2})/Y_{i,t-2}] \times (D_{i,t}-\bar{D})$. In the IV regressions, state-specific changes in per capita state government spending (as a fraction of per capita state GDP) are instrumented with the product of state fixed effects and the change in per capita national government spending (as a fraction of per capita national GDP). The share of young people is instrumented with 20-30 year lagged birth rates. Regression (1) displays the results of the benchmark IV regressions. Regression (2) shows the results of the regression estimated by OLS. In regression (3) we instrument state government spending but we do not instrument the share of young people. In regression (4) we use the share of the people aged 15-29 in total population as independent variable. In regression (5) we instrument the share of young people with 25 year lagged birth rates. In regression (6) we compute the share of young people not focusing only on white men, but rather on all men. In regression (7) we compute the share of young people not focusing only on white men, but rather on the entire population of young men and women. We include time and state fixed effects in all the regressions. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

The difference in magnitude between IV and OLS estimates tend to be analogously large in the entire strand of the literature on local fiscal multipliers, independently on the instrumenting approach or the type of government spending or tax under study (e.g., Nakamura and Steinsson, 2014; Suarez-Serrato and Wingender, 2016; Chodorow-Reich, 2019). This finding indicates that OLS estimates are affected by both the attenuation bias generated by measurement errors in federal military spending and fiscal foresight dynamics (e.g., Ramey, 2011; Auerbach et al., 2019). Our instrumenting strategy corrects for these biases.

The "partial" IV regression yields an estimated coefficient of the interaction between changes in government spending and the share of young people which is larger for the response of output (and smaller for the response of the employment rate) than in the baseline IV regression. This difference could be driven by the endogenous reaction of states' migration flows to a government spending shock, in line with the findings of Blanchard and Katz (1992). If migration raises the population, then it would boost further the change in output, while dampening the response of the employment rate. In Appendix A.5 we confirm this conjecture by showing that although total population does not change following a fiscal shock, the population of young people does rise. This evidence strengthen the relevance of instrumenting the share of young people to avoid any endogeneity concern driven by state migration flows.

Columns (4) and (5) show that the relationship between demographics and fiscal multipliers does not hinge on a specific definition of the young group or instrumenting strategy. Finally, columns (6) and (7) show that the estimated effect of a change in demographics on fiscal multipliers becomes even larger when computing the share of young people over either the entire male population or the overall population: a 1% increase in the share of young people rises the size of fiscal multipliers by around 3.7% - 4%. This pattern is consistent with the fact that white males have a much lower elasticity of labor supply than females and individuals of other racial groups.

2.4 Validation of Exclusion Restrictions on Demographics

Our identification of the age-sensitivity of local fiscal multipliers hinges on instrumenting the current share of young people in total population with lagged birth rates. Our implicit exclusion restriction posits that, conditional on state and time fixed effects, whatever determines the cross-sectional variation in births rates has no other long lasting effect on the size of fiscal multipliers 20-30 years later. Our IV approach would not be valid if the sensitivity to federal government shocks - i.e., η_i of Equation (3) - is related to states' age structure. Yet, in the data the correlation between states' demographic structures and sensitivity to federal government shocks is -0.03. Thus, the geographical distribution of military spending is not related to demographics, corroborating our identification approach.

Local fiscal multipliers could also depend on several alternative sources of heterogeneity across states. However, in order to violate our restriction these alternative mechanisms must necessarily display a very narrow set of correlations (within states and within years) with both current military spending shocks and lagged birth rates.[14] To validate the exclusion restriction of our IV approach, first we report in Table 3 the correlation of the share of young people in total population with a number of state-level key variables which could drive the effects of military spending on output, and could display dynamics across states and over time similar to the observed changes in the age structure of the population.

The first confounding factor we consider is the unemployment rate. Young individuals tend to be relatively more unemployed, and Auerbach and Gorodnichenko (2012) and Nakamura and Steinsson (2014) find that fiscal multipliers may be larger in times of slack. The demographic transition might also be related to the process

[14] We are not concerned about mechanisms that hinge on demographics and affect local fiscal multipliers, such as the role of changes in the cross-sectional distribution of consumption, labor earnings, and wealth that depend *uniquely* on the variation in the age structure of the population. Although not all these mechanisms are active in our quantitative model, they still belong to the causal effect of changes in the age structure of the population on local fiscal multipliers.

of structural transformation from manufacturing to services, and Bouakez et al. (2018) highlight that fiscal multipliers depend on the sectoral composition of spending. For this reason, the second set of variables we study refer to state's sectoral composition, and include the share of services value added over total value added, the share of personal services over total value added and the share of health care services over total value added. We evaluate also the role of the Gini index of labor earnings as a potential confounding factor since Brinca et *al.* (2016) and Hagedorn et *al.* (2019) show that the cross-sectional distribution of labor earnings influences the size of the fiscal multiplier. Then, we consider measures of personal income taxation and unemployment benefits because the age structure of the population of a state could also determine its average per-capita amount of taxes and transfers, and Oh and Reis (2012) argue that the aggregate effects of fiscal policy depend crucially on the distribution of tax/transfers across households. Finally, we study measures of skilled labor and female labor participation, as the U.S. economy has experienced dramatic compositional changes in the labor market which occurred contemporaneously to the demographic transition towards old ages.

Table 3 shows heterogeneity in the co-movements of these key variables with the share of young people: the share of health care services in total value added and the measure of skilled labor have the largest correlations with values around -0.5, whereas the personal income taxation and the Gini index of labor earnings have a very weak correlation with the age structure of population, with values around -0.1. Importantly, even for the two variables with the highest correlations, the relationship with the share of young people weakens substantially if we run a simple panel regression that controls also for time and state fixed effects. In this case, the relationship between the health services share and the age structure is not anymore statistically significant, whereas for the case of skilled labor the statistical significance drop to just 10%. As in our regression we exploit the cross-state and over-time variation, these results confirm that the driving force of the age sensitivity of fiscal multipliers is unlikely to hinge on other confounding factors.

Table 3: Correlations with Share of Young People in Total Population

Unemployment Rate	0.2362***
Services Share in Value Added	-0.3037***
Personal Services Share in Value Added	-0.2814***
Health Care Services Share in Value Added	-0.5328***
Gini Index Labor Earnings	-0.1513***
Unemployment Benefits	-0.1873***
Personal Income Taxation	-0.0881***
Skilled Labor	-0.4765***
Female Labor Participation	-0.2774***

Note: The table reports the correlation between each of these variables with the share of young people in total population across states and over time. *** indicate statistical significance at the 1%.

To further formalize this point, Appendix A.1 reports the results of regressions in which we estimate the age sensitivity of local fiscal multipliers controlling for both the level of each of these key variables and also their interaction with military spending. In all cases, the age sensitivity keeps remarkably constant across specifications and always highly statistically significant. Overall, these results show that the age-sensitivity of local fiscal multipliers holds *above and beyond* any effect that personal income taxation, the unemployment rate, unemployment benefits, the Gini index of labor earnings, the sectoral composition of value added, and the skill and gender composition of workers have on the propagation of military spending.

Although the use of time fixed effects allows us to estimate local fiscal multipliers washing out the common effect across states of national-level shocks, states could display a heterogeneous sensitivity in the response of these common shocks. As long as this heterogeneity correlates with the evolution of the age structure across states, this feature would affect the estimate of the age sensitivity of the multiplier. To address this concern, we introduce additional national-level variables, such as the change in the oil price, the households' debt to GDP ratio, the federal debt to GDP ratio, Ramey (2011) and Ramey and Zubairy (2018)'s series on news about future government spending, and the real interest rate, and interact all of them with state fixed effects. Appendix A.2 shows that the economic and statistical significance of the age sensitivity of local fiscal multipliers does not change.

3 The Model

We build a two-country New Keynesian model with a rich, and yet tractable, life-cycle structure. The two countries - a home and a foreign economy - belong to a monetary union, with a unique Taylor rule which responds to union-level inflation and output gap. In the union there is also a federal government which purchases final consumption goods subject to spending shocks. The government finances its expenditures by levying lump-sum taxes on the households and issuing bonds.

In each country, the household sector has a life-cycle structure whereby individuals face an idiosyncratic aging risk and live through three stages of life: young, mature, and old. All the individuals supply labor, accumulate assets, and consume. The model features credit markets imperfections and age-specific differences in labor supply and labor demand.

The two countries differ only in the relative size of the population. Hereafter we just describe the home country. The variables and parameters of the foreign economy are distinguished by a star superscript.

3.1 Households

In each country there is a continuum of households that belong to three different age groups: young agents (y), mature agents (m), and old agents (o). The demographic structure in the home country is described by the measures of young agents $N_{y,t}$, mature agents $N_{m,t}$, and old agents $N_{o,t}$ such that $N_{y,t}+N_{m,t}+N_{o,t}=N_t$. The total population of the monetary union is $N_{U,t}=N_t+N_t^{\star}$.

Agents move through the three different groups of households in a life-cycle manner as in Yaari (1965) and Blanchard (1985). In the home country, in each period $\omega_n N_{y,t}$ new young agents are born and enter the economy. At any given point in time, households face an idiosyncratic probability to change age groups in the following period: young agents become mature with a probability $1-\omega_y$, mature agents become old with a probability $1-\omega_m$, and old agents die and leave the economy with a probability $1-\omega_o$. We can define the law of motion of population across the three age groups as

$$N_{y,t+1} = \omega_n N_{y,t} + \omega_y N_{y,t}, \tag{4}$$

$$N_{m,t+1} = (1-\omega_y) N_{y,t} + \omega_m N_{m,t}, \text{ and} \tag{5}$$

$$N_{o,t+1} = (1-\omega_m) N_{m,t} + \omega_o N_{o,t}. \tag{6}$$

Individuals face aggregate uncertainty due to fiscal shocks and over the lifetime they experience three idiosyncratic shocks: the transition from young to mature, the transition from mature to old, and the exit from the economy. Although agents are born identical, the idiosyncratic and aggregate uncertainty would generate a distribution of ex-post heterogeneous households. Following Gertler (1999), we define a framework in which the optimal choices of the individuals within each age group aggregate linearly. This approach reduces the relevance of differences *within* age group but it allows us to emphasize the heterogeneity *across* age groups and incorporate nominal rigidities and open economy interactions into a tractable environment. In this way, our model extends a standard two-country New Keynesian economy with a rich life-cycle structure.

First, we introduce a perfect annuity market which insures old agents against the risk of death. Old agents transfer their investment in capital and bonds to financial intermediaries, which pay back the proceedings only to surviving households. Free entry and perfect competition in the annuity market guarantee a premium to the return on investment which compensates old agents for the risk of death.

Second, we assume that households are risk neutral. In this way, the uncertainty on the labor income dynamics due to the transitions from young to mature and from mature to old, and the aggregate fiscal shocks does not affect optimal choices. Nevertheless, we keep a motive for consumption smoothing by assuming that individual preferences belong to the Epstein and Zin (1989) utility family, such that risk neutrality coexists with a positive elasticity of intertemporal substitution.

At time t the agent i of the age group $z = \{y, m, o\}$ chooses consumption $c^i_{z,t}$, labor supply $l^i_{z,t}$, capital $k^i_{z,t+1}$, and nominal bonds $b^i_{z,t+1}$ to maximize

$$\max_{c^i_{z,t}, l^i_{z,t}, k^i_{z,t+1}, b^i_{z,t+1}} v^i_{z,t} = \left\{ \left(c^i_{z,t} - \chi_z \frac{{l^i_{z,t}}^{1+\frac{1}{\nu_z}}}{1+\frac{1}{\nu_z}} \right)^{\eta} + \beta \mathbb{E}_t [v^i_{z',t+1} \mid z]^{\eta} \right\}^{1/\eta} \tag{7}$$

$$\text{s.t.} \quad P_t c^i_{z,t} + P_{I,t} k^i_{z,t+1} + P_{I,t} \varphi^i_{z,t+1} + b^i_{z,t+1} + P_t \tau^i_{z,t} = \dots$$

$$\dots = a^i_{z,t} + W_{z,t} \xi_z l^i_{z,t} + (1-\tau_d) d^i_{z,t} \mathbb{I}_{\{z=m\}} \tag{8}$$

$$\begin{cases} a^i_{z,t} = P_{I,t}(1-\delta) k^i_{z,t} + R_{k,t} k^i_{z,t} + R_{n,t} b^i_{z,t} & \text{if } z = \{y, m\} \\ a^i_{z,t} = \frac{1}{\omega_z} \left[P_{I,t}(1-\delta) k^i_{z,t} + R_{k,t} k^i_{z,t} + R_{n,t} b^i_{z,t} \right] & \text{if } z = \{o\} \end{cases} \tag{9}$$

$$k^i_{z,t+1} = (1-\delta) k^i_{z,t} + x^i_{z,t} - \varphi^i_{z,t+1} \tag{10}$$

$$k^i_{z,t+1} \geqslant 0, \; b^i_{z,t} \geqslant 0 \tag{11}$$

$$c^i_{z,t} = \left[\lambda^{1/\psi_c} {c^i_{H,z,t}}^{\frac{\psi_c - 1}{\psi_c}} + (1-\lambda)^{1/\psi_c} {c^i_{F,z,t}}^{\frac{\psi_c - 1}{\psi_c}} \right]^{\frac{\psi_c}{\psi_c - 1}} \tag{12}$$

$$x^i_{z,t} = \left[\lambda^{1/\psi_I} {x^i_{H,z,t}}^{\frac{\psi_I - 1}{\psi_I}} + (1-\lambda)^{1/\psi_I} {x^i_{F,z,t}}^{\frac{\psi_I - 1}{\psi_I}} \right]^{\frac{\psi_I}{\psi_I - 1}} \tag{13}$$

where β is the time discount factor and χ_z denotes the weight of leisure in the utility. The parameter $(1-\eta)^{-1}$ denotes the elasticity of intertemporal substitution, which drives households' motive to smooth consumption. Finally, ν_z is the labor supply elasticity, which varies exogenously across age groups. Since the utility function displays consumption-labor complementarities,[15] the response of labor supply to a government spending shock depends uniquely on the labor supply elasticity.

In the budget constraint, each household purchases consumption goods $P_t c^i_{z,t}$, and invests in capital $P_{I,t} k^i_{z,t+1}$ and nominal bonds $b^i_{z,t+1}$. Capital investment is subject to convex adjustment costs $\varphi^i_{z,t+1}$. Equation (9) defines the total nominal return on assets $a^i_{z,t}$. If the household is either young or mature, the total nominal return on assets equals the sum of the nominal return on capital and the nominal return of bonds. Instead, the return on assets for old households equals the return granted by the annuity market, that is, the return on assets divided by the survival probability of an old agent ω_o. Households also pay a lump-sum tax $\tau^i_{z,t}$.

Each household earns a nominal labor income $W_{z,t}\xi_z l^i_{z,t}$, where $W_{z,t}$ denotes the wage of agents of the age group $z = \{y, m, o\}$ and ξ_z denotes the age-specific efficiency units of hours worked. These parameters allow us to calibrate the model to match the hump-shaped pattern of labor income over the life-cycle. Finally, we assume that mature agents own the firms and therefore receive firms' nominal dividends, which are taxed at a proportional rate τ_d.

Equation (11) denotes the ad-hoc borrowing constraints that restrict the households from going short in capital and bonds. In equilibrium, mature individuals save for retirement, the old dissaves, and the constraints bind only for young individuals. Given the hump-shaped pattern of labor income over the life cycle, young agents

[15] Nakamura and Steinsson (2014) show that consumption-labor complementarities are required to match the level of the local fiscal multiplier. Gnocchi et *al.* (2016) study data on time use to document that the complementarity between consumption and hours worked is indeed an empirically relevant driver of the response of labor to a government spending shock. Bilbiie (2011) shows that the consumption-labor complementarities can rationalize a positive national consumption fiscal multiplier if prices are not flexible.

would like to borrow and smooth consumption but are prevented from doing so.[16]

Equations (12) and (13) show that households consumption $c^i_{z,t}$ and investment $x^i_{z,t}$ combine final goods produced in both the home and foreign country. The parameter λ captures the degree of home bias of the economy, that is, the amount of home produced goods consumed by households in the home economy.[17] The optimal amount of home goods and foreign goods purchased by households in the home economy equal respectively

$$c^i_{H,z,t} = \lambda \left(\frac{P_{H,t}}{P_t} \right)^{-\psi_c} c^i_{z,t}, \qquad x^i_{H,z,t} = \lambda \left(\frac{P_{H,t}}{P_{I,t}} \right)^{-\psi_I} x^i_{z,t} \tag{14}$$

and

$$c^i_{F,z,t} = (1-\lambda) \left(\frac{P_{F,t}}{P_t} \right)^{-\psi_c} c^i_{z,t}, \qquad x^i_{F,z,t} = (1-\lambda) \left(\frac{P_{F,t}}{P_{I,t}} \right)^{-\psi_I} x^i_{z,t} \tag{15}$$

where $P_{H,t}$ denotes the price of home produced goods, $P_{F,t}$ is the price of foreign produced goods, P_t is the price index of consumption, $P_{I,t}$ is the price index of investment, ψ_c is the elasticity of substitution across home and foreign produced consumption goods, and ψ_I is the elasticity of substitution across home and foreign produced investment goods. Appendix C shows in detail the problems of young, mature, and old agents.

3.2 Production

In each country the production sector is split into one competitive final goods firm and a continuum $j \in [0, 1]$ of intermediate producers under monopolistic competition. In the home country, the final goods firm produces domestic output Y_t with a

[16] In the quantitative analysis, we also consider a version of the model which abstracts from the ad-hoc constraint on bonds. Even in this case, in our life-cycle setting a non-contingent bond is not sufficient to ensure perfect consumption smoothing across generations. Gordon and Varian (1988) show that in a overlapping generations economy markets are complete only if young individuals can trade with unborn generations. This missing market prevents an efficient allocation across generations.

[17] High values of λ imply that households' consumption basket is heavily tilted towards home-produced goods. In this case, government spending shocks in the home economy generate a relatively lower demand of goods produced in the foreign economy. As a result, the local fiscal multiplier increases with the level of λ.

CES aggregator of the different varieties of the intermediate producers

$$Y_t = \left(\int_0^1 {Y_t^j}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{16}$$

where Y_t^j denotes the output produced by the intermediate producer j at time t, and ε is the elasticity of substitution across varieties. The final good firm is perfectly competitive and takes as given the price of the goods produced by the intermediate producers $P_{H,t}^j$, which yields to the standard isoelastic demand function for each variety j. The foreign country has the same structure with the only difference that it produces output $Y_t^\star$ at a production price $P_{F,t}$.

We follow Jaimovich et *al.* (2013) and model the technology of the intermediate firms that produce the differentiated varieties Y_t^j as

$$Y_t^j = \left(\mu \left[L_t^{j,in} \right]^\sigma + (1-\mu) \left[\alpha \left(K_t^j \right)^\kappa + (1-\alpha)(L_t^{j,ex})^\kappa \right]^{\frac{\sigma}{\kappa}} \right)^{\frac{1}{\sigma}} \tag{17}$$

where K_t^j is physical capital, $L_t^{j,in}$ is the labor of inexperienced workers, and $L_t^{j,ex}$ is the labor for experienced workers. The parameters μ and α pin down the shares of inexperienced labor and experienced labor in the production function, whereas $(1-\sigma)^{-1}$ and $(1-\kappa)^{-1}$ control the elasticity of substitution between inexperienced labor, experienced labor, and capital. In the empirically relevant case in which $\sigma > \kappa$, the production function has capital-experience complementarity. This technology generates age-specific differences in labor demand: experience labor is more complementary to capital than inexperienced labor.[18]

Intermediate producers hire experienced workers at the equilibrium nominal wage W_t^{ex}, inexperienced workers at the equilibrium nominal wage W_t^{in}, and rent capital

[18]The notion of capital-experience complementarity is related to the capital-skill complementarity emphazised by Krusell et *al.* (2000) as a rationale for the dynamics of both the supply and the price of skilled labor relative to unskilled labor observed over the last decades.

at the equilibrium nominal gross rate $R_{k,t}$. Then, nominal dividends D_t^j equal

$$D_t^j = P_{H,t}^j Y_t^j - W_t^{ex} L_t^{j,ex} - W_t^{in} L_t^{j,in} - R_{k,t} K_t^j. \tag{18}$$

The firms decide the optimal amount of capital and labor to hire in the following cost minimization problem

$$\min_{\tilde{K}_t^j, L_t^{j,in}, L_t^{j,ex}} \mathbb{E}_t \left\{ \sum_{s=t}^{\infty} Q_{t,s}^m \left(W_s^{ex} L_s^{j,ex} + W_s^{in} L_{H,s}^{j,in} + R_{k,s} K_s^j \right) \right\}, \tag{19}$$

where $Q_{t,s}^m$ denotes the stochastic discount factor of the mature agents between period t and period $s \geq t$. With respect to the firms' price setting behavior, we introduce a nominal price rigidity à la Calvo (1983), such that firms can reset their prices with a probability $1 - \zeta$. This probability is independent and identically distributed across firms, and constant over time. As a result, in each period a fraction ζ of firms cannot reset their prices and maintain the prices of the previous period, whereas the remaining fraction $1 - \zeta$ of firms are allowed to set freely their prices. The properties of the Calvo price friction imply that the optimal reset price at time t is a function of the mark-up $\frac{\varepsilon}{\varepsilon - 1}$ and the stream of future marginal cost.

3.3 Government

In the monetary union there is a government that constitutes of a monetary authority and a fiscal authority. On the monetary side, the government sets the nominal interest rate $R_{n,t}$ following a Taylor rule that reacts to the inflation rate of the monetary union $1 + \pi_t^u \equiv \frac{P_{u,t}}{P_{u,t-1}}$, where $P_t^u \equiv N_t P_t + N_t^\star P_t^\star$, and the gap between the output of the monetary union $Y_t^u \equiv Y_t + Y_t^\star$ and the output of an economy with flexible prices $Y_t^{u,F}$

$$\frac{R_{n,t}}{\bar{R}} = \left[\frac{R_{n,t-1}}{\bar{R}} \right]^{\psi_R} \left[(1 + \pi_t)^{\psi_\pi} \left(\frac{Y_t^u}{Y_t^{u,F}} \right)^{\psi_Y} \right]^{1-\psi_R} \tag{20}$$

where $\bar{R}$ is the steady-state nominal interest rate, ψ_R denotes the degree of interest rate inertia, and ψ_π and ψ_Y capture the degree at which the nominal interest rates respond to inflation and output gap, respectively.

On the fiscal side, the federal government purchases home goods $G_{H,t}$ and foreign goods $G_{F,t}$. The government finances its expenditures with the revenues of a one-period non-contingent bond $B_{g,t}$, that yields a nominal gross interest rate $R_{n,t}$, a nominal lump-sum tax levied in the home country T_t and in the foreign country $T_t^\star$, and the proceeds from dividend taxation $\tau_d(D_{m,t} + D_{m,t}^\star)$. The government budget constraint reads

$$P_{H,t}G_{H,t} + P_{F,t}G_{F,t} + B_{g,t+1} = B_{g,t}R_{n,t} + P_tT_t + P_t^\star T_t^\star + \tau_d(D_{m,t} + D_{m,t}^\star) \tag{21}$$

where $T_t = \int_0^{N_{y,t}} \tau_{y,t}^i \,\mathrm{di} + \int_0^{N_{m,t}} \tau_{m,t}^i \,\mathrm{di} + \int_0^{N_{o,t}} \tau_{o,t}^i \,\mathrm{di}$, and $D_{m,t} = \int_0^{N_{m,t}} d_{m,t}^i \,\mathrm{di}$. Analogous expressions apply for $T_t^\star$ and $D_{m,t}^\star$.

Government expenditures $G_{H,t}$, and $G_{F,t}$ are exogenous and follow first order autoregressive processes

$$\log G_{H,t} = (1 - \rho_G) \log G_{H,SS} + \rho_G \log G_{H,t-1} + \epsilon_{G_H,t}, \tag{22}$$

and

$$\log G_{F,t} = (1 - \rho_G) \log G_{F,SS} + \rho_G \log G_{F,t-1} + \epsilon_{G_F,t}, \tag{23}$$

where $G_{H,SS}$ and $G_{F,SS}$ are the steady-state values of government spending in each country, ρ_G denotes the persistence of the processes, $\epsilon_{G_H,t}$ is a spending shock in home goods, and $\epsilon_{G_F,t}$ is a spending shock in foreign goods. These shocks are independent and identically distributed following a Normal distribution $N(0, 1)$.

We assume that the government follows a fiscal rule which determines the response of debt and tax to the exogenous changes in government spending:

$$\frac{\widehat{B}_{g,t+1}}{Y_{SS}^{u}} = \rho_{bg}\frac{\widehat{B}_{g,t}}{Y_{SS}^{u}} + \phi_{G}\frac{\widehat{P_{H,t}G_{H,t}}}{Y_{SS}^{u}} + \phi_{G}\frac{\widehat{P_{F,t}G_{F,t}}}{Y_{SS}^{u}} + \phi_{T}\frac{\widehat{P_{t}T_{t}}}{Y_{SS}^{u}} + \phi_{T}\frac{\widehat{P_{t}^{\star}T_{t}^{\star}}}{Y_{SS}^{u}} \tag{24}$$

where Y_{SS}^{u} denotes the steady-state value of the output of the monetary union, and $\hat{Z}_t \equiv Z_t - Z_{SS}$ denotes the absolute deviation from steady-state. The parameters ρ_{bg}, ϕ_G, and ϕ_T control to what extent debt and tax finance an increase in government spending and how long the government takes to raise taxes to bring government debt back to the steady state level. For instance, when $\phi_G = 0$, $\rho_{bg} = 0$, and $\phi_T = 0$, spending is fully financed through taxes. As ϕ_G and ρ_{bg} increase, government spending becomes partially financed through debt. As ϕ_T increases, debt levels above steady-state trigger tax adjustments.[19]

3.4 Closing the Model

Our setup allows us to derive optimal policies for each individual that can be aggregated linearly within each age-group. For instance, we can define total young consumption, mature consumption, and old consumption of goods produced in the home economy as

$$C_{H,y,t} = \int_0^{N_{y,t}} c_{H,y,t}^{i}\,\mathrm{di}, \quad C_{H,m,t} = \int_0^{N_{m,t}} c_{H,m,t}^{i}\,\mathrm{di}, \quad \text{and} \quad C_{H,o,t} = \int_0^{N_{o,t}} c_{H,o,t}^{i}\,\mathrm{di},$$

such that the overall total consumption equals $C_{H,t} = C_{H,y,t} + C_{H,m,t} + C_{H,o,t}$. The same applies to all the variables of the model. Appendix C shows that the life-cycle setup of the model allows for a simple linear aggregation within age groups.

Bonds move freely across countries, and the clearing of the market implies that the supply of government bonds equals the sum of individual positions across coun-

[19] Given the non-Ricardian behavior of the agents in this life-cycle economy, national fiscal multipliers tend to be higher when spending is financed relatively more by debt and less by taxes. Local fiscal multipliers are significantly less sensitive to the characteristics of the fiscal rule since the tax burden falls over the entire union.

tries, that is $B_{g,t} = B_t + B_t^\star = B_{y,t} + B_{m,t} + B_{o,t} + B_{y,t}^\star + B_{m,t}^\star + B_{o,t}^\star$. Instead, we assume that labor and physical capital are immobile.[20] The clearing of the rental markets of capital implies $K_t = K_{y,t} + K_{m,t} + K_{o,t}$ and $K_t^\star = K_{y,t}^\star + K_{m,t}^\star + K_{o,t}^\star$. The labor markets clear when $L_{in,t} = \xi_y L_{y,t}$, $L_{ex,t} = \xi_m L_{m,t} + \xi_o L_{o,t}$ and $L_{in,t}^\star = \xi_y L_{y,t}^\star$, $L_{ext,t}^\star = \xi_m L_{m,t}^\star + \xi_o L_{o,t}^\star$. As such $W_{y,t} = W_t^{in}$ and $W_{m,t} = W_{o,t} = W_t^{ex}$.

Then, the resource constraint of the home economy posits that output is split into the consumption of the home goods of the households of both countries, the investment of both countries, and the goods purchased by the government, net of the adjustment costs of capital $Y_t = C_{H,t} + C_{H,t}^\star + G_{H,t} + X_{H,t} + X_{H,t}^\star - \varphi_t$, where φ_t denotes the sum of the adjustment costs bore by all agents in the home economy. Similarly, for the foreign economy we have that $Y_t^\star = C_{F,t} + C_{F,t}^\star + G_{F,t} + X_{F,t} + X_{F,t}^\star - \varphi_t^\star$.

4 Quantitative Analysis

4.1 Calibration

In the calibration exercise, we discipline the life-cycle dynamics by matching some salient facts on the demographics of the U.S. population and the life-cycle pattern of labor income. Throughout the calibration, we set one period of the model to correspond to one quarter.

The calibration of the set of parameters that govern the demographic and life-cycle structure of the model is reported in Tables D.1 and D.2 in the Appendix. We first set the size of the home economy to $N/N^u = 0.02$, which is the average size of a U.S. state. We define young households as the individuals between 20 and 29 years old, mature households are the individuals between 30 and 64 years old, and old households are the individuals above 65 years old. Then, we define the parameters

[20] In the empirical analysis we instrument of the share of young people with lagged birth rates to wash out the effect of migration on local fiscal multipliers. Accordingly, we set that labor is immobile in the model. When we do not control for migration flows in the data, the age sensitivity of local fiscal multipliers is even larger.

that control the law of motion of age group populations to match the average share of young people in total population between 1967 and 2015, the average share of old people in total population between 1967 and 2015, the average number of years that an individual spends as young (10 years), the average number of years that an individual spends as mature (35 years). Matching these moments yields a birth rate of new young agents of $\omega_n = 0.0274$, a probability of the transition from young to mature of $1 - \omega_y = 0.0250$, a probability of the transition from mature to old of $1 - \omega_m = 0.0071$, and a death probability for an old agent of $1 - \omega_o = 0.0274$.

We define the relative disutility of working for mature individuals such that their steady-state hours worked equal 0.35. This condition yields $\chi_m = 131.9$. Then, we define the relative disutility of working for young and old individuals such that their hours worked equal 0.324 and 0.08, respectively. These moments are derived by multiplying the steady-state hours worked by mature individuals with the employment rate of either young or old individuals relative to the employment rate of mature individuals.[21] These conditions yield the values of $\chi_y = 2.4$ and $\chi_o = 14.5$.

The parameters of the production that control the complementarity between inexperienced labor, experienced labor, and capital, σ and κ, are disciplined with the empirical evidence of Jaimovich et al. (2013). These authors estimate these parameters using CPS data, and find that $\sigma = 0.7$ and $\kappa = 0.2$. These values imply that experienced labor is much more complementary to capital than inexperienced labor. Then, we calibrate jointly the remaining parameters of the production function α and μ with the parameters that govern the efficiency unit of hours across age groups ξ_y, ξ_m, and ξ_o, to match the life-cycle dynamics of labor earnings and the share of capital in the production function. Namely, we want to match three targets: the share of labor in the production function of 0.67, the fact that the hourly wage of

[21] The average employment rate of young individuals between 1970 and 2015 equals 76.44%. The employment rate of mature individuals equals 83.57%. The employment rate of old individuals equals 19.09%.

individuals between 20 and 29 years equals on average 71% of the hourly wage of individuals between 30 and 64 years, and the fact that the hourly wage of individuals above 65 years equals on average 72% of the hourly wage of individuals between 30 and 64 years. Accordingly, we need three parameters. Hence, we first normalize the efficiency unit of hours of young and mature agents and set $\xi_y = \xi_m = 1$. Then, we set $\mu = 0.36$, $\alpha = 0.27$, and $\xi_o = 0.72$.[22]

The calibration of the labor supply elasticity is key to generate one of the mechanisms through which the model rationalizes the age-sensitivity of fiscal multipliers. We opt for a conservative approach by disciplining the values of the labor supply elasticity with the evidence on the micro elasticity provided by the literature. The meta-analysis of quasi-experimental studies carried out by Chetty et al. (2013) computes a mean of the intensive margin Frisch elasticity of 0.54. However, these studies tend to focus on groups with weak attachment to the labor force, such as single mothers or workers near retirement. Since we are after the elasticity of white male workers, which feature a much lower elasticity than the rest of the workers, we set the labor supply elasticities across age groups such as its average value is 0.4, which is slightly below the average of the Frisch elasticity estimates and slightly above the average of the Hicksian elasticity estimates in Chetty et al. (2013).

Then, we calibrate the elasticity of mature workers to $\nu_m = 0.2$, consistently with the fact that the elasticity of prime-age workers lies at the lower end of the micro elasticity estimated in the literature. The labor supply elasticity of old workers is set following Rogerson and Wallenius (2013), who point out that only elasticities above 0.75 can rationalize the observed retirement behavior from full-work. Accordingly,

[22] This calibration choice is motivated by the fact that, given the values of σ and κ, the parameters α and μ pin down the share of capital in the production function and the ratio between the hourly wage of young inexperienced workers vis-á-vis older experienced workers. Then, the parameter ξ_o pins down the hourly wage of old workers vis-á-vis mature workers. In the quantitative analysis we quantify the role of the age-specific labor demand through the experience-capital complementarity by computing the local fiscal multipliers in an economy with a standard Cobb-Douglas production function in labor and capital, such as $Y_t = L_t^{1-\alpha} K_t^{\alpha}$. In this case, inexperienced and experienced labor are perfect substitutes and there is a unique equilibrium wage. This economy is calibrated such as $\alpha = 0.33$ to match the share of capital in the production function, and the life-cycle dynamics of labor earnings is matched by setting $\xi_m = 1$, $\xi_y = 0.71$, and $\xi_o = 0.72$.

we calibrate the elasticity of old workers to $\nu_o = 0.75$. Finally, we calibrate the elasticity of young workers such that the weighted-average elasticity of the economy equals 0.4. This procedure yields an elasticity of young workers of $\nu_y = 0.71$, which is slightly lower than the elasticity of old workers. Interestingly, this relative ranking between elasticities across age groups is consistent with the evidence of Rios-Rull (1996), Gomme et al. (2005), and Jaimovich and Siu (2009), which document that the volatility of hours and wages is u-shaped over the life-cycle, and highest for old workers.[23]

The calibration of the set of parameters of the New Keynesian structure of the model is reported in Table D.3 in the Appendix. We set the time discount factor to $\beta = 0.995$, whereas we fix $\eta = -9$ so that the elasticity of intertemporal substitution is 0.1, consistently with the estimates of Hall (1988) and Best et al. (2019).

The capital depreciation rate is set to the standard value of $\delta = 0.025$, which implies a 10% annual depreciation rate. Instead, for the capital adjustment costs we do the following. First, we posit that the adjustment costs for an individual i in the age group z at time t equal $\varphi^i_{z,t+1} = \frac{\varphi}{2}\left(\frac{k^i_{z,t+1}}{k^i_{z,t}} - \vartheta_z\right)^2 k^i_{z,t}$. The parameter ϑ_z captures the life-cycle dynamics of capital accumulation and it is pinned down such that no adjustment cost is paid at steady-state. In the baseline calibration, young households do not own capital and therefore do not bear adjustment costs. The average quarterly capital accumulation rate for mature households is 0.72%, which implies $\vartheta_m = 1.0072$, whereas old households on average deplete capital, and they do so at a quarterly rate of -0.12%, such that $\vartheta_o = 0.9988$. Then, we set $\varphi = 200$ such that the response of investment to a government spending shock bottoms after 8 quarters, in line with the empirical evidence of Blanchard and Perotti (2002).

[23]Our calibration choice for the labor supply elasticity across age groups is consistent with French (2005), Jaimovich and Siu (2009), Rogerson and Wallenius (2009), Erosa et *al.* (2016), Janiak and Monteiro (2016), Karabarbounis (2016), Peterman (2016), who find that young and old individuals have higher labor supply elasticities than mature individuals. Although we cannot discount the possibility that the labor supply elasticity changes with population aging, throughout the paper we assess the effect of aging conditional on a constant labor supply elasticity over time.

We set the elasticity of substitution across varieties to $\epsilon = 9$, which implies a markup of 12.5%, in the ball park of the estimates used in the literature of New Keynesian models. The Calvo price parameter is set to $\zeta = 0.75$, which implies that on average firms adjust their prices every 12 months. Regarding the consumption and investment bundles, we follow Nakamura and Steinsson (2014): we set the home bias to $\lambda = 0.69$ and the elasticity of substitution across home and foreign consumption goods to $\psi_c = 2$. Finally, we impose that the elasticity of substitution across investment goods equals the one of consumption goods, that is, $\psi_i = \psi_c$.

Regarding the fiscal setting of the economy, we first fix the proportional tax on dividends to $\tau_d = 0.9394$. Since dividends are then redistributed in a lump-sum fashion to all households, this proportional rate implies that mature households receive 60% of the overall dividends of the economy. Then, we set the steady-state value of government spending to output ratio to $\frac{G_{H,SS}+G_{F,SS}}{Y^U_{SS}} = 0.204$. This value coincides with the average ratio of total government spending to output observed in the data from 1960 to 2016. To calibrate the persistence of the government spending shock, we follow the approach by Nakamura and Steinsson (2014) and estimate the quarterly persistence of military spending using annual data through a simulated method of moments approach. This procedure yields a value of $\rho_G = 0.953$.[24] Finally, we calibrate the fiscal rule parameters. We calibrate the three parameters ρ_{bg}, ϕ_G, and ϕ_T to match the inertia observed in the data in the response of government debt to a government spending shock. First, we posit that following a government spending shock the ratio of government deficit to debt issuance is u-shaped, with a trough after 6 quarters. Second, throughout the first 8 quarters, new debt issuance covers on average 90% of the total deficit. Third, after the trough, debt

[24]The simulated method of moments yields a value slightly higher than the 0.933 estimated by Nakamura and Steinsson (2014), pointing out to the fact that the extra 10 years of national military in our sample from 2006 to 2015 drive the upward revision of the autoregressive coefficient. Our estimate is the ballpark of the values of estimated in literature (e.g., Leeper et al. (2017) find a value of 0.98, Kormilitsina and Zubairy (2018) find a value of 0.967, and Sims and Wolff (2018) find a value of 0.94). Nevertheless, varying the autoregressive coefficient of military spending has negligible effects on age sensitivity of local fiscal multipliers generated by our model.

issuance starts decreasing and from the 20^{th} quarter onwards, government debt is progressively repaid through increases in lump-sum taxation. This procedure yields the following parameters: $\rho_{bg} = 0.95$, $\phi_G = 4.5$, and $\phi_T = 0.01$.

We set the Taylor rule parameters following the estimates of Clarida et *al.* (2000): the inertia parameter equals $\psi_R = 0.8$, the degree of response to the inflation rate is $\psi_\pi = 1.5$, and the degree of response to the output gap is $\psi_Y = 0.2$.

4.2 Demographics and Local Fiscal Multipliers

What is the effect of a change in the age structure of the economy on the size of local fiscal multipliers in the model? We address this question by replicating the same empirical analysis carried out in Section 2 with the simulated data of our model. In the simulation, we consider the effect of federally-financed increases in (wasteful) government spending in each of the two economies: we shock the economy with innovations to government spending in home goods $G_{H,t}$ and innovations to government spending in foreign goods $G_{F,t}$. These purchases are financed at the federal level, partially through bonds and partially through lump-sum taxes on all the households of the monetary union.

We proceed in two steps. In the first one, we estimate the local output fiscal multiplier in a model in which both economies are symmetric in the shares of population across age groups, which are calibrated to average values observed between 1967 and 2015. To do so, we estimate the following panel regression:

$$\frac{Y_{i,t} - Y_{i,t-2}}{Y_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} + \epsilon_{i,t}, \qquad i \equiv \{H, F\}.$$

This first step yields the model counterpart of the coefficient β of the regression (1), that is, the size of local multipliers for a state with an average share of young people in total population. In the second step, we change the age structure of the home economy by increasing the share of young people by 1%. Then, we estimate again the local fiscal multiplier as before. The difference in the size of the local output fiscal multiplier between the second and the first step yields the model counterpart of the coefficient γ of the regression (1), which defines how local multipliers vary with the age structure of an economy.

Table 4 reports the results of this exercise. In the data, the local output fiscal multiplier for a U.S. state with an average share of young people in total population is 1.51. A 1% increase in the share of young people raises the multiplier by 3.1%, up to 1.56. In the model, the local output fiscal multiplier for a U.S. state with an average share of young people in total population is 1.46. A 1% increase in the share of young people raises the multiplier by 2.7%, up to 1.50. Hence, the model matches almost entirely the size of the local fiscal multiplier and explains 87% of the link between fiscal multipliers and demographics.

Table 4: Local Output Fiscal Multiplier - Data vs. Model

		Data	Model
Average Local Output Fiscal Multiplier	β	1.511	1.463
Sensitivity of Local Output Fiscal Multiplier with States' Age Structure	γ	0.047	0.039
Δ Local Output Fiscal Multiplier of 1% Increase in Share Young People	γ/β	3.1%	2.7%

Note: This table reports the results of the estimation of the local output fiscal multiplier in the data and in the model. The first row reports the estimated value of the local output fiscal multiplier for a U.S. state with an average share of young people in total population. The second row reports how a 1% increase in the share of young people rises the size of the local output fiscal multiplier. The last row computes the age sensitivity of local output fiscal multiplier.

What is the contribution of the different channels of the model to the quantitative implications on the age sensitivity of the local fiscal multiplier? On the one hand, the model features two mechanisms that generate a higher response of the labor of young workers vis-á-vis older workers: the age-specific differences in labor supply and labor demand. The differences in labor supply consist in the fact that the labor supply elasticities vary exogenously across age groups, such as the elasticity of young and old workers is larger than the one of mature workers. The differences in labor demand hinge on the capital-experience complementarity embedded in the production function we consider, such as the demand of experienced labor (i.e., the labor of mature and old workers) is relatively more tied to the stock of capital, and thus fluctuates less over the cycle. On the other hand, the model features two forms of credit market imperfections - the incomplete asset markets and ad-hoc borrowing constraint - that raise the marginal propensity to consume of all households, and especially that of young individuals.

To disentangle the contribution of all these channels, we compare the results of the baseline model with implications of three counterfactual economies, which isolate the quantitative relevance of each channel by eliminating each time a feature of the model in a sequential way. The first counterfactual economy, the "Constant Labor Supply Elasticity", refers to a version of the baseline model in which we eliminate the age-specific differences in the labor supply elasticity and set a unique value across the three age groups: we set the elasticity to the weighted average value of the baseline economy, that is, $\nu_y = \nu_m = \nu_o = 0.4$. The second counterfactual economy, the "No Capital Experience Complementarity", eliminates the age-differences in labor demand, by considering a standard Cobb-Douglas in capital and labor, in which the labor of inexperienced young workers is a perfect substitute to the labor of older experienced workers. Finally, the "No Borrowing Constraint" economy eliminates the ad-hoc constraint, so that young households can borrow. In this economy, the only form of credit market imperfections is given by the incomplete asset markets. Table 5 reports the age sensitivity of the local fiscal multipliers in all these specifications.

The age-specific components that generate a differential response of labor across age groups account overall for 40% of the link between demographics and local

Table 5: Age Sensitivity of Local Output Fiscal Multiplier - Channels

	Data	Baseline	Constant Labor Supply Elasticity	No Capital Experience Complementarity	No Borrowing Constraint
Δ Local Output Fiscal Multiplier of 1% Increase in Share Young People	3.1%	2.7%	2.5%	1.6%	0.8%

Note: This table reports the results of the age sensitivity of local output fiscal multiplier in the data, in the "Baseline" mode, and in a series counterfactual economies, which sequentially eliminates mechanisms of the "Baseline" model. The "Constant Labor Supply Elasticity" economy eliminates the variation in the elasticity of labor supply across age groups, the "No Capital Experience Complementarity" eliminates the differences in the complementarity of young and older labor with respect to capital, and considers a standard Cobb-Douglas production function in labor and capital, and the "No Borrowing Constraint" economy eliminates the ad-hoc borrowing constraint on household' bond-holdings.

multipliers, as the age sensitivity in the economy with a constant labor supply elasticity across age groups and no capital-experience complementarity drops from 2.7% to 1.6%. To validate this implication, in Appendix A.6 we use CPS data to derive measures of labor earnings, hours worked, and hourly wages for young workers and older workers (i.e., any worker above 30 years old). Then, we estimate the local multiplier for each of these labor market variables, and find that the labor earnings, hours, and hourly wages of young workers react relatively more following a government spending shock. These results are consistent with the empirical evidence at the national level on the labor market response to tax shocks reported in Ferraro and Fiori (2019), and more generally in line with the evidence on the relatively higher volatility of labor market outcomes of young workers over the business cycle (e.g., Rios-Rull, 1996; Gomme et al., 2005; Jaimovich and Siu, 2009).

Importantly, we can disentangle the role of labor supply and labor demand, and isolate in which side of the labor market the age-differences matter more in explaining the age sensitivity of local multipliers. We find that age-specific differences in labor demand account for 33% of the link between demographics and local multipliers, whereas labor supply motives account for only 7% of the age sensitivity. This result is consistent with the findings of Jaimovich et al. (2013), who point out that the age-specific differences in labor supply cannot simultaneously account for the high volatility of hours and wages of young workers, whereas the age-specific differences in labor demand can.

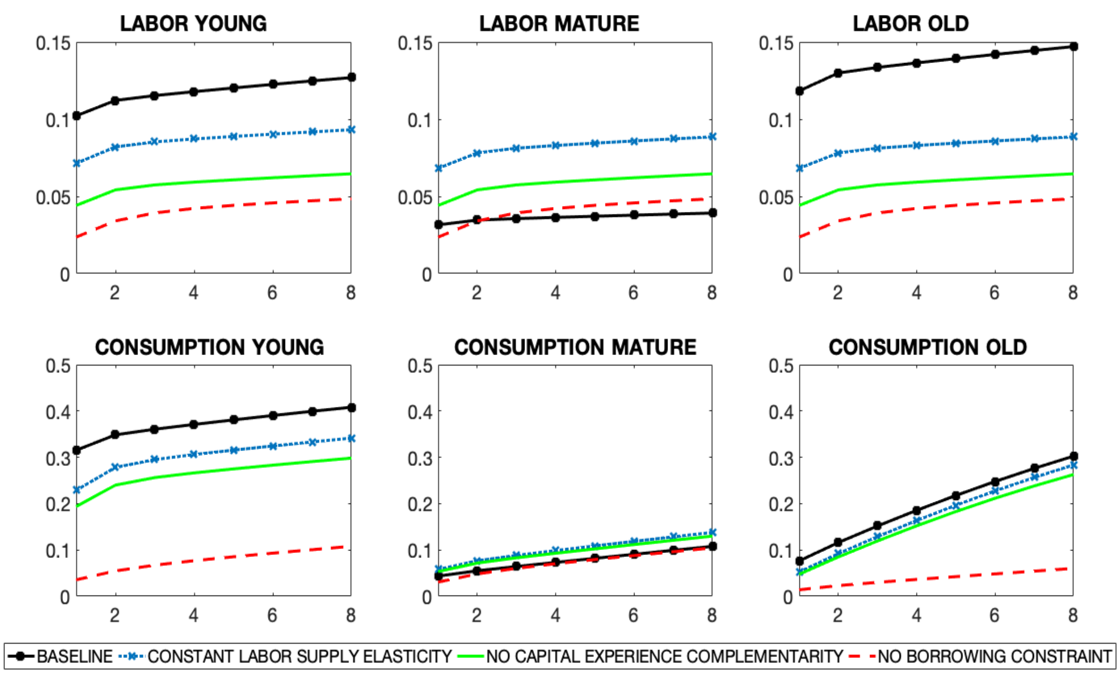
Credit market imperfections account for 60% of the age sensitivity of the local multipliers. This quantitative relevance is equally split between the role of the ad-hoc borrowing constraint and the one of incomplete credit markets. Indeed, when we eliminate the ad-hoc constraint, the age sensitivity drops from 1.6% to 0.8%. The relevance of credit market imperfections holds even in a version of the model in which the young is divided in two groups, one facing a borrowing constraint on bond-holdings and the other one that can freely borrow. When we calibrate the share of borrowing constrained young individuals to 40%, which is the fraction of hand-to-mouth households aged between 20 and 29 in the U.S. as computed by Kaplan et al. (2014), then the age sensitivity equals 1.2%.

Although these findings confirm the key role of the fraction of hand-to-mouth households to understand the effectiveness of fiscal policy discussed by Gali et al. (2007) and Kaplan and Violante (2016), they highlight that even in the absence of the ad-hoc borrowing constraint, the lack of complete markets in a life-cycle setting can still generate local multipliers that depend on the age structure of the population. The relevance of credit market imperfections is also consistent with the findings of Demyanyk et al. (2019), who document that the level of local multipliers depend on households' debt positions and marginal propensities to consume.

The relevance of incomplete markets - above and beyond the fraction of borrowing constrained agents - for the size of fiscal multipliers is also highlighted by Brinca et *al.* (2016), Ferriere and Navarro (2017), and Hagedorn et *al.* (2019). In these papers, markets are incomplete because the idiosyncratic labor income risk is uninsurable and there is no state-contingent bonds. In our environment the lack of complete markets is also rooted in the overlapping generations structure of the model. In equilibrium, given the interest rate and the amount of bonds traded, young agents cannot borrow sufficiently to smooth consumption in the face of a hump-shaped labor income dynamics over the life-cycle.[25] As a result, the marginal propensity to consume of young households is above the one of mature households, as it is in the data. Hence, an economy with relatively more young households features a stronger demand channel.

To shed further light on the contribution of each age group on the age-sensitivity of local fiscal multipliers, we report in Figure 1 the individual cumulative labor and consumption responses across the three different age groups in the baseline model and in all the counterfactual economies.

Figure 1: Consumption Cumulative Responses by Age Groups.



The figure plots the cumulative responses of individual labor (upper panel) and consumption (lower panel) by age groups over eight quarters after the realization of the government spending shock. In each plot we report the cumulative responses under four different scenarios. The squared line corresponds to the "Baseline" economy. The crossed line corresponds to the "Constant Labor Supply Elasticity" economy. The continuous line corresponds to the "No Capital Experience Complementarity" economy. The dashed line corresponds to the "No Borrowing Constraint" economy.

The figure shows that following a government spending shock the responses of young and old households labor are on impact four times larger than the response

[25]The inability to trade bonds/write contracts with the agents that are unborn prevents the (current) young agents from accessing additional asset markets to perfectly smooth consumption.

of labor of mature households. These dynamics are driven by both the age-specific labor supply elasticities and the capital-experience complementarity. Since we consider a utility function with no wealth effect on labor supply, the absence of these two features makes the responses of labor across age groups to coincide, as in the case of the labor responses of the "No Capital Experience Complementarity" economy.

Not only the response of labor, but also the one of consumption displays sizable differences across age groups. Although consumption always rise following a government spending shock due to the complementarity between consumption and leisure in the utility function, the response of the young households is the largest one, even in the case we consider an economy without age-specific differences in labor supply and demand, and also without the ad-hoc borrowing constraint. The rationale of this finding is twofold. First, although old households have a high marginal propensity to consume, they account for a low fraction of the labor force, and therefore they experience a mild positive income effect, which then translates into a relatively low consumption response. Second, young households have a higher marginal propensity to consume than mature workers, which is consistent with the evidence of the literature on the response of age-group consumption to tax changes. Although Shapiro and Slemord (1995), Johnson et *al.* (2006), Agarwal et *al.* (2007), Anderson et *al.* (2016) use different approaches to identify the consumption response to tax shocks, they all conclude that young households display a much larger consumption response than prime-age individuals.[26]

4.3 Population Aging and National Fiscal Multipliers

So far we have been focusing on regional data, as this approach allows us to leverage local heterogeneity and properly identify fiscal multipliers and their sensitivity to

[26] Also Kaplan and Violante (2010), Berger et *al.* (2018), and Carroll et *al.* (2018) provide model-based evidence pointing out that the marginal propensity to consume is highest among young households. Young households display a larger marginal propensity because they are more likely to be liquidity constrained, as documented in Jappelli (1990), Kaplan et *al.* (2014), and Misra and Surico (2014).

changes in the age structure of the population. Nevertheless, the effectiveness of government spending should also be evaluated at the country level looking at national fiscal multiplier. Indeed, Nakamura and Steinsson (2014), Fahri and Werning (2016), and Chodorow-Reich (2019) emphasize that local fiscal multipliers abstract from some general equilibrium forces as they identify the *relative* response of output across geographical areas to federal spending. On the one hand, local multipliers wash out both any monetary policy response to government spending. On the other hand, local multipliers accounts for redistributionary and spillover effects that propagate across states and do not affect aggregate variables. Hence, the fact that the effect of demographics on fiscal multipliers at the state level is economically and statistically significant does not necessarily imply that demographics alter also national multipliers

Notwithstanding, our theoretical model is an ideal laboratory to study how demographics shape the size of national government spending multipliers, as it is consistent with the empirical evidence on local multipliers, and can account for all general equilibrium forces. This section first evaluates whether the link between demographics and multipliers persist also at the national level through the lenses of the model, and then looks at the implications of the progressive aging of the U.S. population on the evolution of national fiscal multipliers over the recent decades.

To do so, we estimate national multipliers in the following exercise. We consider a symmetric increase in government spending in both the home and the foreign economy. Similarly to our definition of national output Y_t^U, we define national government spending as sum of government spending in the home economy and government spending in the foreign economy, that is, $G_t^u = G_{H,t} + G_{F,t}$. Hence, now we consider an increase in national (wasteful) government spending which is financed by all the individuals in the monetary union. We estimate the national output multiplier β_N as

$$\frac{Y_t^u - Y_{t-2}^u}{Y_{t-2}^u} = \beta_N \frac{G_t^u - G_{t-2}^u}{Y_{t-2}} + \epsilon_t.$$

Again, we proceed in two steps. First, we estimate β_N by running the regression on the simulated data from the model which is calibrated to the average population shares observed in the U.S. between 1967 and 2015. Then, we change the age structure of the economy by increasing the share of young people in the overall union by 1% and estimate again β_N. The difference between the estimates of the second and the first step yields the age sensitivity of national output fiscal multipliers. Following the same procedure, we also estimate the age sensitivity of the national consumption, investment, and employment fiscal multiplier.

Table 6: National Fiscal Multipliers

	Output	Consumption	Investment	Employment
Avg. National Fiscal Multiplier	0.82	0.61	-0.79	1.34
Δ National Fiscal Multiplier of 1% Increase in Share Young People	1.1%	1.5%	0.2%	1.3%

Note: This table reports the results of the estimation of the national fiscal multipliers in the model. We consider the two-year output fiscal multiplier, the two-year output consumption fiscal multiplier, the two-year investment fiscal multiplier, and the two-year employment fiscal multiplier. The first row reports the estimated value of the national fiscal multipliers. The second row computes the age sensitivity of national fiscal multipliers.

Table 6 reports the results of this exercise. In the model the national output fiscal multiplier associated with the average population shares observed over the recent decades is 0.82, and a 1% increase in the share of young people raises the multiplier by 1.1%.[27] A similar change in the age structure of the population raises

[27] Nakamura and Steinsson (2014) show that the mapping from local multipliers to national multiplier depend crucially on the monetary policy stance. Yet, although different monetary policy rules affect substantially the level of the national multiplier, they barely change its age sensitivity. For instance, if we consider a hawkish monetary policy and increase the parameter that in the Taylor rule controls the response of the nominal interest

also the consumption multiplier by 1.5% and the employment multiplier by 1.3%. Instead, the investment multiplier barely changes following an increase in the share of young people.

Although the age sensitivity is lower than for the case of local multipliers, it is still highly economically significant: changes in the age structure of an economy affect fiscal multipliers also at the national level. In Appendix B we validate the prediction of the model on the link between demographics and national fiscal multipliers. We estimate a SVAR on both a panel of developed countries and a panel of developing countries and identify government spending shock with a Choleski ordering à la Blanchard and Perotti (2002). In either case, we show that the long-run national output fiscal multiplier is indeed larger in countries with higher shares of young people in total population.

Since the model predicts that also national fiscal multipliers depend on the age structure of the population, we can now evaluate how the effectiveness of government spending has been shaped by the dramatic changes in the demographic structure of the U.S. population over the recent decades. Indeed, the onset of the baby boomers raised the share of young people by 22% between 1967 and 1980. From 1980 to 2015, the U.S. population has progressively shifted towards older ages, with the share of young people shrinking by 30%.

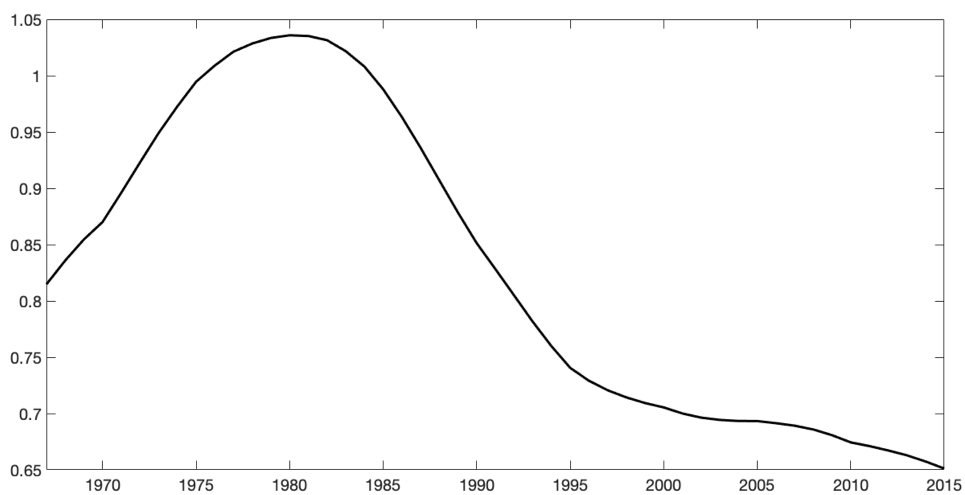
We measure the implications of the U.S. population aging on the effects of government spending by feeding the model with the entire path of population shares observed from 1967 until 2015, and then compute national fiscal multipliers through the lenses of the model. This exercise has to be evaluated with an important caveat. In this exercise, we only change the age structure of the model to isolate the role of the demographic transition on the size of fiscal multipliers. All the other fea-

rate to changes in inflation, ψ_π, from 1.5 to 5, then the output national multiplier drops to 0.2, whereas the age sensitivity keeps being 1.1%. Hence, all the results that follow should be interpreted more in terms of the sensitivity of the national fiscal multiplier to changes in the age structure of the population, rather than looking at the level of multipliers per se.

tures of the model are kept constant, e.g., the monetary policy stance and the degree of credit market imperfections. Although in our model changes in the demographic structure generate endogenous variation in the degree of credit market imperfections, we acknowledge that this pattern captures only a fraction of process of financial development of U.S. credit markets.

Figure 2 shows the results of this exercise for the output fiscal multiplier. The output fiscal multiplier was 0.87 in 1970 and increased up to 1.04 in 1980, when the effect of the baby boom on the share of young people was the greatest. As the share of young people progressively shrinks, the multiplier starts decreasing, drops below 1 in 1985, and reaches a value of 0.65 in 2015. Hence, the model predicts that over the last forty years the size of the output fiscal multipliers went down by 38%.

Figure 2: Fiscal Multipliers from 1967 until 2015.



Note: This graph reports the two-year national output fiscal multipliers in a sequence of versions of the baseline model, which are calibrated to the changes in the population shares observed in the U.S. from 1967 to 2015.

These results are consistent with the evidence of Blanchard and Perotti (2002), Bilbiie et *al.* (2008), and Pereira and Lopes (2014) on the reduction of the size of U.S. fiscal multipliers over time. These papers show that fiscal multipliers in the recent decades are smaller than what they used to be during the 1960s and 1970s. Our model provides a rationale of this empirical finding, by linking the aging of the

U.S. population to the observed reduction in the effectiveness of fiscal policy.

Although over the recent decades the age structure of the U.S. population has already experienced a remarkable shift towards older ages, the population aging is not expected to decelerate. The United Nations project that by 2100 the share of old people will be around 30% and the share of young people will drop a further 26% from 2015 to 2100. To assess the implications of these changes, we feed our model with the projected shares of young, mature, and old people in the U.S. population in 2100, and compute the output fiscal multiplier. The model predicts that in 2100 the output fiscal multiplier will equal 0.38. Hence, in 2100 the output fiscal multiplier will be 63% lower than in 1980, and 42% lower than in 2015.

5 Conclusion

The output effects of government consumption spending depend on the age structure of the population, such that fiscal multipliers are larger in economies with higher shares of young people in total population. Our model predicts that in U.S. over the future decades fiscal policy would become a relatively less effective tool for spurring economy activity. Since most economies are experiencing a similar process of population aging, our results suggest that the reduction in the effectiveness of fiscal policy is a global phenomenon. This result has to be interpreted with two caveats. First, our analysis refers to the effectiveness of fiscal policy in normal times, abstracting from cases in which there is slack in the economy or the stance of monetary policy changes. Second, although fiscal policy - intended in the classical form of purchasing goods from the private sector - becomes less effective in spurring economic activity due to population aging, fiscal interventions targeted to specific age groups could be still highly expansionary. To this end, a new class of model as ours could be used as a laboratory to design and evaluate the effects of such policies.

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A Local Fiscal Multipliers: Further Evidence

A.1 Additional State-Level Controls

The estimates of the age sensitivity of local fiscal multipliers in the baseline regressions could be biased if the exclusion restrictions of our IV approach are violated, which would happen in case there exist potential confounding factors which are highly correlated with both changes (across states and over time) in the current age structure of the population, in 20-30 year lagged birth rates, and in current government spending.

This section addresses this issue by reporting a comprehensive battery of robustness checks, in which we explicitly control for both the level and the interaction with changes in government spending of the lagged values of the same set of state-level key variables introduced in Section 2.4: per capita real federal personal taxes (provided by the BEA), the unemployment rate (provided from the BLS from 1976 on), the ratio of unemployment benefits over personal income (provided from the BLS from 1976 on), the Gini index of labor earnings (derived from labor earnings across individuals in CPS data from 1977 on), a measure of skilled labor (derived from CPS data from 1977 on), a measure of female labor participation (derived from CPS data from 1977 on), the share of services in value added (provided by the BEA), the share of personal services in value added (provided by the BEA), and the share of health care services in value added (provided by the BEA).

Table A.1 shows the estimate of the output fiscal multiplier, whereas Table A.2 reports a similar battery of robustness checks for the employment rate fiscal multiplier. In all cases, the estimated coefficient on the interaction between state government spending and the log-share of young people is always highly statistically and economically significant. The introduction of additional controls alters the level of fiscal multipliers but not the sensitivity of multipliers to states' age structure.

Table A.1: Response of Output to a Government Shock - Additional State-Level Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Personal Taxes	Unempl. Rate	Unempl. Benefits	Gini Earnings	Skilled Labor	Female Labor Participation	Services Share	Personal Services Share	Health Care Services Share
	IV	IV	IV	IV	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.506***	0.581	1.434***	1.232***	1.080**	1.0177**	1.252***	1.510***	1.041**
	(0.409)	(0.407)	(0.390)	(0.477)	(0.453)	(0.478)	(0.368)	(0.407)	(0.408)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t} - \bar{D})$	0.049***	0.041***	0.049***	0.069***	0.077***	0.072***	0.053***	0.061***	0.034**
	(0.018)	(0.016)	(0.017)	(0.017)	(0.022)	(0.018)	(0.018)	(0.021)	(0.016)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (VAR_{i,t} - \bar{V}AR)$	-0.043	0.254	-0.069	9.203	4.097	18.649	-4.787	-18.361	-34.473
	(0.043)	(0.270)	(0.042)	(14.738)	(5.450)	(18.969)	(2.986)	(23.774)	(21.193)
$D_{i,t}$	0.001***	0.001**	0.001***	0.001**	0.001*	0.001*	0.001**	0.001***	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.369	0.452	0.363	0.348	0.353	0.350	0.370	0.365	0.368
N. Obs.	2374	2031	2374	1982	1982	1982	2374	2374	2374

Note: The table reports the estimates of panel regressions across U.S. states using data from 1967 to 2015 at an annual frequency, in which the dependent variable is the change in per capita real output. In all regressions, the independent variables are the change in per capita government spending, $(G_{i,t} - G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita government spending and the log-share of young people, $[(G_{i,t} - G_{i,t-2})/Y_{i,t-2}] \times (D_{i,t} - \bar{D})$. State-specific changes in state per capita government spending (as a fraction of state per capita GDP) are instrumented with the product of state fixed effects and the change in national per capita government spending (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. All regressions add each time a new (lagged) state-level control, and its interaction with the change in per capita government spending. Column (1) introduces the ratio of personal income taxes over total households' income, Column (2) introduces the unemployment rate, Column (3) introduces the ratio of unemployment benefits over total households' income, Column (4) introduces the Gini index of labor earnings, Column (5) introduces the share of skilled labor participation, Column (6) introduces the share of female labor participation, Column (7) introduces the share of services value added in total value added, Column (8) introduces the share of personal services value added in total value added, and Column (9) introduces the share of health services value added in total value added. All regressions include time and state fixed effects. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

Table A.2: Response of Employment Rate - Additional State-Level Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Personal Taxes	Unempl. Rate	Unempl. Benefits	Gini Earnings	Skilled Labor	Female Labor Participation	Services Share	Personal Services Share	Health Care Services Share
	IV	IV	IV	IV	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.093***	0.351	1.060***	0.629**	0.507*	0.608**	1.076***	1.057***	1.001***
	(0.218)	(0.228)	(0.198)	(0.291)	(0.294)	(0.293)	(0.190)	(0.219)	(0.239)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times$	0.035***	0.040***	0.036***	0.043***	0.049***	0.047***	0.031***	0.039***	0.032**
$(D_{i,t}-\bar{D})$	(0.011)	(0.010)	(0.010)	(0.012)	(0.011)	(0.011)	(0.011)	(0.014)	(0.013)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times$	-0.012	-0.154	-0.028	25.739***	2.871	23.428*	0.683	-13.601	-7.784
$(VAR_{i,t}-\bar{V}AR)$	(0.027)	(0.134)	(0.020)	(9.987)	(2.094)	(11.631)	(1.036)	(12.636)	(10.846)
$D_{i,t}$	0.001	-0.001*	0.001	-0.001	-0.001*	-0.001*	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.618	0.720	0.614	0.655	0.670	0.661	0.633	0.614	0.621
N. Obs.	2374	2031	2374	1982	1982	1982	2374	2374	2374

Note: The table reports the estimates of panel regressions across U.S. states using data from 1967 to 2015 at an annual frequency, in which the dependent variable is the change in employment rate. In all regressions, the independent variables are the change in per capita government spending, $(G_{i,t}-G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita government spending and the log-share of young people, $[(G_{i,t}-G_{i,t-2})/Y_{i,t-2}] \times (D_{i,t}-\bar{D})$. State-specific changes in state per capita government spending (as a fraction of state per capita GDP) are instrumented with the product of state fixed effects and the change in national per capita government spending (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. All regressions add each time a new (lagged) state-level control, and its interaction with the change in per capita government spending. Column (1) introduces the ratio of personal income taxes over total households' income, Column (2) introduces the unemployment rate, Column (3) introduces the ratio of unemployment benefits over total households' income, Column (4) introduces the Gini index of labor earnings, Column (5) introduces the share of skilled labor participation, Column (6) introduces the share of female labor participation, Column (7) introduces the share of services value added in total value added, Column (8) introduces the share of personal services value added in total value added, and Column (9) introduces the share of health services value added in total value added. All regressions include time and state fixed effects. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

A.2 Additional National-Level Controls

In the baseline regressions we control for time fixed effects, which wash out the effects of national-level factor. Yet, if states differ in the responsiveness to national-level factors, and this heterogeneity correlates with the age structure of the population, then our estimates of the age sensitivity of local fiscal multipliers could be biased.

This section addresses this point by running a battery of regressions in which each time we control for the interaction between a key national-level variable and state fixed effects, so that the regressions control for states' heterogeneous responsiveness to these national-level variables. Namely, as national-level variables we consider the oil price (the annual average spot price of West Texas Intermediate), households' debt to GDP (the ratio of the credit market instruments - liability - of the households and nonprofit organizations from the Financial Accounts of the U.S. over the series of national GDP provided by the BEA), federal debt to GDP (the ratio of the total public debt from the U.S. Office of Management and Budget over the series of national GDP provided by the BEA), the military news variable of Ramey (2011) and Ramey and Zubairy (2018), and the real interest rate (the difference between the effective federal funds rate from the St. Louis Federal Reserves FRED database and the change in the Consumer Price Index for all urban consumers from the BLS).

Table A.3 reports the results of the regressions in which the dependent variable is the change in real per capita output whereas in Table A.4 the dependent variable is the employment rate. In all cases, the age sensitivity of local fiscal multipliers is always highly statistically significant, and again roughly constant across specifications.

Table A.3: Response of Output with Additional National-Level Variables

	(1)	(2)	(3)	(4)	(5)
	Oil Price	Households' Debt	Federal Debt	Real Interest Rate	Ramey News
	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.311***	1.661***	1.511***	1.500***	1.508***
	(0.333)	(0.451)	(0.443)	(0.395)	(0.416)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t}-\bar{D})$	0.039**	0.065***	0.041**	0.048***	0.039**
	(0.015)	(0.022)	(0.017)	(0.017)	(0.018)
$D_{i,t}$	0.001**	0.002**	0.002***	0.001**	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.446	0.371	0.397	0.405	0.389
N. Obs.	2374	2374	2374	2374	2374

Note: The table reports the estimates of panel regressions across U.S. states using data from 1967 to 2015 at an annual frequency, in which the dependent variable is the change in per capita real output. In all regressions, the independent variables are the change in per capita government spending, $(G_{i,t}-G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita government spending and the log-share of young people, $[(G_{i,t}-G_{i,t-2})/Y_{i,t-2}] \times (D_{i,t}-\bar{D})$. State-specific changes in state per capita government spending (as a fraction of state per capita GDP) are instrumented with the product of state fixed effects and the change in national per capita government spending (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. All regressions include one additional national-level control to the benchmark specification, which we interact with state-fixed effects. Regression (1) includes the log-difference of the real oil price. Regression (2) includes households' debt to GDP ratio. Regression (3) includes federal debt to GDP ratio. Regression (4) includes the level of the real interest rate. Regression (5) includes Ramey government spending news variable. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

Table A.4: Response of Employment Rate with Additional National-Level Variables

	(1) Oil Price IV	(2) Households' Debt IV	(3) Federal Debt IV	(4) Real Interest Rate IV	(5) Ramey News IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.104***	1.070***	1.025***	1.069***	1.073***
	(0.207)	(0.013)	(0.216)	(0.211)	(0.222)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times$	0.033***	0.040***	0.034***	0.032***	0.035***
$(D_{i,t} - \bar{D})$	(0.011)	(0.013)	(0.011)	(0.011)	(0.011)
$D_{i,t}$	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.630	0.635	0.641	0.639	0.625
N. Obs.	2374	2374	2374	2374	2374

Note: The table reports the estimates of panel regressions across U.S. states from 1967 to 2015, at an annual frequency, in which the dependent variable is the change in employment rate. In all regressions, the independent variables are the change in per capita government spending, $(G_{i,t} - G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the change in per capita government spending and the log-share of young people, $[(G_{i,t} - G_{i,t-2})/Y_{i,t-2}] \times (D_{i,t} - \bar{D})$. State-specific changes in state per capita government spending (as a fraction of state per capita GDP) are instrumented with the product of state fixed effects and the change in national per capita government spending (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. All regressions include one additional national-level control to the benchmark specification, which we interact with state-fixed effects. Regression (1) includes the log-difference of the real oil price. Regression (2) includes households' debt to GDP ratio. Regression (3) includes federal debt to GDP ratio. Regression (4) includes the level of the real interest rate. Regression (5) includes Ramey government spending news variable. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

A.3 Controlling for Dynamics

This section shows that the results on the age sensitivity of local fiscal multipliers do not change in case we explicitly take into account the dynamics of output, employment, and government spending. To do so, we extend the baseline regressions by introducing either the lagged two-year change in the dependent variable of interest (i.e., either output per capita or the employment rate), or the lagged two-year change in government spending, or both. We also consider a regression in which we control for state-specific time trends.

Table A.5 shows that although again the level of the local multipliers may change substantially, the variation in the age sensitivity is much more limited, especially in the case of the estimation of the local output multiplier. Moreover, in all cases the age sensitivity keeps being statistically significant, which only one case in which the significance is just at the 10%, and not at either the 1% or 5% level.

Table A.6 computes the 1-year and 4-year impact local output multipliers, and shows that the size of the multipliers increases with the time horizon. In either case, a 1% increase in the share of young people raises the multiplier by 2.5%, and the estimate is statistically significant at the 5% level. Finally, the table shows that the confidence bands around the estimated age sensitivity barely change if we use the Driscoll and Kray (1998) standard error procedure.

Table A.5: Response of Output and Employment Rate to a Government Shock

	Dependent Variable: Output per Capita				Dependent Variable: Employment Rate			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	IV	IV	IV	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	0.803^{**}	1.488^{**}	0.806^{*}	1.561^{***}	0.383^{***}	1.023^{***}	0.399^{***}	0.976^{***}
	(0.316)	(0.597)	(0.441)	(0.461)	(0.124)	(0.033)	(0.132)	(0.212)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t} - \bar{D})$	0.032^{**}	0.046^{***}	0.032^{**}	0.062^{***}	0.009^{*}	0.033^{***}	0.009^{*}	0.041^{***}
	(0.016)	(0.017)	(0.016)	(0.019)	(0.005)	(0.011)	(0.005)	(0.011)
$D_{i,t}$	0.001	0.002^{***}	0.001	0.002^{**}	-0.001^{***}	0.001	-0.001^{***}	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\frac{Y_{i,t-1}-Y_{i,t-3}}{Y_{i,t-3}}$	0.626^{***}		0.627^{***}					
	(0.012)		(0.012)					
$\frac{E_{i,t-1}-E_{i,t-3}}{E_{i,t-3}}$					0.718^{***}		0.719^{***}	
					(0.009)		(0.009)	
$\frac{G_{i,t-1}-G_{i,t-3}}{Y_{i,t-3}}$		-0.110	-0.060			-0.036	-0.042	
		(0.301)	(0.253)			(0.065)	(0.050)	
State-Specific Time Trend	NO	NO	NO	YES	NO	NO	NO	YES
R^2	0.625	0.372	0.625	0.377	0.844	0.625	0.843	
N. Obs.	2325	2325	2325	2374	2325	2325	2325	2374

Note: The table reports the estimates of panel regressions across U.S. states using data from 1967 to 2015 at an annual frequency, following the same specifications of the regressions studied in Table 1. Columns (1) - (4) reports the results of regressions in which the dependent variable is the two-year change in real per-capita output, whereas Columns (5) - (8) reports the results of regressions in which the dependent variable is the two-year change in the employment rate. Column (1) adds to the baseline specification the lagged value of the two-year change in real per-capita output, $Y_{i,t-1} - Y_{i,t-3}/Y_{i,t-3}$. Column (2) and (6) adds to the baseline specification the lagged value of the two-year change in real per-capita government spending, $G_{i,t-1} - G_{i,t-3}/Y_{i,t-3}$. Column (3) adds to the baseline specification the lagged value of both the two-year change in real per-capita output, $Y_{i,t-1} - Y_{i,t-3}/Y_{i,t-3}$, and the two-year change in real per-capita government spending, $G_{i,t-1} - G_{i,t-3}/Y_{i,t-3}$. Columns (4) and (8) add to the baseline specification state-specific time-trends. Column (5) adds to the baseline specification the lagged value of the two-year change in the employment rate, $E_{i,t-1} - E_{i,t-3}/E_{i,t-3}$. Column (7) adds to the baseline specification the lagged value of both the two-year change in the employment rate, $E_{i,t-1} - E_{i,t-3}/E_{i,t-3}$, and the two-year change in real per-capita government spending, $G_{i,t-1} - G_{i,t-3}/Y_{i,t-3}$. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

Table A.6: Local Output Multipliers, Different Time Horizons, and Driscoll-Kraay Errors

	(1)	(2)	(3)
	1 Year	4 Year	2 Year Driscoll-Kraay
	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-1}}{Y_{i,t-1}}$	0.964** (0.409)		
$\frac{G_{i,t}-G_{i,t-4}}{Y_{i,t-4}}$		1.960*** (0.530)	
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$			1.511*** (0.411)
$\frac{G_{i,t}-G_{i,t-1}}{Y_{i,t-1}} \times (D_{i,t} - \bar{D})$	0.024** (0.011)		
$\frac{G_{i,t}-G_{i,t-4}}{Y_{i,t-4}} \times (D_{i,t} - \bar{D})$		0.046** (0.020)	
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t} - \bar{D})$			0.047*** (0.017)
$D_{i,t}$	0.001*** (0.001)	0.004*** (0.002)	0.002** (0.001)
R^2	0.353	0.347	0.374
N. Obs.	2374	2276	2374

Note: The table reports the estimates of panel regressions across U.S. states using data from 1967 to 2015, following the some variants of the specifications of the regressions studied in Table 1. Column (1) derives the changes in both real per-capita output and real per-capita military spending with a one-year lag, Column (2) considers a four-year lag, whereas Column (3) considers a two-year lag and computes standard errors following the Driscoll and Kray (1998) procedure. In all cases, the dependent variable is the change in real per-capita output. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

A.4 Cumulative Fiscal Multipliers

The econometric specification of the regression (1) in Section 2 computes a two-year impact output fiscal multiplier. Ramey and Zubairy (2018) argue that cumulative multipliers describe better the effectiveness of fiscal policy than impact multipliers.

To derive the cumulative local fiscal multipliers, we follow Dupor and Guerrero (2017). Namely, we estimate the following IV regression

$$\begin{aligned}\frac{\left(\sum_{j=1}^{2} Y_{i,t+1-j} - 2Y_{i,t-2}\right)}{Y_{i,t-2}} &= \alpha_i + \delta_t + \beta \frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} + \dots \\ &\dots + \gamma \frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} \left(D_{i,t} - \bar{D}\right) + \zeta D_{i,t} + \epsilon_{i,t}\end{aligned}$$

where the dependent variable is the two-year cumulative change in per capita output of state i, and the independent variables are state fixed effects α_i, time fixed effects δ_t, the two-year cumulative change in per capita state government spending $\frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}}$, the interaction between the two-year cumulative in per capita state government spending and the demeaned log-share of young people in total population $D_{i,t} - \bar{D}$, where $\bar{D} = \sum_i \sum_t D_{i,t}$, and the log-share of young people in total population $D_{i,t}$ multiplied by 100. In this regression, β defines the two-year cumulative output local fiscal multiplier for a state with an average share of young people in total population and γ defines how two-year cumulative fiscal multipliers vary with the age structure of a state relative to the average. Analogously, we estimate two-year cumulative employment fiscal multipliers as

$$\begin{aligned}\frac{\left(\sum_{j=1}^{2} E_{i,t+1-j} - 2E_{i,t-2}\right)}{E_{i,t-2}} &= \alpha_i + \delta_t + \beta \frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} + \dots \\ &\dots + \gamma \frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} \left(D_{i,t} - \bar{D}\right) + \zeta D_{i,t} + \epsilon_{i,t}.\end{aligned}$$

In this case, the instrumenting strategy hinges on the following first-stage regression, which leverage the cumulative change in per capita national government expenditures (as a fraction of per capita national GDP), that is

$$\frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} = \alpha_i + \delta_t + \eta_i \frac{\left(\sum_{j=1}^{2} G_{t+1-j} - 2G_{t-2}\right)}{Y_{t-2}} + \zeta X_{i,t} + \epsilon_{i,t}$$

where $X_{i,t}$ includes the instruments for both the share of young people, and its interaction with two-year cumulative changes in government spending.

Table A.7 shows that the estimates of neither β nor γ change substantially when we estimate two-year cumulative multiplier rather than two-year impact multiplier.

Table A.7: Cumulative Local Fiscal Multipliers

	(1) Output per Capita	(2) Employment Rate
$\frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}}$	1.453***	1.019***
	(0.405)	(0.212)
$\frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} \times \left(D_{i,t} - \bar{D}\right)$	0.046***	0.033***
	(0.016)	(0.011)
$D_{i,t}$	0.003***	0.001
	(0.001)	(0.001)
R^2	0.369	0.618
N. Observations	2374	2374

Note: The table reports the estimates of a panel IV regression across U.S. states from 1967 to 2015, at an annual frequency. In regression (1) the dependent variable is the two-year cumulative change in output per capita. In regressions (2) the dependent variable is the two-year cumulative change in employment rate. The independent variables are the two-year cumulative change in per capita state government spending (as a fraction of per capita state GDP), $(G_{i,t} - G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (aged 20-29) in total population times 100, $D_{i,t}$, and the interaction between the two-year cumulative change in per capita state government spending (as a fraction of per capita state GDP) and the log-share of young people, $[(G_{i,t} - G_{i,t-2})/Y_{i,t-2}] \times \left(D_{i,t} - \bar{D}\right)$. In both regressions, two-year cumulative state-specific changes in per capita state government spending (as a fraction of per capita state GDP) are instrumented with the product of state fixed effects and the two-year cumulative change in per capita national government spending (as a fraction of per capita national GDP). The share of young people is instrumented with 20-30 year lagged birth rates. We include time and state fixed effects in all the regressions. Robust standard errors clustered at the state level are reported in brackets. *** indicates statistical significance at the 1%.

A.5 Population Response to Government Spending Shocks

Table A.8 studies the response of state population to a government spending shock. In this case, we estimate a simplified regression in which we consider as independent variable just the change in state government spending:

$$\frac{Pop_{i,t} - Pop_{i,t-2}}{Pop_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} + \epsilon_{i,t}$$

where $Pop_{i,t}$ denotes the population of state i at time t. In particular, we consider four different definitions of population: (i) overall population, (ii) young population (i.e., people between 20 and 29 years old), (iii) mature population (i.e., people between 30 and 64 years old), and (iv) old population (i.e., people above 65 years old). Given data availability on the disaggregation of total population across age groups, this set of regressions uses annual data from 1969 until 2015.

Table A.8: Response of Population to a Government Spending Shock Across U.S. States

	(1) Overall Population IV	(2) Young Population IV	(3) Mature Population IV	(4) Old Population IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	-0.179 (0.303)	1.145*** (0.399)	-0.398 (0.403)	-0.070 (0.212)
R^2	0.611	0.654	0.584	0.790
N. Observations	2295	2295	2295	2295

Note: The table reports the estimates of panel regressions across U.S. states from 1969 to 2015 at an annual frequency. In Column (1) the dependent variable is the state overall white male population. In Column (2) the dependent variable is the state white male young population (aged 20-29). In Column (3) the dependent variable is the state white male mature population (aged 30-64). In Column (4) the dependent variable is the state white male old population (aged 65+). The independent variable is the change in per capita state government spending (as a fraction of per capita state GDP), which is instrumented with the product of state fixed effects and the change in per capita national government spending (as a fraction of per capita national GDP). We include time and state fixed effects in all the regressions. Robust standard errors clustered at the state level are reported in brackets. *, **, and *** indicate statistical significance at the 10%, 5% and 1%, respectively.

Column (1) of Table A.8 shows that the overall population does not change following a government spending shock. Yet, this aggregate result compounds different dynamics of the populations by age group. On the one hand, column (2) shows that the young population does rise following a fiscal shock. On the other hand, columns (3) and (4) show that mature and old population shrink following a government spending shock, even though this effect is not statistically significant.

These results are consistent with the findings of the literature on the sensitivity of state population to shocks. On the one hand, Blanchard and Katz (1992) show that state migration flows are important transmission mechanisms of changes in state unemployment rates over time. On the other hand, Nakamura and Steinsson (2014) find that overall state population does not react to government spending shocks at short horizon. Our results emphasize that although overall population may not change following a fiscal shock, this aggregate pattern masks heterogenous reactions in the population of different age groups.

This evidence validates our approach in instrumenting the share of young people with lagged birth rates. Indeed, as the young population does react to fiscal shocks, using raw log-shares of the young people in total population would also capture the endogenous reaction of states' age structure to government spending shocks. Hence, instrumenting the log-share of young people with lagged birth rates is key to identify the causal effect of demographics on the size of fiscal multipliers.

A.6 Labor Market Response to Government Spending Shocks

In the model, 40% of the age sensitivity of the output local fiscal multiplier hinges on the presence of age-specific differences in both labor supply and demand. On the one hand, we assume that the labor supply elasticity varies exogenously across age groups, such as the elasticity of young and old individuals is larger than the one of mature individuals. On the other hand, the production function is characterized capital-experience complementarity, such as the demand of experienced labor is relatively more persistent over the cycle as it is tied to the stock of capital. These two features makes both the hours worked and the hourly wage of young workers to relatively more elastic.

In this section, we validate in the data the model mechanism through which the age structure of the population affects the labor response to government spending shock, as the labor of young workers is relatively more responsive. To do so, we use CPS data to build a measure by state of total labor earnings, hours worked, and the hourly wage of both young workers (i.e., workers between 20 and 29 years old) and older (i.e., workers above 30 years old). Consistently with the definition of the share of young people in total population used in the baseline local multiplier regressions, we focus on white male workers employed in the private sector. We also exclude non full-time and self-employed workers.

Then, we estimate the following regression

$$\frac{X_{i,t} - X_{i,t-2}}{X_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} + \epsilon_{i,t} \tag{1}$$

where we consider each time a different dependent variable $X_{i,t}$, consisting of the per-capita labor earnings, per-capita hours worked, and per-capita hourly wage of young workers, and per-capita labor earnings, per-capita hours worked, and per-capita hourly wage of older workers.

Again, we instrument state military spending with a first-stage regression in which the independent variable is the product of a state fixed effect and the change in national military spending. Since CPS data start in 1977, we are left with 1887 observations, which is a substantial reduction in the sample size with respect our benchmark analysis, that spans from 1967 to 2015.

Table A.9: Labor Market Response to a Government Spending Shock Across U.S. States

	Labor Earnings		Hours Worked		Hourly Wage	
	(1)	(2)	(3)	(4)	(5)	(6)
	Young Workers	Older Workers	Young Workers	Older Workers	Young Workers	Older Workers
	IV	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.327**	0.878	1.036	0.449	0.746*	0.291
	(0.678)	(0.648)	(0.711)	(0.407)	(0.450)	0.670
R^2	0.114	0.306	0.100	0.121	0.206	0.392
N. Observations	1887	1887	1887	1887	1887	1887

Note: The table reports the estimates of panel regressions across U.S. states from 1969 to 2015 at an annual frequency. In Column (1) the dependent variable is the two-year change in per-capita labor earnings of young workers (i.e., workers between 20 and 29 years old). In Column (2) the dependent variable is the two-year change in per-capita labor earnings of older workers (i.e., workers above 30 years old). In Column (3) the dependent variable is the two-year change in per-capita hours worked of young workers (i.e., workers between 20 and 29 years old). In Column (4) the dependent variable is the two-year change in per-capita hours worked of older workers (i.e., workers above 30 years old). In Column (5) the dependent variable is the two-year change in the per-capita hourly wage of young workers (i.e., workers between 20 and 29 years old). In Column (6) the dependent variable is the two-year change in the per-capita hourly wage of older workers (i.e., workers above 30 years old). In all regressions, the independent variable is the change in per capita state government spending (as a fraction of per capita state GDP), which is instrumented with the product of state fixed effects and the change in per capita national government spending (as a fraction of per capita national GDP). We include time and state fixed effects in all regressions. Robust standard errors clustered at the state level are reported in brackets. ** indicates statistical significance at the 10%, 5% and 1%, respectively.

Table A.9 reports the estimates of the coefficient β, which defines the local multiplier for each of the dependent variables of interest. The results indicate that the labor market outcomes of young workers are more responsive than those of older workers. In all cases, the size of the multiplier of young workers is twice as large as the one of older workers, and is statistically different from zero in the case of labor earnings and the hourly wage, whereas the response of hours is surrounded by a high degree of uncertainty mainly because of the known measurement issues that characterize the accounting of hours worked.

This evidence is in line with the findings of Jaimovich and Siu (2009) and Jaimovich et al. (2013), which document that both the hours worked and the hourly wage of young workers are highly volatile over the business cycle. Moreover, the fact that both the hours worked and the hourly wage response of young individuals is larger than those of older workers further corroborates our modeling choices of the age-specific differences in labor demand and supply.

A.7 Relevance of Birth Rates

In the baseline regression we instrument the share of young people in total population with lagged birth rates. This approach aims at avoiding any endogeneity of states' age structure with respect to government spending shocks. In particular, states' age structure would not be exogenous to government spending shocks if they trigger migration flows.[28] The use of lagged birth rates as an instrument imposes an identifying exclusion restriction which posits that, conditional on state and time fixed effects, whatever determines the cross-sectional variation in birth rates has no other long lasting effect on the size of fiscal multipliers 20-30 years later.

In this section we study the relevance of lagged birth rates as an instrument for the share of young people in total population, by reporting the results of the first-stage regression of the share of young people on lagged birth rates. We consider four different cases for the share of young white males, the share of young males, and the share of overall young people: (*i*) we regress the raw share of young people on the raw series of lagged birth rates and both time and state fixed effects; (*ii*) we regress the residual series of the raw share of young people on the residual series of the raw series of lagged birth rates. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is is either the share of young people or the lagged birth rates and the independent variables are state and time fixed effects; (*iii*) we regress the log-share of young people on the series of lagged birth rates in logarithm and both time and state fixed effects; (*iv*) we regress the residual series of the log-share of young people on the residual series of the series of lagged birth rates in logarithm. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is either the log-share of young people or the logged lagged birth rates and the independent variables are state and time fixed effects.

[28] Blanchard and Katz (1992) show that state migration reacts to shocks. We find that although total population does not change following government spending shocks, the population of young people does rise.

Table A.10: First Stage Regression Share of Young White Males on Lagged Birth Rates

	(1) Share Young People	(2) Share Young People Residuals	(3) Share Young People Log	(4) Share Young People Log, Residuals
Lagged Birth Rates	0.317*** (0.062)			
Lagged Birth Rates (Residuals)		0.317*** (0.014)		
Lagged Birth Rates (Log)			0.509*** (0.064)	
Lagged Birth Rates (Log, Residuals)				0.509*** (0.018)
State FE	YES	NO	YES	NO
Year FE	YES	NO	YES	NO
R^2	0.938	0.176	0.934	0.259
N. Observations	2374	2374	2374	2374

Note: The table reports the results of the first-stage regression in which the share of young white males (aged 20-29) in the total white male population is regressed on 20-30 year lagged birth rates. In column (1) the raw share of young people is regressed on the raw series of lagged birth rates, in addition to state and year fixed effects. In column (2) the residual series of the raw share of young people is regressed on the residual series of the raw series of lagged birth rates. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the raw series and the independent variables are state and time fixed effects. In column (3) the log-share of young people is regressed on the series of lagged birth rates in logarithm, in addition to state and year fixed effects. In column (4) the residual series of the log-share of young people is regressed on the residual series of the raw series of lagged birth rates in logarithm. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the log series and the independent variables are state and time fixed effects. Robust standard errors clustered at the state level are reported in brackets. *** indicates statistical significance at the 1%.

Table A.11: First Stage Regression Share of Young Males on Lagged Birth Rates

	(1) Share Young People	(2) Share Young People Residuals	(3) Share Young People Log	(4) Share Young People Log, Residuals
Lagged Birth Rates	0.280*** (0.062)			
Lagged Birth Rates (Residuals)		0.280*** (0.013)		
Lagged Birth Rates (Log)			0.446*** (0.059)	
Lagged Birth Rates (Log, Residuals)				0.446*** (0.017)
State FE	YES	NO	YES	NO
Year FE	YES	NO	YES	NO
R^2	0.913	0.159	0.915	0.228
N. Observations	2374	2374	2374	2374

Note: The table reports the results of the first-stage regression in which the share of young males (aged 20-29) in the total male population is regressed on 20-30 year lagged birth rates. In column (1) the raw share of young people is regressed on the raw series of lagged birth rates, in addition to state and year fixed effects. In column (2) the residual series of the raw share of young people is regressed on the residual series of the raw series of lagged birth rates. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the raw series and the independent variables are state and time fixed effects. In column (3) the log-share of young people is regressed on the series of lagged birth rates in logarithm, in addition to state and year fixed effects. In column (4) the residual series of the log-share of young people is regressed on the residual series of the raw series of lagged birth rates in logarithm. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the log series and the independent variables are state and time fixed effects. Robust standard errors clustered at the state level are reported in brackets. *** indicates statistical significance at the 1%.

Table A.12: First Stage Regression Share of Young People on Lagged Birth Rates

	(1)	(2)	(3)	(4)
	Share Young People	Share Young People Residuals	Share Young People Log	Share Young People Log, Residuals
Lagged Birth Rates	0.262*** (0.057)			
Lagged Birth Rates (Residuals)		0.262*** (0.012)		
Lagged Birth Rates (Log)			0.427*** (0.057)	
Lagged Birth Rates (Log, Residuals)				0.427*** (0.016)
State FE	YES	NO	YES	NO
Year FE	YES	NO	YES	NO
R^2	0.921	0.159	0.922	0.226
N. Observations	2374	2374	2374	2374

Note: The table reports the results of the first-stage regression in which the share of young people (aged 20-29) in the total population is regressed on 20-30 year lagged birth rates. In column (1) the raw share of young people is regressed on the raw series of lagged birth rates, in addition to state and year fixed effects. In column (2) the residual series of the raw share of young people is regressed on the residual series of the raw series of lagged birth rates. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the raw series and the independent variables are state and time fixed effects. In column (3) the log-share of young people is regressed on the series of lagged birth rates in logarithm, in addition to state and year fixed effects. In column (4) the residual series of the log-share of young people is regressed on the residual series of the raw series of lagged birth rates in logarithm. Each residual variable is derived by taking the residuals of a regression in which the dependent variable is the log series and the independent variables are state and time fixed effects. Robust standard errors clustered at the state level are reported in brackets. *** indicates statistical significance at the 1%.

Table A.10 reports the results on the first-stage regressions for the share of young white males, Table A.11 reports the results on the first-stage regressions for the share of young males, and Table A.12 reports the results on the first-stage regressions for the share of overall young people. The results indicate that in all cases the lagged birth rates are a relevant instrument for the current share of young people in total population, as the relative coefficient on the instrument is always highly statistically significant at the 1% level. Moreover, when we use state and time fixed effects, the R^2 of the regressions ranges between 91% and 94%. Even in the case we use the residual series and we abstract from the state and time fixed effects, the R^2 still ranges between 22% and 24%. Hence, birthrates in a state do have a predictive power for the future age composition in that state.

Furthermore, comparing the results of Tables A.10-A.12, we find that lagged birth rates are a more relevant instrument for the share of young white males than for the share of young males or the share of all young people. Indeed, the regressions with the share of young white males feature the highest values for the R^2.

B National Fiscal Multipliers

The fact that at the state level demographics have an effect on fiscal multipliers which is statistically and economically significant does not necessarily imply that the same applies also at the national level. In this section we provide some suggestive evidence showing that also national fiscal multipliers depend on demographics. To do so, we run a SVAR à la Blanchard and Perotti (2002) on both a panel of developed countries and a panel of developing countries. In either case, we show that the long-run national output fiscal multiplier is larger in countries with higher shares of young people in total population.

B.1 Data

We take the data from Ilzetzki et *al.* (2013). These authors compiled an unbalanced panel on government spending, GDP, current account, real effective exchange rate, and interest rates at quarterly frequency from 1960Q1 until 2009Q4 for 19 developed countries and 25 developing countries.[29] Then, we take the data on the demographic structure of each country from the World Population Prospects prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. The data on demographics are at the annual frequency from 1950 on.

B.2 Econometric Specification

We estimate fiscal multiplier using a SVAR system as in Blanchard and Perotti (2002), such that

[29] The developed countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States. The developing countries are Argentina, Botswana, Brazil, Bulgaria, Chile, Colombia, Croatia, Czech Republic, Ecuador, El Salvador, Estonia, Hungary, Latvia, Lithuania, Malaysia, Mexico, Peru, Poland, Romania, Slovakia, Slovenia, South Africa, Thailand, Turkey, and Uruguay.

$$AX_{i,t} = \sum_{k=1}^{K} C_k X_{i,t-k} + BU_{i,t}$$

where $X_{i,t}$ is a vector that consists of the logarithm of real government expenditure, the logarithm of real GDP, the ratio of the real current account balance over GDP, and the log difference of the real effective exchange rate of country i. To identify government spending shocks, we follow the identification assumption of Blanchard and Perotti (2002): we assume that government spending reacts to changes in the other macroeconomic variables with the delay of a quarter. This assumption defines a Cholesky decomposition in which government spending is ordered first. For the selection of the lag structure of the panel SVAR we follow Ilzetzki et *al.* (2013) by choosing $K = 4$ lags. The results do not change if we choose a number of lags between 1 and 8.

To identify the role of demographics on fiscal multipliers, we do the following. First, we take all the developed countries and split them in two sets: 9 countries with high shares of young people in total population, and 10 countries with low share of young people in total population. Second, we estimate the SVAR system on the two different panels and compare the results. Then, we repeat the same exercise for the developing countries. In this case, we find 11 countries with high shares of young people and 14 countries with low shares.[30,31]

Finally, we follow Ilzetzki et *al.* (2013) and define the long-run output fiscal multiplier as $\frac{\sum_{t=0}^{\infty}(1+r_i)^{-t}\Delta Y_{i,t}}{\sum_{t=0}^{\infty}(1+r_i)^{-t}\Delta G_{i,t}}$, where $t = 0$ denotes the date in which the government

[30] We consider developed and developing countries separately because Ilzetzki et *al.* (2013) show that national fiscal multipliers in developed countries are large and positive, while in developing countries are large and negative. The results of Ilzetzki et *al.* (2013) suggest that other factors (e.g., the exchange rate policy rule, the degree of trade openness, and the level of public debt) could be explaining the differences in fiscal multipliers across our sets of countries.

[31] Table B.1 reports countries' average share of young people (age 20-29) over total population computed from 1970 to 2010. We show how we group the countries in the set with high shares of young people and the set with low shares of young people. In the case of developed countries, the nine countries with high shares of young people have shares in the range of 15%-15.6%. Instead, the ten countries with low shares of young people have shares in the range of 13.5%-14.7%. In the case of developing countries, the eleven countries with high shares of young people have shares in the range of 16.4%-17.2%. Instead, the fourteen countries with low shares of young people have shares in the range of 14.7%-15.9%.

expenditure shock occurs, and r_i is the median of the country specific nominal interest rate.

B.2.1 Results

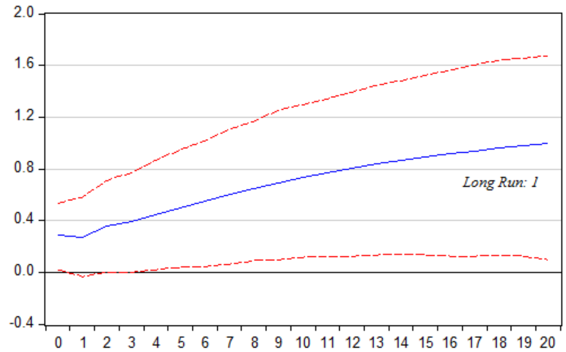
Figure B.1 reports the response of national output to an increase in government spending in both developed countries and developing countries. We also report the estimates of the long-run fiscal multiplier. Panel (a) shows the response in developed countries with high shares of young people in total population whereas Panel (b) plots the response in developed countries with low shares of young people in total population.

Although the impact response is similar across groups, in countries with low shares of young people the fiscal multipliers becomes statistically insignificant from zero from the first quarter on, leading to a long-run multiplier of -0.11. Instead, in countries with high shares of young people the fiscal multiplier is always statistically significant and the long-run multiplier equals 1.

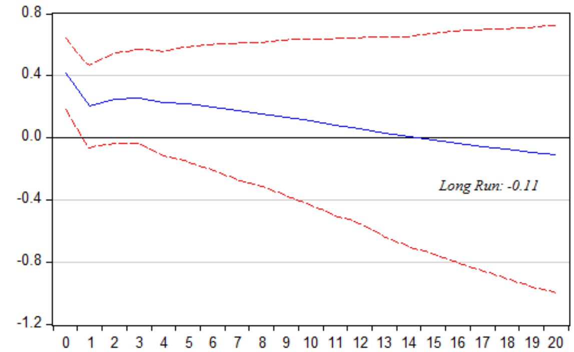
Panel (c) and Panel (d) report the same set of results for developing countries. As already pointed out in Ilzetzki et *al.* (2013), fiscal multipliers in developing countries tend to be negative. Nevertheless, we find again that fiscal multipliers vary with the demographic structure of the countries. In the developing countries with high shares of young workers the impact responses are positive for the first ten periods, and interestingly the point estimate of the cumulative fiscal multiplier after two quarters is around 0.5, and is statistically different from zero. Then, the responses turn into negative values and as a result the long-run multiplier is -0.39. Instead, in the panel of developing countries with low shares of young people fiscal multipliers are much smaller. The impact responses are always negative and in the long-run the multiplier drops down to -1.2

Figure B.1: National Fiscal Multipliers and Demographics.

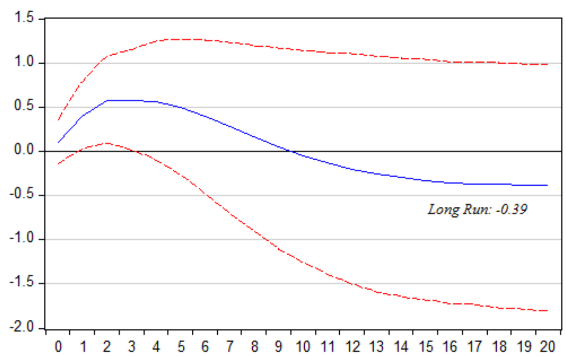
(a) High Income Countries - High Share of Young



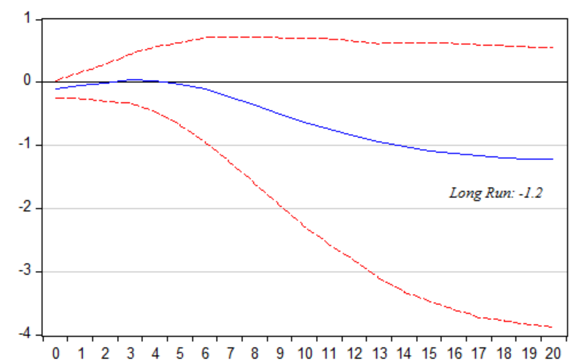
(b) High Income Countries - Low Share of Young



(c) Low Income Countries - High Share of Young



(d) Low Income Countries - Low Share of Young



Note: Panel (a) plots the cumulative national fiscal multipliers over twenty quarters following a government expenditure shock in a panel of nine high income countries with high shares of young people (i.e., age 20-29) in total population. Panel (b) plots the cumulative national fiscal multipliers in a panel of eleven high income countries with low shares of young people in total population. Panel (c) plots the cumulative national fiscal multipliers in a panel of eleven low income countries with high shares of young people in total population. Panel (d) plots the cumulative national fiscal multipliers in a panel of fourteen low income countries with low shares of young people in total population. In each Panel, the dotted lines display 90% confidence bands. The data on government expenditures and real GDP at quarterly frequency from 1960 until 2009 across 19 high income countries and 25 low income countries is from Ilzetzki et *al.* (2013).

Table B.1: Demographic Structure Across Countries

Average Share of Young People (Age 20-29) in Total Population			
Developed Countries		Developing Countries	
High Shares of Young People	Low Shares of Young People	High Shares of Young People	Low Shares of Young People
United States 15.0%	Sweden 13.5%	Mexico 16.4%	Hungary 14.7%
Portugal 15.0%	United Kingdom 13.9%	Ecuador 16.5%	Czech Republic 14.7%
Netherlands 15.1%	Norway 13.9%	Chile 16.6%	Bulgaria 14.9%
Greece 15.1%	Belgium 14.1%	Malaysia 16.6%	Uruguay 15.1%
Australia 15.2%	Denmark 14.1%	Peru 16.8%	Latvia 15.1%
Spain 15.5%	Germany 14.1%	Colombia 16.9%	Estonia 15.1%
Israel 15.6%	France 14.3%	Turkey 16.9%	Croatia 15.1%
Canada 15.6%	Ireland 14.3%	Botswana 17.0%	Lithuania 15.5%
Iceland 15.6%	Italy 14.5%	South Africa 17.1%	Slovenia 15.6%
	Finland 14.7%	Thailand 17.1%	Romania 15.8%
		Brazil 17.2%	Argentina 15.7%
			El Salvador 15.9%
			Poland 15.9%
			Slovakia 15.9%

Note: The table reports the average share of young people (age 20-29) over total population in percentage terms from 1970 until across both developed countries and developing countries.

C More on the Household Sector

In this Section we provide the maximization problems and the optimal conditions for each age group separately. We show that the optimal decisions of each individual are linear in wealth, so we can linearly aggregate the optimal choices of individuals within each age group to form a representative agent for each of the three age groups. For the sake of exposition, we derive the aggregation results only for the home economy. Nevertheless, the aggregation of the optimal choices of households within each age group in the foreign economy follows the same procedure. We derive all the problems and first-order conditions in real terms. We denote $\tilde{b}^j_{z,t} = \frac{b^j_{z,t}}{P_t}$ as the real bond-holdings of an individual i in the age group z at time t, $\tilde{a}^j_{z,t} = \frac{a^j_{z,t}}{P_t}$ is the real total return on assets of an individual i in the age group z at time t, $r_{k,t} = \frac{R_{k,t}}{P_t}$ is the real return on capital, and $w_{in,t} = \frac{W_{in,t}}{P_t}$ and $w_t = \frac{W_{ext,t}}{P_t}$ are the real wages. Finally, as in our calibration, we set $\psi_c = \psi_I$ such that $P_t = P_{I,t}$.

C.1 Old Agents

Assuming interior solutions for capital and bond holdings, the decision problem of an old agent i is

$$\max_{c^i_{o,t}, l^i_{o,t}, k^i_{o,t+1}, \tilde{b}^i_{o,t+1}} v^i_{o,t} = \left\{ \left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}} \right)^{\eta} + \beta\omega_o \mathbb{E}_t [v^i_{o,t+1}]^{\eta} \right\}^{1/\eta} \tag{C.1}$$

subject to

$$c^i_{o,t} + k^i_{o,t+1} + \tilde{b}_{o,t+1} + \frac{\varphi}{2} \left(\frac{k^i_{o,t+1}}{k^i_{o,t}} - \vartheta_o \right)^2 \frac{k^i_{o,t}}{\omega_o} = \tilde{a}^i_{o,t} + w_t \xi_o l^i_{o,t} - \tau^i_{o,t}$$
$$\tilde{a}^i_{o,t} = \left\{ k^i_{o,t} \left[(1-\delta) + r_{k,t} \right] + \tilde{b}^i_{o,t} \frac{R_{n,t}}{1+\pi_t} \right\} \left(\frac{1}{\omega_o} \right).$$

In order to solve the stochastic version of the problem we follow Farmer (1990) closely. Define

$$f_o(Q_{o,t}) \equiv \left(1 + (\beta\omega_o)^{\frac{1}{1-\eta}} Q_{o,t}^{\frac{\eta}{1-\eta}}\right)^{\frac{1-\eta}{\eta}} \tag{C.2}$$

$$g_o(Q_{o,t}) \equiv \left(1 + (\beta\omega_o)^{\frac{1}{1-\eta}} Q_{o,t}^{\frac{\eta}{1-\eta}}\right)^{-1} \tag{C.3}$$

$$Q_{o,t} \equiv \mathbb{E}_t \left(\frac{f_o(Q_{o,t+1}) R_{n,t+1}}{\omega_o(1+\pi_{t+1})}\right) \tag{C.4}$$

We conjecture that the old consume a fraction of a measure of wealth ($W_{o,t}$), define as the sum of financial assets ($a^i_{o,t}$) and the present value of human capital gains ($HC^i_{o,t}$), net of the present value of taxes ($T^i_{o,t}$) and the present value of adjustment costs ($ADJ^i_{o,t}$). Moreover, the value function is given by

$$c^i_{o,t} = \varepsilon_t \varsigma_t \left[\tilde{a}^i_{o,t} + HC^i_{o,t} - T^i_{o,t} - ADJ^i_{o,t}\right] = \varepsilon_t \varsigma_t W_{o,t} \tag{C.5}$$

$$v^i_{o,t} = (\varepsilon_t \varsigma_t)^{\frac{-1}{\eta}} \left(c^i_{o,t} - \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right) \tag{C.6}$$

Finally we set $(\varepsilon_t \varsigma_t)^{\frac{\eta-1}{\eta}} \equiv f_o(Q_{o,t})$, and thus $g_o(Q_{o,t}) = \varepsilon_t \varsigma_t$

Using the conjecture for the value and policy functions

$$\begin{aligned}
v^i_{o,t} &= (\varepsilon_t \varsigma_t)^{\frac{\eta-1}{\eta}} W_{o,t} - (\varepsilon_t \varsigma_t)^{\frac{-1}{\eta}} \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}} \\
v^i_{o,t} &= f_o(Q_{o,t}) \left[\tilde{a}^i_{o,t} + HC^i_{o,t} - T^i_{o,t} - ADJ^i_{o,t}\right] - (\varepsilon_t \varsigma_t)^{\frac{-1}{\eta}} \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}
\end{aligned}$$

Rearranging the budget constraint we have that

$$\tilde{a}^i_{o,t+1} = \frac{R_{n,t+1}}{(1+\pi_{t+1})\,\omega_o} \Big(\tilde{a}^i_{o,t} + w_t \xi_o l^i_{o,t} - \tau^i_{o,t} - adj^i_{o,t} - c^i_{o,t}\Big).$$

where $adj^i_{o,t} = \left(1 - \frac{(1-\delta+r_{k,t+1})(1+\pi_{t+1})}{R_{n,t+1}}\right) k^i_{o,t+1} + \frac{\varphi}{2}\left(\frac{k^i_{o,t+1}}{k^i_{o,t}} - \vartheta_o\right)^2 \frac{k^i_{o,t}}{\omega_o}$. Thus,

$$
\begin{aligned}
v^i_{o,t} &= f_o(Q_{o,t})\Big[\frac{R_{n,t}}{(1+\pi_t)\,\omega_o}\Big(\tilde{a}^i_{o,t-1} + w_{t-1}\xi_o l^i_{o,t-1} - \tau^i_{o,t-1} - adj^i_{o,t-1} - c^i_{o,t-1}\Big) + \\
&\quad + HC^i_{o,t} - T^i_{o,t} - ADJ^i_{o,t}\Big] - (\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\chi_o\frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}} \\
v^i_{o,t} &= \frac{f_o(Q_{o,t})R_{n,t}}{(1+\pi_t)\,\omega_o}\Big(\tilde{a}^i_{o,t-1} + w_{t-1}\xi_o l^i_{o,t-1} - \tau^i_{o,t-1} - adj^i_{o,t-1} - c^i_{o,t-1}\Big) + \\
&\quad + f_o(Q_{o,t})HC^i_{o,t} - f_o(Q_{o,t})T^i_{o,t} - f_o(Q_{o,t})ADJ^i_{o,t} - (\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\chi_o\frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}
\end{aligned}
$$

Taking expectations $\mathbb{E}_{t-1}$, and using (C.4)[32]

$$
\begin{aligned}
\mathbb{E}_{t-1}(v^i_{o,t}) &= Q_{o,t-1}\Big(\tilde{a}^i_{o,t-1} + w_{t-1}\xi_o l^i_{o,t-1} - \tau^i_{o,t-1} - \mathbb{E}_{t-1}adj^i_{o,t-1} - c^i_{o,t-1}\Big) + \\
&\quad + \mathbb{E}_{t-1}f_o(Q_{o,t})HC^i_{o,t} - \mathbb{E}_{t-1}f_o(Q_{o,t})T^i_{o,t} - \mathbb{E}_{t-1}f_o(Q_{o,t})ADJ^i_{o,t} - \\
&\quad - \mathbb{E}_{t-1}\left[(\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\chi_o\frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right]
\end{aligned}
$$

Then, define

$$
\begin{aligned}
HC^i_{o,t} &\equiv w_t\xi_o l^i_{o,t} + \mathbb{E}_t\left[\frac{f(Q_{o,t+1})HC^i_{o,t+1}}{Q_{o,t}}\right] + \\
&\quad + \frac{(Q_{o,t}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t}}\left[\chi_o\frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right] - \mathbb{E}_t\left[(\varepsilon_{t+1}\varsigma_{t+1})^{\frac{-1}{\eta}}\chi_o\frac{(l^i_{o,t+1})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right] \\
T^i_{o,t} &\equiv \tau^i_{o,t} + \mathbb{E}_t\left[\frac{f(Q_{o,t+1})T^i_{o,t+1}}{Q_{o,t}}\right] \\
ADJ^i_{o,t} &\equiv \mathbb{E}_t adj^i_{o,t} + \mathbb{E}_t\left[\frac{f(Q_{o,t+1})ADJ^i_{o,t+1}}{Q_{o,t}}\right]
\end{aligned}
$$

Using these results and adding and subtracting $(Q_{o,t-1}\beta\omega_o)^{\frac{1}{1-\eta}}\left[\chi_o\frac{(l^i_{o,t-1})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right]$,

[32] We assume $\mathbb{E}_{t-1}\frac{f_o(Q_{o,t})R_{n,t}}{(1+\pi_t)\omega_o}adj^i_{o,t-1} \approx Q_{o,t-1}\mathbb{E}_{t-1}adj^i_{o,t-1}$, essentially ignoring the effect of uncertainty on the portfolio allocation between bonds and capital. To a first order approximation the agent is indifferent between holding bonds or capital.

the expected value function simplifies to

$$\begin{aligned}
\mathbb{E}_{t-1}(v^i_{o,t}) =& Q_{o,t-1}\Big(\tilde{a}^i_{o,t-1} + HC^i_{o,t-1} - T^i_{o,t-1} - ADJ^i_{o,t-1} - c^i_{o,t-1} - \frac{(Q_{o,t-1}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t-1}}\left[\chi_o \frac{(l^i_{o,t-1})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right]\Big) \\
=& Q_{o,t-1}\Big(W_{o,t-1} - c^i_{o,t-1} - \frac{(Q_{o,t-1}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t-1}}\left[\chi_o \frac{(l^i_{o,t-1})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right]\Big)
\end{aligned}$$

We can now use this result into the objective function to obtain

$$\max v^i_{o,t} = \left\{\left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)^\eta + \beta\omega_o\left[Q_{o,t}\Big(W_{o,t} - c^i_{o,t} - \frac{(Q_{o,t}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\Big)\right]^\eta\right\}^{1/\eta}$$

The first order condition with respect to consumption gives,

$$\begin{aligned}
{v^i_{o,t}}^{1-\eta}\left(\left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)^{\eta-1} + \beta\omega_o\left[Q_{o,t}\Big(W_{o,t} - c^i_{o,t} - \frac{(Q_{o,t}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\Big)\right]^{\eta-1}(-Q_{o,t})\right) &= 0 \\
\left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right) = (\beta\omega_o Q_{o,t})^{\frac{1}{\eta-1}}\left[Q_{o,t}\Big(W_{o,t} - c^i_{o,t} - \frac{(Q_{o,t}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\Big)\right]& \\
c^i_{o,t} = \left(1 + (\beta\omega_o)^{\frac{1}{1-\eta}} Q_{o,t}^{\frac{\eta}{1-\eta}}\right)^{-1} W_{o,t} = \varepsilon_t\varsigma_t W_{o,t}&
\end{aligned}$$

We can now replace the solution for $c^i_{o,t}$, which matches our conjecture, into the value function to obtain

$$\begin{aligned}
v^i_{o,t} &= \left[\left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)^\eta + \beta\omega_o\left[Q_{o,t}\Big([1 + (\beta\omega_o)^{\frac{1}{1-\eta}} Q_{o,t}^{\frac{\eta}{1-\eta}}]c^i_{o,t} - c^i_{o,t} - \frac{(Q_{o,t}\beta\omega_o)^{\frac{1}{1-\eta}}}{Q_{o,t}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\Big)\right]^\eta\right]^{1/\eta} \\
v^i_{o,t} &= \left\{\left(1 + (\beta\omega_o)^{\frac{1}{1-\eta}} Q_{o,t}^{\frac{\eta}{1-\eta}}\right)\left(c^i_{o,t} - \chi_o \frac{{l^i_{o,t}}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)^\eta\right\}^{1/\eta}
\end{aligned}$$

Using the definition for $f_o(Q_{o,t})$ we confirm our guess, obtaining

$$v^i_{o,t} = (\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\left(c^i_{o,t} - \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)$$

Combining (C.2) and (C.4) we obtain the condition that determines the marginal propensity to consume of the old.

$$Q_{o,t} = ((\varepsilon_t \varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} (\beta\omega_o)^{\frac{-1}{\eta}}$$
$$((\varepsilon_t \varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} = \mathbb{E}_t \left(\frac{R_{n,t+1} (\beta\omega_o)^{\frac{1}{\eta}} (\varepsilon_{t+1} \varsigma_{t+1})^{\frac{\eta-1}{\eta}}}{\omega_o (1 + \pi_{t+1})} \right)$$

Finally, from the first order conditions of (C.1) labor is set such that

$$l^i_{o,t} = \left(\frac{\xi_o w_t}{\chi_o} \right)^{\nu_o},$$

and, to a first order approximation the individual is indifferent between holding bonds or capital. The no-arbitrage condition on investment posits that the expected return on capital should equalize the expected return on bonds, that is,

$$\left(\frac{R_{n,t+1}}{1 + \pi_{t+1}} \right) = \left(\frac{(1-\delta) + r_{k,t+1} - \frac{\varphi}{2} \left(\frac{k^i_{o,t+2}}{k^i_{o,t+1}} - \vartheta_o \right)^2 + \varphi \left(\frac{k^i_{o,t+2}}{k^i_{o,t+1}} - \vartheta_o \right) \frac{k^i_{o,t+2}}{k^i_{o,t+1}}}{\left[1 + \frac{\varphi}{\omega_o} \left(\frac{k^i_{o,t+1}}{k^i_{o,t}} - \vartheta_o \right) \right]} \right)$$

If the constraint binds, we no longer have an interior solution. In this case the consumption policy function can be easily obtained from the budget constraint of the agent. The labor optimality condition remains the same.

C.2 Mature Agents

The decision problem of a mature agent i, assuming interior solutions for capital and bond holdings, is

$$\max_{c^i_{m,t}, l^i_{m,t}, k^i_{m,t+1}, b^i_{m,t+1}} v^i_{m,t} = \left\{ \left(c^i_{m,t} - \chi_m \frac{{l^i_{m,t}}^{1+\frac{1}{\nu_m}}}{1 + \frac{1}{\nu_m}} \right)^{\eta} + \beta \mathbb{E}_t [\omega_m v^i_{m,t+1} + (1-\omega_m) v^i_{o,t+1}]^{\eta} \right\}^{1/\eta} \tag{C.7}$$

subject to

$$k^i_{m,t+1} + \tilde{b}^i_{m,t+1} + c^i_{m,t} + \frac{\varphi}{2}\left(\frac{k^i_{m,t+1}}{k^i_{m,t}} - \vartheta_m\right)^2 k^i_{m,t} = \tilde{a}^i_{w,t} + w_t l^i_{m,t} + (1-\tau_d)d^i_{m,t} - \tau^i_{m,t}$$

$$\tilde{a}^i_{m,t} = k^i_{m,t}((1-\delta) + r_{k,t}) + \tilde{b}^i_{m,t}\frac{R_{nt}}{1+\pi_t}.$$

Define

$$f_m(Q_{m,t}) \equiv \left(1 + (\beta)^{\frac{1}{1-\eta}} Q_{m,t}^{\frac{\eta}{1-\eta}}\right)^{\frac{1-\eta}{\eta}} \tag{C.8}$$

$$g_m(Q_{m,t}) \equiv \left(1 + (\beta)^{\frac{1}{1-\eta}} Q_{m,t}^{\frac{\eta}{1-\eta}}\right)^{-1} \tag{C.9}$$

$$Q_{m,t} \equiv \mathbb{E}_t\left(\frac{\mathfrak{z}_{t+1} R_{n,t+1} f_m(Q_{m,t+1})}{(1+\pi_{t+1})}\right) \tag{C.10}$$

where $\mathfrak{z}_{t+1} = (\omega_m + (1-\omega_m)\varepsilon_{t+1}^{\frac{\eta-1}{\eta}})$.

We conjecture that the mature consume a fraction of a measure of wealth $(W_{m,t})$, define as the sum of financial assets $(a^i_{m,t})$, the present value of human capital gains $(HC^i_{m,t})$ and dividends $(D^i_{m,t})$, net of the present value of taxes $(T^i_{m,t})$ and the present value of adjustment costs $(ADJ^i_{m,t})$. Moreover, the value function is given by

$$c^i_{m,t} = \varsigma_t\left[\tilde{a}^i_{m,t} + HC^i_{m,t} + D^i_{m,t} - T^i_{m,t} - ADJ^i_{m,t}\right] = \varsigma_t W_{m,t} \tag{C.11}$$

$$v^i_{m,t} = (\varsigma_t)^{\frac{-1}{\eta}}\left(c^i_{m,t} - \chi_o \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}}\right) \tag{C.12}$$

Finally we set $(\varsigma_t)^{\frac{\eta-1}{\eta}} \equiv f_m(Q_{m,t})$, and thus $g_m(Q_{m,t}) = \varsigma_t$.

Using the conjecture for the value and policy functions

$$\begin{aligned}
v^i_{m,t} &= (\varsigma_t)^{\frac{\eta-1}{\eta}} W_{m,t} - (\varsigma_t)^{\frac{-1}{\eta}} \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \\
v^i_{m,t} &= f_m(Q_{m,t})\left[\tilde{a}^i_{m,t} + HC^i_{m,t} + D^i_{m,t} - T^i_{m,t} - ADJ^i_{m,t}\right] - (\varsigma_t)^{\frac{-1}{\eta}} \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}}
\end{aligned}$$

Rearranging the budget constraint, we have that

$$\tilde{a}^i_{m,t+1} = \frac{R_{n,t+1}}{(1+\pi_{t+1})}\Big(\tilde{a}^i_{m,t} + w_t l^i_{m,t} + (1-\tau_d)d^i_{m,t} - \tau^i_{m,t} - adj^i_{m,t} - c^i_{m,t}\Big).$$

where $adj^i_{m,t} = \left(1 - \frac{(1-\delta+r_{k,t+1})(1+\pi_{t+1})}{R_{n,t+1}}\right) k^i_{m,t+1} + \frac{\varphi}{2}\left(\frac{k^i_{m,t+1}}{k^i_{m,t}} - \vartheta_m\right)^2 k^i_{m,t}$.

Thus,

$$\begin{aligned}
v^i_{m,t} &= f_m(Q_{m,t})\Big[\frac{R_{n,t}}{(1+\pi_t)}\Big(\tilde{a}^i_{m,t-1} + w_{t-1}l^i_{m,t-1} + (1-\tau_d)d^i_{m,t} - \tau^i_{m,t-1} - adj^i_{m,t-1} - c^i_{m,t-1}\Big) + \\
&\quad + HC^i_{m,t} + D^i_{m,t} - T^i_{m,t} - ADJ^i_{m,t}\Big] - (\varsigma_t)^{\frac{-1}{\eta}}\chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \\
v^i_{m,t} &= \frac{f_m(Q_{m,t})R_{n,t}}{(1+\pi_t)}\Big(\tilde{a}^i_{m,t-1} + w_{t-1}l^i_{m,t-1} + (1-\tau_d)d^i_{m,t} - \tau^i_{m,t-1} - adj^i_{m,t-1} - c^i_{m,t-1}\Big) + \\
&\quad + f_m(Q_{m,t})\left(HC^i_{m,t} + D_{m,t} - T^i_{m,t} - ADJ^i_{m,t}\right) - (\varsigma_t)^{\frac{-1}{\eta}}\chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}}
\end{aligned}$$

The value function of the old at time t who was a mature individual at time $t-1$ can be written as [33]

$$\begin{aligned}
v^i_{o,t}\mid_{m,t-1} &= f_o(Q_{o,t})\left[\tilde{a}^i_{o,t} + HC^i_{o,t} - T^i_{o,t} - ADJ^i_{o,t}\right] - (\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}} \\
v^i_{o,t}\mid_{m,t-1} &= \frac{f_o(Q_{o,t})R_{n,t}}{(1+\pi_t)}\Big(\tilde{a}^i_{m,t-1} + w_{t-1}l^i_{m,t-1} + (1-\tau_d)d^i_{m,t} - \tau^i_{m,t-1} - adj^i_{m,t-1} - c^i_{m,t-1}\Big) + \\
&\quad + f_o(Q_{o,t})HC^i_{o,t} - f_o(Q_{o,t})T^i_{o,t} - f_o(Q_{o,t})ADJ^i_{o,t} - (\varepsilon_t\varsigma_t)^{\frac{-1}{\eta}}\chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}
\end{aligned}$$

[33] We assume that $adj^i_{m,t-1} \approx adj^i_{m,t-1|o,t}$ for an individual transitioning from mature to the old age. The difference might only arise due to the second order effects when the covariance between the rates of return on bonds and capital is considered.

We can now obtain $[\omega_m v^i_{m,t} + (1-\omega_m)v^i_{o,t}]$,

$$
\begin{aligned}
&\omega_m v^i_{m,t} + (1-\omega_m)v^i_{o,t} = \\
&= \frac{(\omega_m f_m(Q_{m,t}) + (1-\omega_m) f_o(Q_{o,t}))R_{n,t}}{(1+\pi_t)} \Bigg(\tilde{a}^i_{m,t-1} + w_{t-1} l^i_{m,t-1} + \\
&\quad + (1-\tau_d) d^i_{m,t} - \tau^i_{m,t-1} - adj^i_{m,t-1} - c^i_{m,t-1} \Bigg) - \omega_m (\varsigma_t)^{\frac{-1}{\eta}} \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} + \\
&\quad + \omega_m \left(f_m(Q_{m,t}) HC^i_{m,t} + f_m(Q_{m,t}) D_{m,t} - f_m(Q_{m,t}) T^i_{m,t} - f_m(Q_{m,t}) ADJ^i_{m,t} \right) + \\
&\quad + (1-\omega_m) \left(f_o(Q_{o,t}) HC^i_{o,t} - f_o(Q_{o,t}) T^i_{o,t} - f_o(Q_{o,t}) ADJ^i_{o,t} \right) - (1-\omega_m)(\varepsilon_t \varsigma_t)^{\frac{-1}{\eta}} \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}
\end{aligned}
$$

Note that

$$
\begin{aligned}
\frac{(\omega_m f_m(Q_{m,t}) + (1-\omega_m) f_o(Q_{o,t}))R_{n,t}}{(1+\pi_t)} &= \frac{(\omega_m (\varsigma_t)^{\frac{\eta-1}{\eta}} + (1-\omega_m)(\varepsilon_t \varsigma_t)^{\frac{\eta-1}{\eta}})R_{n,t}}{(1+\pi_t)} \\
&= \frac{\mathfrak{z}_t (\varsigma_t)^{\frac{\eta-1}{\eta}} R_{n,t}}{(1+\pi_t)} = \frac{\mathfrak{z}_t f_m(Q_{m,t}) R_{n,t}}{(1+\pi_t)}
\end{aligned}
$$

Therefore, taking expectations $\mathbb{E}_{t-1}$, and using (C.10)[34]

$$
\begin{aligned}
&\mathbb{E}_{t-1}[\omega_m v^i_{m,t} + (1-\omega_m)v^i_{o,t}] = \\
&= Q_{m,t-1} \Big(\tilde{a}^i_{m,t-1} + w_{t-1} l^i_{m,t-1} + (1-\tau_d) d^i_{m,t} - \tau^i_{m,t-1} - \mathbb{E}_{t-1} adj^i_{m,t-1} - c^i_{m,t-1} \Big) + \\
&\quad + \mathbb{E}_{t-1} \omega_m f_m(Q_{m,t}) \left(HC^i_{m,t} + D_{m,t} - T^i_{m,t} - ADJ^i_{m,t} \right) - \mathbb{E}_{t-1} \omega_m (\varsigma_t)^{\frac{-1}{\eta}} \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \\
&\quad + \mathbb{E}_{t-1} (1-\omega_m) f_o(Q_{o,t}) \left(HC^i_{o,t} - T^i_{o,t} - ADJ^i_{o,t} \right) - \mathbb{E}_{t-1} (1-\omega_m)(\varepsilon_t \varsigma_t)^{\frac{-1}{\eta}} \chi_o \frac{(l^i_{o,t})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}
\end{aligned}
$$

[34] Once again, we assume $\mathbb{E}_{t-1} \frac{f_m(Q_{m,t}) R_{n,t}}{(1+\pi_t)} adj^i_{m,t-1} \approx Q_{m,t-1} \mathbb{E}_{t-1} adj^i_{m,t-1}$, essentially ignoring the effect of uncertainty on the portfolio allocation between bonds and capital. To a first order approximation the agent is indifferent between holding bonds or capital.

Then, define

$$
\begin{aligned}
HC^i_{m,t} &\equiv w_t l^i_{m,t} + \mathbb{E}_t \omega_m \frac{f(Q_{m,t+1}) HC^i_{m,t+1}}{Q_{m,t}} + \mathbb{E}_t (1-\omega_m) \frac{f(Q_{o,t+1}) HC^i_{o,t+1}}{Q_{m,t}} - \\
&\quad - \mathbb{E}_t \frac{(\varsigma_t)^{\frac{-1}{\eta}}}{Q_{m,t}} \left[\omega_m \chi_m \frac{(l^i_{m,t+1})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} + (\varepsilon_{t+1})^{\frac{-1}{\eta}} (1-\omega_m) \chi_o \frac{(l^i_{o,t+1})^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}} \right] + \\
&\quad + \frac{(Q_{m,t}\beta)^{\frac{1}{1-\eta}}}{Q_{m,t}} \left[\chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right] \\
D^i_{m,t} &\equiv (1-\tau_d) d^i_{m,t} + \mathbb{E}_t \frac{\omega_m f(Q_{m,t+1}) D^i_{m,t+1}}{Q_{m,t}} \\
T^i_{m,t} &\equiv \tau^i_{m,t} + \mathbb{E}_t \frac{\omega_m f(Q_{m,t+1}) T^i_{m,t+1}}{Q_{m,t}} + \mathbb{E}_t \frac{(1-\omega_m) f(Q_{o,t+1}) T^i_{o,t+1}}{Q_{m,t}} \\
ADJ^i_{m,t} &\equiv \mathbb{E}_t adj^i_{m,t} + \mathbb{E}_t \frac{\omega_m f(Q_{m,t+1}) ADJ^i_{m,t+1}}{Q_{m,t}} + \mathbb{E}_t \frac{(1-\omega_m) f(Q_{o,t+1}) ADJ^i_{o,t+1}}{Q_{m,t}}
\end{aligned}
$$

Using these results and adding and subtracting $(Q_{m,t-1}\beta)^{\frac{1}{1-\eta}} \left[\chi_m \frac{(l^i_{m,t-1})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right]$, we obtain

$$
\begin{aligned}
&\mathbb{E}_{t-1}[\omega_m v^i_{m,t} + (1-\omega_m) v^i_{o,t}] = \\
&= Q_{m,t-1} \Big(\tilde{a}^i_{m,t-1} + HC^i_{m,t-1} + D^i_{m,t-1} - T^i_{m,t-1} - \\
&\qquad - ADJ^i_{m,t-1} - c^i_{m,t-1} - \frac{(Q_{m,t-1}\beta)^{\frac{1}{1-\eta}}}{Q_{m,t-1}} \left[\chi_m \frac{(l^i_{m,t-1})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right] \Big) \\
&= Q_{m,t-1} \Big(W_{m,t-1} - c^i_{m,t-1} - \frac{(Q_{m,t-1}\beta)^{\frac{1}{1-\eta}}}{Q_{m,t-1}} \left[\chi_m \frac{(l^i_{m,t-1})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right] \Big)
\end{aligned}
$$

We can now use this result into the Bellman equation to obtain

$$
\max v^i_{m,t} = \left\{ \left(c^i_{m,t} - \chi_m \frac{{l^i_{m,t}}^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right)^{\eta} + \beta \left[Q_{m,t} \Big(W_{m,t} - c^i_{m,t} - \frac{(Q_{m,t}\beta)^{\frac{1}{1-\eta}}}{Q_{m,t}} \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \Big) \right]^{\eta} \right\}^{1/\eta}
$$

The first order condition with respect to consumption allow us to obtain,

$$
c^i_{m,t} = \left(1 + (\beta)^{\frac{1}{1-\eta}} Q_{m,t}^{\frac{\eta}{1-\eta}} \right)^{-1} W_{m,t} = \varsigma_t W_{m,t}
$$

We can now replace the solution for $c^i_{m,t}$, which matches our conjecture, into the value function to obtain

$$v^i_{m,t} = (\varsigma_t)^{\frac{-1}{\eta}} \left(c^i_{m,t} - \chi_m \frac{(l^i_{m,t})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right)$$

Combining (C.8) and (C.10) we obtain the condition that determines the marginal propensity to consume of the mature agents.

$$\begin{aligned} Q_{m,t} &= ((\varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} (\beta)^{\frac{-1}{\eta}} \\ ((\varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} &= \mathbb{E}_t \left(\frac{\mathfrak{z}_{t+1} R_{n,t+1} (\beta)^{\frac{1}{\eta}} (\varsigma_t)^{\frac{\eta-1}{\eta}}}{(1+\pi_{t+1})} \right) \end{aligned}$$

Finally, from the first order conditions of (C.7) labor is set such that

$$l^i_{m,t} = \left(\frac{w_t}{\chi_m} \right)^{\nu_m},$$

and, to a first order approximation the individual is indifferent between holding bonds or capital. The no-arbitrage condition on investment posits that the expected return on capital should equalize the expected return on bonds, that is,

$$\left(\frac{R_{n,t+1}}{1+\pi_{t+1}} \right) = \left(\frac{(1-\delta) + r_{k,t+1} - \frac{\varphi}{2} \left(\frac{k^i_{m,t+2}}{k^i_{m,t+1}} - \vartheta_m \right)^2 + \varphi \left(\frac{k^i_{m,t+2}}{k^i_{m,t+1}} - \vartheta_m \right) \frac{k^i_{m,t+2}}{k^i_{m,t+1}}}{\left(1 + \varphi \left(\frac{k^i_{m,t+1}}{k^i_{m,t}} - \vartheta_m \right) \right)} \right) \tag{C.13}$$

If the constraint binds, we no longer have an interior solution. In this case the consumption policy function can be easily obtained from the budget constraint of the agent. The labor optimality condition remains the same.

C.3 Young Agents

For the problem of the young we follow a similar procedure to obtain

$$f_y(Q_{y,t}) \equiv (\varepsilon_{y,t}\varsigma_t)^{\frac{\eta-1}{\eta}} \tag{C.14}$$

$$Q_{y,t} = ((\varepsilon_{y,t}\varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} (\beta)^{\frac{-1}{\eta}} \tag{C.15}$$

$$((\varepsilon_{y,t}\varsigma_t)^{-1} - 1)^{\frac{1-\eta}{\eta}} = \mathbb{E}_t \left(\frac{\mathfrak{z}_{y,t+1} R_{n,t+1} (\beta)^{\frac{1}{\eta}} (\varsigma_t)^{\frac{\eta-1}{\eta}}}{(1+\pi_{t+1})} \right) \tag{C.16}$$

$$c^i_{y,t} = \varepsilon_{y,t}\varsigma_t \left[\tilde{a}^i_{y,t} + HC^i_{y,t} - T^i_{y,t} - ADJ^i_{y,t} \right] = \varepsilon_{y,t}\varsigma_t W_{y,t} \tag{C.17}$$

$$v^i_{y,t} = (\varepsilon_{y,t}\varsigma_t)^{\frac{-1}{\eta}} \left(c^i_{y,t} - \chi_y \frac{(l^i_{y,t})^{1+\frac{1}{\nu_y}}}{1+\frac{1}{\nu_y}} \right) \tag{C.18}$$

where $\mathfrak{z}_{y,t+1} = (\omega_y \varepsilon_{y,t+1}^{(\eta-1)/\eta} + (1-\omega_y))$ and,

$$\begin{aligned}
HC^i_{y,t} &\equiv w_{in,t}\xi_y l^i_{y,t} + \mathbb{E}_t \omega_y \frac{f(Q_{y,t+1}) HC^i_{y,t+1}}{Q_{y,t}} + \mathbb{E}_t (1-\omega_y) \frac{f(Q_{m,t+1}) HC^i_{m,t+1}}{Q_{y,t}} - \\
&\quad -\mathbb{E}_t \frac{(\varsigma_t)^{\frac{-1}{\eta}}}{Q_{y,t}} \left[\omega_y \varepsilon_{y,t}^{\frac{-1}{\eta}} \chi_y \frac{(l^i_{y,t+1})^{1+\frac{1}{\nu_y}}}{1+\frac{1}{\nu_y}} + (1-\omega_y)\chi_m \frac{(l^i_{m,t+1})^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}} \right] + \\
&\quad + \frac{(Q_{y,t}\beta)^{\frac{1}{1-\eta}}}{Q_{y,t}} \left[\chi_y \frac{(l^i_{y,t})^{1+\frac{1}{\nu_y}}}{1+\frac{1}{\nu_y}} \right] \\
T^i_{y,t} &\equiv \tau^i_{y,t} + \mathbb{E}_t \frac{\omega_y f(Q_{y,t+1}) T^i_{y,t+1}}{Q_{y,t}} + \mathbb{E}_t \frac{(1-\omega_y) f(Q_{m,t+1})(T^i_{m,t+1} - D^i_{m,t+1})}{Q_{y,t}} \\
ADJ^i_{y,t} &\equiv \mathbb{E}_t adj^i_{y,t} + \mathbb{E}_t \frac{\omega_y f(Q_{y,t+1}) ADJ^i_{y,t+1}}{Q_{y,t}} + \mathbb{E}_t \frac{(1-\omega_y) f(Q_{m,t+1}) ADJ^i_{m,t+1}}{Q_{y,t}}
\end{aligned}$$

Finally, labor is set such that

$$l^i_{y,t} = \left(\frac{\xi_y w_{in,t}}{\chi_y} \right)^{\nu_y},$$

and, the no-arbitrage condition on investment posits that the expected return on capital should equalize the expected return on bonds, that is,

$$\left(\frac{R_{n,t+1}}{1+\pi_{t+1}}\right)=\left(\frac{(1-\delta)+r_{k,t+1}-\frac{\varphi}{2}\left(\frac{k^i_{y,t+2}}{k^i_{y,t+1}}-\vartheta_m\right)^2+\varphi\left(\frac{k^i_{y,t+2}}{k^i_{y,t+1}}-\vartheta_m\right)\frac{k^i_{y,t+2}}{k^i_{y,t+1}}}{\left(1+\varphi\left(\frac{k^i_{y,t+1}}{k^i_{y,t}}-\vartheta_m\right)\right)}\right) \tag{C.19}$$

If the borrowing constraint for the young binds then equations (C.14) - (C.18) no longer describe the optimal conditions. The consumption policy function can be easily obtained from the budget constraint of the agent. In this case $c^i_{y,t} = w_t \xi_y l^i_{y,t} - \tau^i_{y,t}$.

C.4 Aggregation

In this Section we show that we can linearly aggregate the optimal choices of individuals across each age group, such that for a variable $x_{z,t}$ we have that $x_{z,t} = \int_0^{N_{z,t}} x^i_{y,t}\,\mathrm{di}$.

Firstly we must ensure that at steady state adjustment costs are zero. Given the arbitrage conditions (C.1), (C.13), and its counterpart for the young problem, we have that the ratio of capital for any agent within a type is constant, which is to say that $\frac{k^i_{y,t+1}}{k^i_{y,t}} = \frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}}$, $\frac{k^i_{m,t+1}}{k^i_{m,t}} = \frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}}$, and $\frac{k^i_{o,t+1}}{k^i_{o,t}} = \frac{\hat{k}_{o,t+1}}{\hat{k}_{o,t}}$, where $\frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}}$, $\frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}}$, and $\frac{\hat{k}_{o,t+1}}{\hat{k}_{o,t}}$ define given age-group specific values for the ratio of physical capital holdings over time. Then given that individuals are born with no capital at steady state we have that

$$k_{y,t+1}=\int_0^{N_{y,t}} k^i_{y,t+1}=\int_0^{N_{y,t+1}} k^i_{y,t+2}=k_{y,t+2}=k_{y,SS}$$

As the young individuals who become mature are selected randomly

$$k_{y,SS}=\int_0^{N_{y,t+1}} k^i_{y,t+2}=\int_0^{\omega_y N_{y,t+1}} \frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}} k^i_{y,t+1}=\omega_y\frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}}\int_0^{N_{y,t}} k^i_{y,t+1}=\omega_y\frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}}k_{y,SS}$$

Hence, $\frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}} \mid_{SS} = \frac{1}{\omega_y}$. For mature agents we have that

$$k_{m,t+1} \;=\; \int_0^{N_{m,t}} k^i_{m,t+1} = \int_0^{N_{m,t+1}} k^i_{m,t+2} = k_{m,t+2} = k_{my,SS}$$

where

$$\begin{aligned}
k_{m,SS} &= \int_0^{N_{m,t+1}} k^i_{m,t+2} = \int_0^{\omega_m N_{m,t+1}} \frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}} k^i_{m,t+1} + \int_0^{(1-\omega_y)N_{y,t+1}} \frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}} k^i_{y,t+1} = \dots \\
\dots &= \omega_m \frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}} \int_0^{N_{m,t}} k^i_{m,t+1} + (1-\omega_y) \frac{\hat{k}_{y,t+1}}{\hat{k}_{y,t}} \int_0^{N_{y,t}} k^i_{y,t+1} = \dots \\
\dots &= \omega_m \frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}} k_{m,SS} + \frac{(1-\omega_y)}{\omega_y} k_{y,SS}.
\end{aligned}$$

As a result, we have that

$$\frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}} \mid_{SS} = \frac{1}{\omega_m} \left(1 - \frac{(1-\omega_y)}{\omega_y} \frac{k_{y,SS}}{k_{m,SS}} \right).$$

Analogously, we have that

$$\frac{\hat{k}_{o,t+1}}{\hat{k}_{o,t}} \mid_{SS} = \frac{1}{\omega_o} \left(1 - (1-\omega_m) \frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}} \mid_{SS} \frac{k_{m,SS}}{k_{o,SS}} \right).$$

Thus, if we set

$$\vartheta_y = \frac{1}{\omega_y}$$

$$\vartheta_m = \frac{1}{\omega_m} \left(1 - \frac{(1-\omega_y)}{\omega_y} \frac{k_{y,SS}}{k_{m,SS}} \right)$$

$$\vartheta_o = \frac{1}{\omega_o} \left(1 - (1-\omega_m) \vartheta_m \frac{k_{m,SS}}{k_{o,SS}} \right)$$

we ensure that at steady state capital adjustment costs are zero. At steady state agents accumulate or reduce capital at a constant rate while within a group $z \in \{y, m, o\}$. Nonetheless, as individuals transition across groups through their life cycle, the aggregate capital holdings of each group remain constant and no adjust cost of capital is paid.

Ensuring that at steady state adjustment costs are zero is important for aggregation since the only non-linear term left in the consumption decision is the quadratic term in the adjustment cost condition. As we solve a linearized version of the model around the steady state this quadratic term disappears such that the choice variables across agents within a group can be easily aggregated to find a condition for each group. Consequently, for instance, the aggregate consumption of all old agents at time t is simply given by

$$c_{o,t} = \varepsilon_t \varsigma_t \left[\tilde{a}_{o,t} + HC_{o,t} - T_{o,t} - ADJ_{o,t}\right].$$

where we excluded the quadratic terms which are irrelevant in a first order approximated solution and thus, $ADJ_{o,t} = \tilde{adj}_{o,t} + \frac{(1+\pi_{t+1})\omega_o}{R_{n,t+1}} ADJ_{o,t+1}$ and $\tilde{adj}^{i}_{o,t} = \left(1 - \frac{(1-\delta+r_{k,t+1})(1+\pi_{t+1})}{R_{n,t+1}}\right) k^{i}_{o,t+1}$. Therefore, the equilibrium conditions can be defined without explicitly incorporating the heterogeneity within age groups.

As some young agents become mature and some mature agents become old every period, when we aggregate and discard the quadratic adjustment terms, the flow of assets are given by

$$k_{y,t+1} + \tilde{b}_{y,t+1} = \omega_y(\tilde{a}_{y,t} + l_{y,t}\xi_y w_{in,t} + \tau_{y,t} - c_{y,t}) \tag{C.20}$$

$$\tilde{a}_{y,t} = k_{y,t}\left[(1-\delta) + r_{k,t}\right] + \tilde{b}_{y,t}\frac{R_{n,t+1}}{1+\pi_{t+1}} \tag{C.21}$$

$$k_{m,t+1} + \tilde{b}_{m,t+1} = \omega_m(\tilde{a}_{m,t} + l_{m,t}w_t + d_{m,t} + \tau_{m,t} - c_{m,t}) + \dots \tag{C.22}$$

$$\dots + (1-\omega_y)(\tilde{a}_{y,t} + l_{y,t}\xi_y w_t + \tau_{y,t} - c_{y,t}) \tag{C.23}$$

$$\tilde{a}_{m,t} = k_{m,t}\left[(1-\delta) + r_{k,t}\right] + \tilde{b}_{m,t}\frac{R_{n,t+1}}{1+\pi_{t+1}} \tag{C.24}$$

$$k_{o,t+1}+\tilde{b}_{o,t+1}=\tilde{a}_{o,t}+\xi_o l_{o,t}w_t+\mathrm{tr}_{o,t}-c_{o,t}+\ldots \quad (C.25)$$

$$\cdots+(1-\omega_m)(\tilde{a}_{m,t}+l_{m,t}w_t+d_{m,t}+\tau_{m,t}-c_{m,t}) \quad (C.26)$$

$$\tilde{a}_{o,t}=k_{o,t}\left[(1-\delta)+r_{k,t}\right]+\tilde{b}_{o,t}\frac{R_{n,t+1}}{1+\pi_{t+1}} \quad (C.27)$$

We then define the stochastic discount factor for the mature group as

$$Q_t^m=\beta\mathfrak{z}_{t+1}\frac{\left[\omega_m\left(c_{m,t+1}-\chi_m\frac{l_{m,t+1}^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}}\right)+(1-\omega_m)\varepsilon_{t+1}^{\frac{-1}{\eta}}\left(c_{o,t+1}-\chi_o\frac{l_{o,t+1}^{1+\frac{1}{\nu_o}}}{1+\frac{1}{\nu_o}}\right)\right]^{(1-\eta)}}{\left(c_{m,t}-\chi_m\frac{l_{m,t}^{1+\frac{1}{\nu_m}}}{1+\frac{1}{\nu_m}}\right)^{(1-\eta)}}$$

Finally, given that we are interested in a solution under a linear approximation,

$$\begin{aligned}\left(\frac{k^i_{m,t+1}}{k^i_{m,t}}-\vartheta_m\right) &= \left(\frac{\hat{k}_{m,t+1}}{\hat{k}_{m,t}}-\vartheta_m\right)\approx\vartheta_m\left(\frac{\hat{k}_{m,t+1}-\hat{k}_{m,t+1}\mid_{SS}}{\hat{k}_{m,t+1}\mid_{SS}}-\frac{\hat{k}_{m,t}-\hat{k}_{m,t}\mid_{SS}}{\hat{k}_{m,t}\mid_{SS}}\right)\\ &= \vartheta_m\left(\frac{1}{N_{m,t}}\frac{k_{m,t+1}-k_{m,t+1}\mid_{SS}}{k_{m,t+1}\mid_{SS}}-\frac{1}{N_{m,t-1}}\frac{k_{m,t}-k_{m,t}\mid_{SS}}{k_{m,t}\mid_{SS}}\right)\\ &\approx \vartheta_m\left(\frac{k_{m,t+1}N_{m,t-1}}{k_{m,t}N_{m,t}}-1\right)\end{aligned}$$

then the aggregated arbitrage condition for mature agents becomes

$$\frac{R_{n,t+1}}{1+\pi_{t+1}}=\frac{(1-\delta)+r_{k,t+1}+\varphi\vartheta_m^2\left(\frac{k_{m,t+1}}{k_{m,t}}\frac{N_{m,t}}{N_{m,t+1}}-1\right)\frac{k_{m,t+1}}{k_{m,t}}\frac{N_{m,t}}{N_{m,t+1}}}{\left(1+\vartheta_m\varphi\left(\frac{k_{m,t}}{k_{m,t-1}}\frac{N_{m,t-1}}{N_{m,t}}-1\right)\right)} \quad (C.28)$$

Given the hump-shaped life-cycle earnings profile, the young wants to borrow, the mature wants to save for retirement and the old dissaves (see Constantinides et *al.* (2002) for an simple OLG model with the same features). Thus, $\tilde{a}_{y,t}=0$ and from (C.20) we obtain the consumption of the young. (C.23) simplifies to $k_{m,t+1}+\tilde{b}_{m,t+1}=\omega_m(\tilde{a}_{m,t}+l_{m,t}w_t+d_{m,t}+\tau_{m,t}-c_{m,t})$. [35]

[35] Given the probabilistic nature of the death transition, a very small share of old individuals might live for a very long time. In such cases assets would eventually be completely consumed and the borrowing constraint would bind. As the mass of old individuals in this situation is very small, for simplicity we assume the intermediary that offers the annuity provides consumption to the old individuals living for too long such that the condition (C.5) always holds within this age group.

D More on Calibration

This section reports the values of the entire set of parameters of the model. Table D.1 reports the calibration choices on the set of parameters that govern the demographics in the model, and Table D.2 reports the calibration of the parameters that define the life cycle of hours worked and wages. Finally, Table D.3 reports the calibration choices of the block of parameters that comes with the structure of a standard open-economy New Keynesian model.

Table D.1: Calibration - Demographics

Parameter	Value	Target
Birth Rate of New Young Agents	$\omega_n = 0.0024$	Share of Young in Population
Probability Transition from Young to Mature	$1 - \omega_y = 0.0250$	Avg. Number of Years as Young: 10y
Probability Transition from Mature to Old	$1 - \omega_m = 0.0071$	Avg. Number of Years as Mature: 30y
Death Probability of Old Agents	$1 - \omega_o = 0.0274$	Share of Old in Population
Relative Size Population Home Economy	$N/N^u = 0.02$	Average Size U.S. State

Table D.2: Calibration - Life-Cycle of Hours and Wages

Parameter	Value	Target
Complementarity Experience Labor and Capital	$\kappa = 0.2$	Jaimovich et al. (2013)
Complementarity Inexperience Labor and Capital	$\sigma = 0.7$	Jaimovich et al. (2013)
Weight Experience Labor	$\alpha = 0.27$	Share of Capital = 0.33
Weight Inexperience Labor	$\mu = 0.36$	Wage Young = 71% Wage Mature
Disutility Labor for Young Agents	$\chi_y = 2.4$	Fraction of Hours Worked = 0.324
Disutility Labor for Mature Agents	$\chi_m = 131.9$	Fraction of Hours Worked = 0.35
Disutility Labor for Old Agents	$\chi_o = 14.5$	Fraction of Hours Worked = 0.08
Efficiency Units of Hours for Young Agents	$\xi_y = 1$	Normalization
Efficiency Units of Hours for Mature Agents	$\xi_m = 1$	Normalization
Efficiency Units of Hours for Old Agents	$\xi_o = 0.72$	Wage Old = 72% Wage Mature
Labor Supply Elasticity for Young Agents	$\nu_y = 0.71$	Weighted Average Labor Supply Elasticity = 0.4
Labor Supply Elasticity for Mature Agents	$\nu_m = 0.2$	Chetty et *al.* (2013)
Labor Supply Elasticity for Old Agents	$\nu_o = 0.75$	Rogerson and Wallenius (2013)

Table D.3: Calibration - Standard Parameters

Parameter	Value	Target/Source
Time Discount Factor	$\beta = 0.995$	Standard Value
Elasticity Intertemporal Substitution	$\eta = -9$	EIS $= 0.1$
Capital Depreciation Rate	$\delta = 0.025$	Standard Value
Capital Adjustment Cost	$\varphi = 200$	Peak Investment Response After 8 Quarters
Home Bias in Consumption & Investment	$\lambda = 0.69$	Nakamura and Steinsson (2014)
Elasticity Substitution Home & Foreign Consumption	$\psi_c = 2$	Nakamura and Steinsson (2014)
Elasticity Substitution Home & Foreign Investment	$\psi_i = 2$	$\psi_i = \psi_c$
Elasticity Substitution Across Varieties	$\epsilon = 9$	Standard Value
Calvo Parameter	$\zeta = 0.75$	Standard Value
Dividend Tax Rate	$\tau_d = 0.9394$	Mature Agents Receive 60% Total Dividends
Steady-State Government Spending to Output Ratio	$\frac{G_{H,SS}+G_{F,SS}}{Y^u_{SS}} = 0.204$	Data
Persistence Government Spending Shock	$\rho_G = 0.953$	Data
Inertia of Government Debt	$\rho_{bg} = 0.95$	Dynamic Response to Spending of Government Debt
Response to Spending of Government Debt	$\phi_G = 4.5$	Dynamic Response to Spending of Government Debt
Response to Spending of Taxation	$\phi_T = 0.01$	Dynamic Response to Spending of Taxation
Inertia of Taylor Rule	$\psi_R = 0.8$	Clarida et *al.* (2000)
Taylor Rule Response to Inflation	$\psi_\pi = 1.5$	Clarida et *al.* (2000)
Taylor Rule Response to Output Gap	$\psi_Y = 0.2$	Clarida et *al.* (2000)