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

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Abstract

We document that fiscal multipliers depend on demographics. We use the variation in government military spending and birth rates across U.S. states, and show that local fiscal multipliers increase with the share of young people in total population. To rationalize this fact, we build a parsimonious open-economy life-cycle New Keynesian model with credit market imperfections and age-specific labor supply elasticities. The model explains 65% of the relationship between local fiscal multipliers and demographics. We use the model to study the implications of population aging, and find that nowadays U.S. national fiscal multipliers are 36% lower than forty years ago.

Key Words: Life-cycle, Population Aging, Fiscal Policy.

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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 by how much output expands following a rise in government spending. Yet, fiscal multipliers are not constant structural parameters, but rather they depend on the type of government spending and the characteristics of the economy.

In this paper we shed light on a novel determinant of the effectiveness of fiscal policy: the age structure of an economy. We study a panel of output, military government spending, and demographic characteristics across U.S. states and document that local fiscal multipliers rise with the share of young people in total population. To rationalize this fact, we build a parsimonious open-economy life-cycle New Keynesian model with credit market imperfections and age-specific labor supply elasticities. The model explains 65% of the link between local fiscal multipliers and demographics. Then, we use the model to study the implications of population aging. The model predicts that nowadays U.S. national fiscal multipliers are 36% lower than forty years ago.

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. Yet, government spending shocks generate migration flows that alter states' age structure. To avoid any endogeneity concern, we exploit the heterogeneity in fertility across U.S. states and instrument the share of young people with lagged birth rates. Then, we use the geographical distribution of government military spending to estimate fiscal multipliers, as in Nakamura and Steinsson (2014). Usually, the literature on national military spending and fiscal multipliers identifies government spending shocks by assuming that the U.S. do not embark in a war when national output is low (Barro, 1981; Barro and Redlick, 2011; Ramey, 2011). Instead, we refer to a much weaker exogeneity restriction and posit that the U.S. do not embark in a war when the output of a specific state is lower than the output of all the other states.

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.

To rationalize the link between demographics and fiscal multipliers, we build an open-economy life-cycle New Keynesian model with credit market imperfections and age-specific labor supply elasticities. Namely, we consider a staggered price 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. In this way, we end up with a fairly tractable environment, which extends a standard two-country New Keynesian model with a rich life-cycle structure.

The model features credit market imperfections. Households can trade capital and non-contingent bonds, but cannot go short in either asset. In this environment, young agents - who face a hump-shaped labor income over the life-cycle - optimally decide not to invest and be hand-to-mouth. The model features also age-specific differences in labor supply such that the Frisch elasticity varies across the three age groups. In the empirically relevant parametrization, young and old households have a higher Frisch elasticity than prime-age households.

In the model government spending triggers a negative income effect for the households, which smooth consumption by working longer hours. The rise of labor - and thus the size of fiscal multipliers - depends on households' Frisch elasticity and marginal propensity to consume. Moreover, price rigidities define a demand channel through which government spending raises even further employment and output.

How can demographics alter fiscal multipliers? The link is twofold. First, the high Frisch elasticity of young workers makes young employment much more responsive to government spending shocks than the employment of prime-age workers. Second, an economy with relatively more young households features a stronger demand channel. Indeed, the credit market imperfections boost the marginal propensity to consume of young households well above the one of prime-age households, as it is in the data. Consequently, as the proportion of young workers increase, both labor and output react more sharply to a fiscal shock.

In the quantitative analysis, the model explains 97% of the size of fiscal multipliers and 65% of the link between fiscal multipliers and demographics. In the model increasing the share of young people by 1% above the average share across U.S. states raises the local output fiscal multiplier by 2%, from 1.46 up to 1.49.

Does the link between demographics and fiscal multipliers persist also at the national level? Although our evidence shows that the effect of demographics on fiscal multipliers at the state level is economically and statistically significant, this result does not necessarily imply that demographics alter also national multipliers. Nakamura and Steinsson (2014) and Chodorow-Reich (2017) show that local fiscal multipliers wash out any monetary policy response to government spending, and consider the local effect of federally financed policies. Both features make local multipliers larger than national ones. On the other hand, local multipliers are dampened by an expenditure switching and import leakage behavior that do not take place at the national level. We evaluate in the model the effects of government spending on *national* output and find that demographics still matter: increasing the share of young people by 1% raises the national output fiscal multiplier by 1.2%.

Finally, we use the model to study the implications of the U.S. population aging for fiscal policy. After the post-World War II baby boom, the demographic structure of the U.S. population has progressively shifted towards older ages: the share of young people in total population plummeted by 30% from 1980 to 2015. Once we feed this shift in population shares into our model, we find that nowadays the national output fiscal multiplier is 36% lower than forty years ago. Since most advanced economies are experiencing a process of population aging, the model suggests that over time fiscal policy could become a relatively less effective tool for spurring economy activity.[1,2]

This paper is related to the literature that focuses on the implications of demographics for long-run trends (Aksoy et *al.*, 2016; Carvalho et *al.*, 2016), and short-term fluctuations (Jaimovich and Siu, 2009; Wong, 2016). 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 (2016). Our paper differs from this strand of the literature on two main dimensions. First, we focus on the elasticity of output to fiscal shocks. We follow Nakamura and Steinsson (2014) and Chodorow-Reich (2017), and exploit the heterogeneity across U.S. states to estimate the causal effect of demographics on fiscal multipliers.[3] Second, we build a quantitative model that can be used as a laboratory to measure the effects of changes in the age structure of an economy on fiscal multipliers.

2 Empirical Evidence

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

[1]Bilbie et *al.* (2008) find that in the U.S. fiscal multipliers decreased from the 1980s on and rationalize this fact through the increased asset market participation observed over the recent decades. Our result is consistent with this evidence: in our model population aging dampens fiscal multipliers by reducing the share of young hand-to-mouth households.

[2]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).

[3]Anderson et *al.* (2016) and Ferraro and Fiori (2016) estimate the responses to fiscal shocks of the consumption and unemployment rate across different age groups. Both papers identify fiscal shocks using the narrative approach of Romer and Romer (2010).

We study a panel of output and military government spending 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 allows us to identify the *local fiscal multiplier*, which is a federally-financed open-economy fiscal multiplier. This multiplier estimates the increase of output in a specific state (say, California) relative to all the other U.S. states when the federal government spends one additional dollar in California, and this extra dollar is financed by taxing individuals in all U.S. states.

2.1 Data

We study a data set of military government spending, output, employment, 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 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 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, $\bar{D}=\sum_i\sum_t D_{i,t}$ is the average log-share of young people, 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.[4]

In the baseline regression we consider the share of young people as the share 20-29 years old white males over the total population of white males. 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 by how much a 1% increase in federal government spending raises output per capita 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 (demeaned) log-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 with a

[4]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. The Appendix shows that results do not change if we consider a two-year cumulative fiscal multiplier rather than a two-year impact fiscal multiplier.

similar regression, in which the dependent variable is 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 the causal effect of government spending on output and employment following the approach of Nakamura and Steinsson (2014). We use the heterogeneous sensitivity of states' military procurements to an increase in federal military spending.[5] This IV strategy implies 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 government spending (as a fraction of per capita national GDP) and a state fixed effect:

$$\frac{G_{i,t} - G_{i,t-2}}{Y_{i,t-2}} = \alpha_i + \delta_t + \eta_i \frac{G_t - G_{t-2}}{Y_{t-2}} + \zeta X_{i,t} + \epsilon_{i,t} \quad (3)$$

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 captures the exogenous component of federal military spending.

The use of military spending to estimate national fiscal multipliers follows the work of Barro (1981), Barro 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 instrumenting approach 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 relatively to the output of all the other states.

The panel dimension of the data is crucial to identify the link between demo-

[5]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%.

graphics and fiscal multipliers. We study whether the effects government spending shocks on output and employment depend on states' age structure. The identification comes from cross-state variation - and its changes over time - in the share of young people in total population. For instance, in 2015 the share of people between 20 and 29 years old 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. 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.

Yet, if government spending shocks trigger migration flows, then states' age structure would not be exogenous to fiscal policy.[6] To avoid any concern on the endogeneity of demographics, we instrument the share of young people with lagged birth rates. 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.[7] We implicitly assume that the fertility of twenty-thirty years ago is exogenous to current government spending shocks. This IV approach would not be valid if the sensitivity to federal government shocks - that is, η_i from Equation (3)- is related on states' age structure. We find that in the data the correlation between states' demographic structures and states' sensitivity to federal government shocks is -0.03, corroborating our identification strategy.

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.

[6] 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.

[7] 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)
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 from 1967 to 2015, at an annual frequency. In regression (1) the dependent variable is the change in output per capita. In regressions (2) the dependent variable is the change in employment rate. The independent variables are the change in per capita state government expenditures (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 (age 20-29) in total population, $D_{i,t}$, and the interaction between the change in per capita state government expenditures (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, state-specific changes in per capita state government expenditures (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 expenditures (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%.

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 is statistically significant at the 1% level and equals 1.51. 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 fiscal 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 equals 1.27 - 1.65.

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. In this case, the implied inter-quantile range of employment fiscal multipliers across U.S. states is 0.92 - 1.20.

Table 2 studies the robustness of the causal effect of demographics on 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 benchmark IV regression. The following columns show the results for the plain OLS regression, the partial IV regression in which the share of young people is not instrumented, the baseline regression in which we use a different measure of young people (those aged 15-29), and the baseline 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 not computed only over the white male population, but also on the entire male population and the overall population.

The partial IV regression yields an estimated coefficient of the interaction between changes in government spending and the log-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 full IV regression. This difference could be driven by the endogenous reaction of states' migration flows following a government spending shock. If migration raises the population of young people, then it would boost further the change in output, while dampening the response of the employment rate. In the Appendix we confirm this claim by showing that although total population does not change following a fiscal shock, the population of young people does rise. This evidence confirms the validity of instrumenting the share of young people to

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 expenditures (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 (age 20-29) in total population, $D_{i,t}$, and the interaction between the change in per capita state government expenditures (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 expenditures (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 expenditures (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.

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 a specific instrumenting strategy. Finally, columns (6) and (7) display that the estimated effect of a change in demographics on fiscal multipliers becomes 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. Importantly, in all cases the role of demographics on fiscal multipliers is highly significant both in statistical and economic terms.

The effect of demographics on fiscal multipliers could be biased by potential confounding factors which are highly correlated with changes in states' age structures. Section A of the Appendix addresses this issue by reporting a comprehensive battery of robustness checks for the estimates of both the output fiscal multiplier and the employment fiscal multiplier. First, we show that the link between demographics and fiscal multipliers holds even after introducing 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 (2017)'s series on news about future increases in government spending, and the real interest rate. Second, the role of demographics on fiscal multipliers remains even after introducing additional state-level variables, such as the change in house price, per capita households' income, per capital federal personal taxes, the unemployment rate, and per capita unemployment benefits. Third, using CPS data we compute measures of skilled labor and female labor participation at the state level. Again, the addition of these variables does not alter the economic and statistical significance of the effect of demographics on fiscal multipliers.

Overall these results point out that demographics matter for the size of fiscal multipliers, such that multipliers are larger in economies with higher shares of young people. Yet, we want to stress that our regressions do not estimate exactly the same elasticity of output with respect of government spending that is usually studied in the literature on national fiscal multipliers. We estimate a local fiscal multiplier, that Nakamura and Steinsson (2014) define as an "open-economy relative multiplier". Although the effects of demographics on fiscal multipliers at the state level are economically and statistically significant, these results do not necessarily imply that demographics alter also national fiscal multipliers.

Section B of the Appendix studies if national fiscal multipliers vary with the age structure of an economy. We estimate a SVAR à la Blanchard and Perotti (2002) on a panel of forty-four countries, and find that national fiscal multipliers are larger in the economies with higher shares of young people in total population. Although this context does not control for all potential confounding factors behind the relationship between demographics and fiscal multipliers, these results still suggest that demographics affect the effectiveness of fiscal policy also at the national level.

3 The Model

3.1 Environment

We extend a standard two-country New Keynesian model with a rich and tractable life-cycle structure. We consider two countries - a home country and a foreign country - that belong to a monetary union. Each country follows a version of the cashless Calvo (1983) staggered price New Keynesian model. Both countries are subject to a unique monetary policy Taylor rule, which responds to union-level inflation and output. In the economy there is also a union-level government which purchases final consumption goods subject to spending shocks. The government finances its expenditures by levying lump-sum taxes on households and issuing bonds.

In each country, the household sector has a life-cycle structure, whereby individuals face three stages of life: young, mature, and old. All the individuals supply labor, accumulate assets, and consume. The model features age-specific labor supply such that labor supply elasticities are age dependent. In addition, credit markets are imperfect. Although households can trade capital and nominal bonds, the credit markets are incomplete. On the one hand, the bond is non-contingent and its return does not depend on households' idiosyncratic risk. On the other hand, households face a borrowing constraint such that they cannot go short in either asset.

The two countries differ only in the total size of the population and the demographic composition. Since the two economies are symmetric, we just describe the home country. The variables and parameters of the foreign economy are distinguished by a star superscript.

3.2 Households

In each country there is a continuum of households that belong to three different 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 $N_t + N_t^{\star} = N_{U,t}$.

Agents move through the three different groups of households in a life-cycle manner following Yaari (1965), Blanchard (1985), and Weil (1989). 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 of time, households face a probability to change age group 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

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

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

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

Over the lifetime each individual faces 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 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. In this way, we end up with a fairly tractable environment with three representative agents, that extends a standard two-country New Keynesian model 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 that if the overall nominal return on the assets of old households equals $R_{a,t}$, then in equilibrium surviving old households earn a nominal interest rate $R_{a,t}/\omega_o$. Hence, the financial intermediaries 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 transition from young to mature and from mature to old 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.

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

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

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

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

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

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

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

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

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

where β is the time discount factor and χ_z denotes the weight of leisure in the utility. Although households are risk-neutral, they have a motive to smooth consumption which is driven by the positive elasticity of intertemporal substitution, which equals $(1-\eta)^{-1}$. Finally, ν_z is the Frisch elasticity, which is age-specific. The variation across young agents, mature agents, and old agents of the Frisch elasticity generates age-specific differences in the supply of labor.

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 a convex adjustment cost $\varphi^i_{z,t}\left(k^i_{z,t+1} \right)$. The total nominal return on assets $a^i_{z,t}$ is defined in Equation (9). In case the households is either young or mature, the total return on assets equals the sum of the return on capital and bonds, where $R_{k,t}$ defines the nominal rental rate of capital, and $R_{n,t}$ is the nominal gross 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 probability an old agent survives to the next period ω_o. Households also incur a lump-sum tax $\tau^i_{z,t}$.

Each household earns a nominal labor income $W_{z,t}\xi_z l^i_{z,t}$. We assume that households of different age-groups provide different efficiency units of hours worked. Namely, we normalize the efficiency units of hours of mature agents to one, $\xi_m = 1$. We assume that young and old households provide labor at a reduced efficiency, such that $\xi_o, \xi_y < 1$. These conditions allow us to calibrate the model to match the hump-shaped pattern of wages 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.

Equations (12) and (13) show that households consumption and investment combine final goods produced in both the home and foreign country. The parameter λ captures the degree of openness of the home economy, that is, the amount of imported goods consumed by households in the home economy. 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, 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. The price indexes of consumption P_t and investment $P_{I,t}$ are respectively defined as

$$P_t = \left[\lambda {P_{H,t}}^{1-\psi_c} + (1-\lambda) {P_{F,t}}^{1-\psi_c} \right]^{\frac{1}{1-\psi_c}} \tag{16}$$

and

$$P_{I,t} = \left[\lambda {P_{H,t}}^{1-\psi_I} + (1-\lambda){P_{F,t}}^{1-\psi_I}\right]^{\frac{1}{1-\psi_I}}. \tag{17}$$

The Appendix reports the problem of young agents, mature agents, and old agents separately, and also shows the full set of first-order conditions.

3.3 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 CES aggregator of the different varieties of each intermediate producer

$$Y_t = \left(\int_0^1 {Y_t^j}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{18}$$

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 $P_{H,t}^j$. Hence, the demand of output of each producer is isoelastic

$$Y_t^j = \left(\frac{P_{H,t}^j}{P_{H,t}}\right)^{-\varepsilon} Y_t, \tag{19}$$

and the price level of the home country $P_{H,t}$ equals

$$P_{H,t} = \left(\int {P_{H,t}^j}^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}. \tag{20}$$

The foreign country has the same structure with the only difference that it produces output $Y_t^\star$ at a production price $P_{F,t}$.

The intermediate firms produce the differentiated varieties Y_t^j

$$Y_t^j = (L_t^j)^{1-\alpha} K_t^{j\,\alpha} \tag{21}$$

using labor L_t^j and physical capital K_t^j. Then, intermediate producers hire workers at the equilibrium nominal wage W_t and rent capital from home residents at the equilibrium nominal gross rate $R_{k,t}$. Hence, nominal dividends D_t^j equal

$$D_t^j = P_{H,t}^j Y_t^j - W_t L_t^j - R_{k,t} K_t^j. \tag{22}$$

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

$$\min_{\tilde{K}_t^j, L_t^j} \mathbb{E}_t \left\{ \sum_{s=t}^{\infty} Q_{t,s}^m \left(W_s L_s^j + R_{k,s} K_s^j \right) \right\}, \tag{23}$$

where $Q_{t,s}^m$ denotes the stochastic discount factor of the mature agents between period t and period $s \geq t$. Given firms' nominal marginal costs Φ_t^j, the cost minimization problem implies the following first-order conditions for labor and capital

$$W_t = \Phi_t^j (1-\alpha) \frac{Y_t^j}{L_t^j} \qquad \text{and} \qquad R_{k,t} = \Phi_t^j \alpha \frac{Y_t^j}{K_s^j}. \tag{24}$$

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. Firms set their optimal prices by maximizing the expected discounted stream of real dividends

$$\max_{P^j_{H,t}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \zeta^s Q^m_{t,t+s} \frac{\left(P^j_{H,t} - \Phi^j_{t+s}\right)}{P_{t+s}} Y^j_{t+s} \right\}. \tag{25}$$

In the maximization problem, firms take into account that with a probability ζ they have to keep the current price $P^j_{H,t}$ also in the following period.

Then, the optimal reset price $P^{j,\#}_{H,t}$ for a firm that can change its price is

$$P^{j,\#}_{H,t} = \frac{\varepsilon}{\varepsilon - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \zeta^s Q^m_{t,t+s} \Phi^j_{t+s} P^{\varepsilon}_{H,t+s} P^{-1}_{t+s} Y_{t+s}}{\mathbb{E}_t \sum_{s=0}^{\infty} \zeta^s Q^m_{t,t+s} P^{\varepsilon}_{H,t+s} P^{-1}_{t+s} Y_{t+s}}. \tag{26}$$

Since every intermediate producer has the same capital-to-labor ratio, then the marginal costs are equalized across firms, that is, $\Phi^j_t = \Phi_t$. Consequently, there is only one optimal reset price $P^{\#}_{H,t}$ that is chosen by any firm that has been given the possibility to change its price. Using the properties of the Calvo price friction, we can derive the law of motion for the aggregate price level

$$P^{1-\varepsilon}_{H,t} = (1 - \zeta) P^{\#}_{H,t}{}^{1-\varepsilon} + \zeta P^{1-\varepsilon}_{H,t-1}. \tag{27}$$

3.4 Government

In the monetary union there is a government that constitutes of a fiscal authority and a monetary authority. On the fiscal side, the 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 $R_{n,t}$, and a nominal lump-sum taxes levied in the home country Tr_t and in the foreign country $\mathrm{Tr}^{\star}_t$, and the proceeds from dividend taxation $\tau_d(D_{m,t} + D^{\star}_{m,t})$. The government budget constraint reads

$$P_{H,t}G_{H,t} + P_{F,t}G_{F,t} + B_{g,t+1} = B_{g,t}R_{n,t} + P_tT_t + P^{\star}_t T^{\star}_t + \tau_d(D_{m,t} + D^{\star}_{m,t}). \tag{28}$$

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

$$\log G_{H,t} = (1 - \rho_G) \log G_{H,SS} + \rho_G \log G_{H,t-1} + \epsilon_{G_H,t}, \text{ and} \tag{29}$$

$$\log G_{F,t} = (1 - \rho_G) \log G_{F,SS} + \rho_G \log G_{F,t-1} + \epsilon_{G_F,t}, \tag{30}$$

where $G_{H,SS}$ and $G_{F,SS}$ are the steady-state values of government spending in both countries, ρ_G denotes the persistence of the processes, $\epsilon_{G_H,t}$ is shock to spending in home goods, and $\epsilon_{G_F,t}$ is a shock to spending 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 exogenous changes in government expenditure:

$$\begin{aligned} \frac{B_{g,t+1} - B_{g,SS}}{Y_{SS}^U} &= \rho_{bg} \frac{B_{g,t+1} - B_{g,SS}}{Y_{SS}^U} + \phi_G \frac{P_{H,t} \left(G_{H,t} - G_{H,SS} \right)}{Y_{SS}^U} + \dots \\ &\dots + \phi_G \frac{P_{F,t} \left(G_{F,t} - G_{F,SS} \right)}{Y_{SS}^U} + \phi_T \frac{P_t \left(T_t - T_{SS} \right)}{Y_{SS}^U} + \phi_T \frac{P_t^\star \left(T_t^\star - T_{SS}^\star \right)}{Y_{SS}^U} \end{aligned} \tag{31}$$

where $B_{g,SS}$, Y_{SS}^U, T_{SS}, and $T_{SS}^\star$ denote the steady-state values of government bonds, union output, total lump-sum taxes in the home economy, and total lump-sum taxes in the foreign economy, respectively. The parameters ρ_{bg}, ϕ_G and ϕ_T control the extent that debt and tax financing are used when government spending increases and how long the government takes to start increasing taxes to bring government debt back to the its steady state level. For instance, when $\phi_G = 0$, $\rho_{bg} = 0$, and $\phi_T = 1$, the spending is fully financed through taxes. As ϕ_G and ρ_{bg} increase, government spending becomes partially financed through debt issuance.

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 $P^u_t \equiv N_t P_t + N^\star_t P^\star_t$, and the gap between the output of the monetary union $Y^u_t \equiv N_t Y_t + N^\star_t Y^\star_t$ and the potential output of an economy with flexible prices Y^F_t, that is,

$$\frac{R_{n,t}}{\bar{R}} = \left[\frac{R_{n,t-1}}{\bar{R}}\right]^{\psi_R} \left[(1+\pi_t)^{\psi_\pi} \left(\frac{Y^u_t}{Y^F_t}\right)^{\psi_Y}\right]^{1-\psi_R} \tag{32}$$

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.

3.5 Closing the Model

Our two assumptions that wash out agents' idiosyncratic uncertainty 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 respectively as

$$C^y_t = \int_0^{N_{y,t}} c^i_{y,t}\,\mathrm{di}, \quad C^m_t = \int_0^{N_{m,t}} c^j_{m,t}\,\mathrm{dj}, \quad \text{and} \quad C^o_t = \int_0^{N_{o,t}} c^j_{o,t}\,\mathrm{dj},$$

The same applies to all the variables of the model. The Appendix shows that the life-cycle setup of the model reduces to the existence of three representative agents.

Bonds can move freely across countries, and the clearing of the bond market is such that the supply of government bonds equals the sum of individual positions across countries, that is

$$B_{g,t} = B_t + B^\star_t = B^y_t + B^m_t + B^o_t + B^{y,\star}_t + B^{m,\star}_t + B^{o,\star}_t.$$

Instead, we assume that labor and physical capital are immobile. The clearing of the rental markets of capital at home and foreign economies imply

$$K_t = K_t^y + K_t^m + K_t^o, \quad \text{and} \quad K_t^\star = K_t^{y,\star} + K_t^{m,\star} + K_t^{o,\star}.$$

The labour markets clear when

$$L_t = \xi_y L_t^y + \xi_m L_t^m + \xi_o L_t^o, \quad \text{and} \quad L_t^\star = \xi_y L_t^{y,\star} + \xi_m L_t^{m,\star} + \xi_o L_t^{o,\star}.$$

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

$$Y_t = C_{H,y,t} + C_{H,m,t} + C_{H,o,t} + c^\star_{H,y,t} + C^\star_{H,m,t} + C^\star_{H,o,t} + G_{H,t} + X_{H,t} + X^\star_{H,t} - \varphi_t, \tag{33}$$

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

$$Y_t^\star = C_{F,y,t} + C_{F,m,t} + C_{F,o,t} + C^\star_{F,y,t} + C^\star_{F,m,t} + C^\star_{F,o,t} + G_{F,t} + X_{F,t} + X^\star_{F,t} - \varphi_t^\star. \tag{34}$$

4 Quantitative Analysis

4.1 Calibration

In the calibration exercise, we group the parameters of the model in two sets. A first set of parameters is calibrated as in standard open-economy New Keynesian models. The second set of parameters, that discipline the life-cycle structure, is instead calibrated to match 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 first set of parameters is reported in Table 3. We set the time discount factor to $\beta = 0.99$, whereas we fix $\eta = -9$ to define an elasticity of intertemporal substitution which equals 0.1, at the lower end of the empirical estimates, as discussed by Hall (1988).

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 j in the age group z at time t equal $\varphi_z\left(k^j_{z,t+1}\right) = \frac{\varphi}{2}\left(\frac{k^j_{z,t+1}}{k^j_{z,t}} - \vartheta_z\right)^2 k^j_{z,t}$. The parameter ϑ_z captures the life-cycle dynamics of capital accumulation and it is pinned down by steady-state values. 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 0.39%, which implies $\vartheta_m = 1.0038$, whereas old households on average deplete capital, and they do so at a quarterly rate of -0.41%, such that $\vartheta_o = 0.9959$. Then, we set $\kappa = 108$ such that the two-year national fiscal multiplier for investment equals -0.9, which coincide with the estimate of Blanchard and Perotti (2002).

Regarding the consumption and investment bundles, there are three parameters to be calibrated: the home bias λ, the elasticity of substitution across home and foreign consumption goods ψ_c, and the elasticity of substitution across home and foreign investment goods ψ_i. Following 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 $\psi_c = 2$. Then, we impose that the elasticity of substitution across home and foreign investment goods equals the one of consumption goods, that is, $\psi_i = \psi_c$. We set the elasticity of substitution across varieties to $\epsilon = 7$, which implies a markup of 17%, in the ball park of the estimates used in the literature of New Keynesian models. The capital share in the production function is set to $\alpha = 0.30$, and the Calvo price parameter to $\zeta = 0.75$, which implies that on average firms adjust their prices every 12 months.

Table 3: Calibration - Standard Parameters

Parameter	Value	Target/Source
Time Discount Factor	$\beta = 0.99$	Standard Value
Elasticity Intertemporal Substitution	$\eta = -9$	EIS = 0.1
Capital Depreciation Rate	$\delta = 0.025$	Standard Value
Capital Adjustment Cost	$\kappa = 108$	Two-Year National Investment Fiscal Multiplier = -0.9
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	$\epsilon = 7$	Standard Value
Capital Share in Production	$\alpha = 0.33$	Standard Value
Calvo Parameter	$\zeta = 0.75$	Standard Value
Dividend Taxation Rate	$\tau_d = 0.9394$	Mature Agents Receive 60% Total Dividends
Steady-State Government Spending to Output Ratio	$\frac{G_{H,SS}+G_{F,SS}}{Y^U_{SS}} = 0.3$	Data
Persistence Government Spending Shock	$\rho_G = 0.933$	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)

Table 4: Calibration - Demographics & Life-Cycle of Hours and Wages

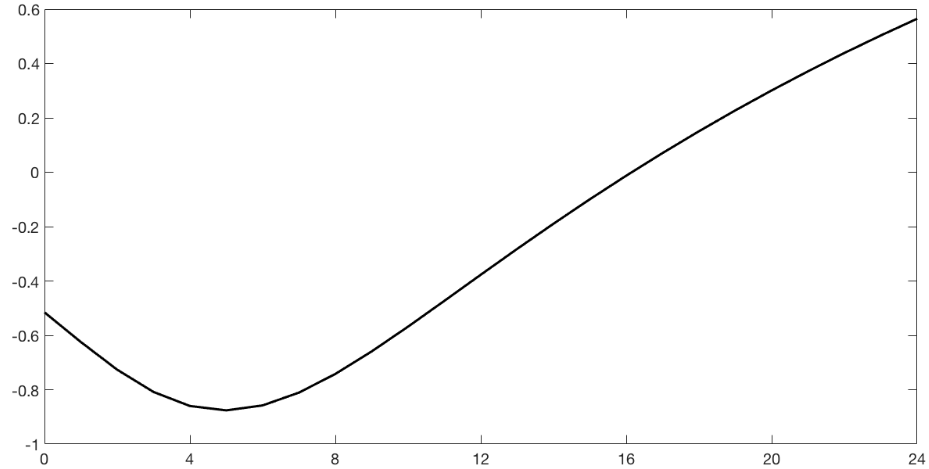
Parameter	Value	Target
	Panel a: Demographics	
Birth Rate of New Young Agents	$\omega_n = 0.0241$	Share of Young in Population
Probability Transition from Young to Mature	$1 - \omega_y = 0.0250$	Avg. Number of Years as Young: 10y
Probability Transition from Mature to Old	$1 - \omega_m = 0.0083$	Avg. Number of Years as Mature: 30y
Death Probability of Old Agents	$1 - \omega_o = 0.0320$	Share of Old in Population
Relative Size Population Home Economy	$N/N^u = 0.1$	Relative Size of California
	Panel b: Hours and Wages	
Disutility Labor for Young Agents	$\chi_y = 4.9963$	Fraction of Hours Worked = 0.35
Disutility Labor for Mature Agents	$\chi_m = 490.1585$	Fraction of Hours Worked = 0.35
Disutility Labor for Old Agents	$\chi_o = 1.6923$	Fraction of Hours Worked = 0.35
Efficiency Units of Hours for Young Agents	$\xi_y = 0.62$	Wage Young = 62% Wage Mature
Efficiency Units of Hours for Mature Agents	$\xi_m = 1$	Normalization
Efficiency Units of Hours for Old Agents	$\xi_o = 0.21$	Wage Old = 21% Wage Mature
Frisch Elasticity for Young Agents	$\nu_y = 0.92$	Weighted Avg. Frisch Elasticity = 0.5
Frisch Elasticity for Mature Agents	$\nu_m = 0.2$	Chetty et *al.* (2011)
Frisch Elasticity for Old Agents	$\nu_o = 0.92$	Weighted Avg. Frisch Elasticity = 0.5

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 $\frac{G_{H,SS}+G_{F,SS}}{Y^U_{SS}} = 0.3$. This value coincides with the average ratio of total government spending (the sum of federal and local government spending) to output observed in the data from 1960 to 2016. The persistence of the government spending shock is calibrated to $\rho_G = 0.933$, which matches the persistence of the military procurement data, as computed by Nakamura and Steinsson (2014). Finally, we calibrate the fiscal rule parameters. To calibrate the three parameters ρ_{bg}, ϕ_G, and ϕ_T, we derive three moments to match. First, we posit that following a government spending shock the ratio of debt issuance to government deficit is u-shaped, with a trough after 6 quarters. Second, throughout the first 8 quarters, new debt issuance covers roughly 70% of total deficit. Third, after the trough, debt issuance starts decreasing and after 16 quarters government debt is progressively repaid through an increase in lump-sum taxation. This procedure yields the following parameters: $\rho_{bg} = 0.95$, $\phi_G = 4.5$, and $\phi_T = 0.01$. Figure 1 reports the implied dynamic response of the ratio of debt issuance to government deficit in the model.

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

The calibration of the set of parameters that govern the demographic and life-cycle structure of the model is reported in Table 4. We first set the parameters that define the law of motion of age group populations to match the share of young people in total population as computed in 1980, the share of old people in total population as computed in 1980, the average number of years that an individual spends as

Figure 1: Dynamic Response of the Ratio of Debt Issuance to Government Deficit



The figure plots the response in the model of the ratio of debt issuance to government deficit to a change in government spending as implied by the calibration of the fiscal rule.

young (10 years), the average number of years that an individual spends as mature (30 years). Matching these moments yields a birth rate of new young agents of $\omega_n = 0.0241$, 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 $1 - \omega_m = 0.0083$, and a death probability for an old agent of $1 - \omega_o = 0.0320$. Finally, we set the size of the home economy to $N/N^u = 0.1$, which is the relative population size of California.

We define the relative disutility of working such that steady-state hours worked equal 0.35. This condition yields the values of $\chi_y = 4.9963$, $\chi_m = 490.1585$, and $\chi_o = 1.6923$. The efficiency unity of hours worked across the age groups are calibrated such that the model is consistent with the life-cycle dynamics of labor income. First, we normalize the efficiency unity of hours of mature agents and set $\xi_m = 1$. Then, we use CPS data and find that the labor income of individuals between 20 and 29 years equals on average 62% of the labor income of individuals between 30 and 64 years. Consequently, we set $\xi_y = 0.62$. We follow the same procedure for the labor income of individuals above 65 years and find that $\xi_o = 0.21$.

Finally, we calibrate the labor supply elasticity of the mature agents such that the Frisch elasticity of this group equals $\nu_m = 0.2$, the value estimated by Chetty et *al.* (2011) in a meta-analysis of quasi-experimental studies across countries. As far the Frisch elasticities of the young and the old are concerned, Jaimovich and Siu (2009) document that the volatility of hours of young and old workers is much higher than the volatility of hours of prime-age workers. To be consistent with this fact, we assume that the Frisch elasticities of young and old workers are higher than the one of mature individuals. First, we posit that the Frisch elasticity of the young and the old coincide. Second, we set the values such that the weighted average Frisch elasticity of the economy equals 0.5. This procedure yields the values of $\nu_y = \nu_o = 0.92$.

4.2 Results

4.2.1 Demographics and Local Fiscal Multipliers

What is the effect a change in the age structure of the economy on local fiscal multipliers in the model? In this Section we address this question by replicating the same empirical analysis carried out in Section 2 on the simulated data of our model.

First, 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 1980. Namely, 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). Second, 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 stage and the first stage yields the model counterpart of the coefficient γ of the regression (1).

Table 5 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 1.511. A 1% increase in the share of young people raises the multiplier by 3.1%, up to 1.514. In the model, the local output fiscal multiplier for a U.S. state with an average share of young people in total population is 1.460. A 1% increase in the share of young people raises the multiplier by 2%, up to 1.489. Hence, the model can account for 97% of the size of fiscal multipliers and 65% of the link between fiscal multipliers and demographics.

Table 5: Output Local Fiscal Multiplier - Data vs. Model

		Data	Model
Avg. Local Output Fiscal Multiplier	β	1.511	1.460
Sensitivity of Output Fiscal Multiplier with States' Age Structure	γ	0.047	0.029
Effect on Output Fiscal Multiplier of 1% Increase in Share Young People	γ/β	3.1%	2.0%

Why does the model predict that local fiscal multipliers increase with the share of young people in total population? In the model, the link between demographics and the size of multipliers is twofold. First, the high Frisch elasticity of young workers makes young employment much more responsive to government spending shocks than the employment of prime-age workers. Second, an economy with relatively more young households features a stronger demand channel. Indeed, the credit market imperfections boost the marginal propensity to consume of young households well above the one of prime-age households, as it is in the data. Consequently, as the proportion of young workers increase, both labor and output react more sharply to a fiscal shock.

4.2.2 Demographics and National Fiscal Multipliers

Does the link between demographics and fiscal multipliers persist also at the national level? Although our evidence shows that the effect of demographics on fiscal multipliers at the state level is economically and statistically significant, this result does not necessarily imply that demographics alter also national multipliers. Indeed, Nakamura and Steinsson (2014) and Beraja et al. (2016) find that local and aggregate elasticities to the same type of shocks may be substantially different.

We evaluate the role of the age structure on the size of national fiscal multiplier through the lenses of the model. To do so, we run the following exercise. First, we consider a symmetric increase in government spending in both the home economy 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, weighted by the relative size of each economy: $G_t^u = N_t G_{H,t} + N_t^\star G_{F,t}$. Then, we estimate the national output multiplier as

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

Following the same procedure, we also estimate the national consumption fiscal multiplier, the national investment fiscal multiplier, and the national employment fiscal multiplier. Second, we change the age structure of the economy by increasing the share of young people by 1% and estimate again the same set of fiscal multipliers.

Table 6 shows that a 1% in the share of young people leads to an increase in the national output fiscal multiplier by 1.2%, from 1.32 up to 1.34. It also raises the consumption, investment, and employment multiplier by 1.7%, 0.5%, and 0.8%, respectively.

These results confirm that changes in the age structure of an economy affect fiscal multipliers also at the national level. This finding is consistent with the empirical evidence we report in the Appendix, in which 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.

Table 6: National Fiscal Multipliers

	Output	Consumption	Investment	Employment
Avg. National Fiscal Multiplier	1.32	1.21	−0.90	1.87
Effect on National Fiscal Multiplier of 1% Increase in Share Young People	1.2%	1.7%	0.5%	0.8%

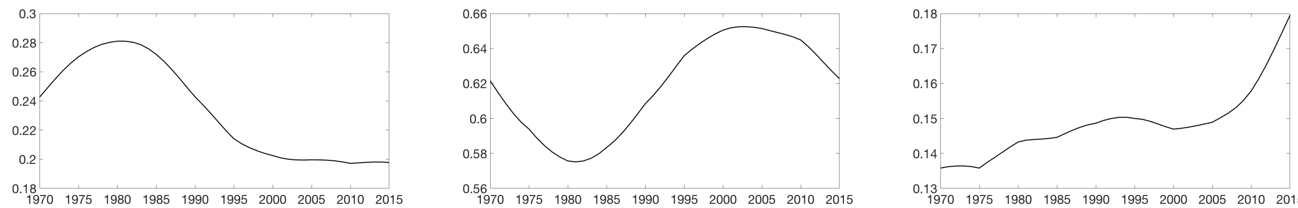
5 Population Aging and Fiscal Multipliers

After the post-World War II baby boom, the demographic structure of the U.S. population has progressively shifted towards older ages. Figure 2 report the share of young people (between 20 and 29 years old), mature people (between 30 and 64 years old), and old people (above 65 years old) over the population above 20 years old. Panel (a) shows that the share of young people has peaked in the 1980, and has been constantly decreasing thereafter. From 1980 to 2015, the share of young people has shrunk by 30%. Also, Panel (b) and Panel (c) shows that after the 1980s the U.S. population tilted towards people in their prime-age, whereas more recently the share of old people has been increasing dramatically.

What are the implications of the aging of the U.S. population on the effectiveness of fiscal policy? We address this question by computing through the lenses of the model national fiscal multipliers for the entire path of population shares observed from 1970 until 2015. Table 7 reports the fiscal multipliers implied by the model for the population shares observed in 1970, 1980, 1990, 2000, and 2010. Instead,

Figure 2: Changes in the Age Structure of the U.S. Population from 1970 until 2015.

(a) Share of Young People (b) Share of Mature People (c) Share of Old People



Note: Panel (a) plots the share of young white men, defined as the white men individuals between 20 and 29 years old, over the entire population of white men above 20 years old. Panel (b) plots the share of mature white men, defined as the white men individuals between 30 and 64 years old, over the entire population of white men above 20 years old. Panel (c) plots the share of old white men, defined as the white men individuals above 65 years old, over the entire population of white men above 20 years old. The data is from the Survey of Epidemiology and End Results of the National Cancer Institutes.

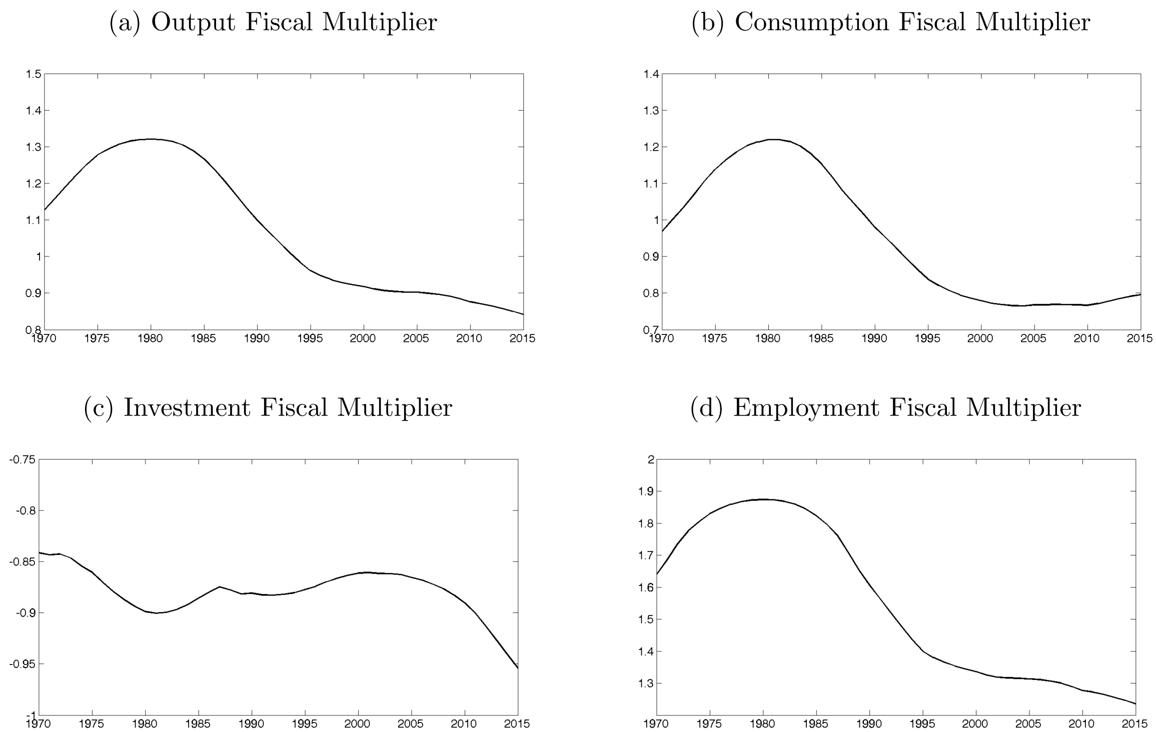
Table 7: National Fiscal Multipliers Over the Recent Decades

	1970	1980	1990	2000	2010
Output	1.13	1.32	1.10	0.92	0.88
Consumption	0.96	1.22	0.98	0.78	0.77
Investment	−0.84	−0.90	−0.88	−0.86	−0.89
Employment	1.64	1.87	1.61	1.34	1.28

Figure 3 shows the entire path for these multipliers, year by year, from 1970 on.

The results show that the output fiscal multipliers was 1.13 in 1970 and increased up to 1.32 in 1980 at the peak of the Baby Boom. Then, as the share of young people progressively shrinks, the fiscal multiplier starts decreasing, drops below 1 in 1994, and reaches a value of 0.84 in 2015. Hence, the model predicts that over the last forty years the size of the output fiscal multipliers went down by 36%. A similar pattern characterizes also the consumption and employment multiplier: over the last forty years the consumption fiscal multiplier decreased by 34% (from 1.22 down to 0.80) whereas the employment fiscal multipliers experienced a drop of 35% (from 1.87 down to 1.24). Instead, the investment fiscal multipliers is roughly constant until the early 2000s. Then, as the share of old people increases dramatically over

Figure 3: Fiscal Multipliers from 1970 until 2015.



the last 10 years, we observe that the investment fiscal multiplier becomes more and more negative, reaching a value of -0.95% in 2015.

These results are consistent with the empirical evidence of Blanchard and Perotti (2002) and Bilbiie et *al.* (2008) on the reduction of the size of fiscal multipliers over time. Both papers show that fiscal multipliers in the recent decades are smaller than what they used to be during the 1960s and 1970s. From this perspective, our model provides a rationale of this empirical finding, by linking the process of aging of the U.S. population to the observed reduction in the effectiveness of fiscal policy. Since most advanced economies are experiencing a process of population aging, the results of our model suggest that over time fiscal policy could become a relatively less effective tool for spurring economy activity.[8]

[8]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).

6 Conclusion

This paper shows that the age structure of an economy determines the effectiveness of fiscal policy such that fiscal multipliers are larger in economies with higher shares of young people in total population.

First, we identify the causal effect of a change in demographics on the size of fiscal multipliers using the variation across U.S. states in government spending and lagged birth rates. We find that a 1% increase in the share of people between 20 and 29 years in total population raises the local fiscal multipliers by 3.1%.

Second, to rationalize this finding we build an open-economy life-cycle New Keynesian model with credit market imperfections and age-specific labor supply elasticities. The model can explain 65% of the link between demographics and local fiscal multipliers: in the model a 1% increase in the share of people between 20 and 29 years in total population raises the local fiscal multipliers by 2%.

Third, we show that demographics affect the size of fiscal multipliers also at the national level. Indeed, in the model a 1% increase in the share of people between 20 and 29 years in total population raises the *national* fiscal multipliers by 1.2%.

Fourth, we use the model to study the implications of population aging for the effectiveness of fiscal policy. After the post-World War II baby boom, the demographic structure of the U.S. population has progressively shifted towards older ages: the share of young people in total population plummeted by 30% from 1980 to 2015. We feed the model with the shares of the U.S. population by age groups from 1970 until 2015. The model predicts that nowadays national fiscal multipliers are 36% lower than forty years ago. This result suggests that the process of population aging could dampen over time the effectiveness of fiscal policy.

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A Local Fiscal Multipliers: Further Evidence

In Section 2 we have documented the causal effect of demographics on fiscal multipliers, such that fiscal multipliers are larger in economies with higher shares of young people in total population. This result could be biased by potential confounding factors which are highly correlated with changes in states' age structures. In this Section we address this issue and report a comprehensive battery of robustness checks for the estimates of both the output fiscal multiplier and the employment fiscal multiplier.

First, we define a number of national controls, such as 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 (2017), 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).

Second, we consider state-level controls, such as the house price (provided by the U.S. Federal Housing Finance Agency from 1975 on), per capita real income (provided by the BEA), per capita real federal personal taxes (provided by the BEA), the unemployment rate (provided from the BLS from 1976 on), and per capita real unemployment benefits (provided by the BLS).

Table A.1 shows the estimate of the output fiscal multiplier - and its relationship with the share of young people in total population - in a number of alternative specifications of the baseline regression in which we add each time an additional control variables. For the national level variables, we build state-specific values by

Table A.1: Response of Output to a Government Shock across U.S. States - Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	National Controls					State Controls				
	Oil Price	Households' Debt	Federal Debt	Real Interest Rate	Ramey News	House Price	Households' Income	Personal Taxes	Unempl. Rate	Unempl. Benefits
	IV	IV	IV	IV	IV	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***	0.795***	1.366***	1.468***	0.627	1.500***
	(0.333)	(0.451)	(0.443)	(0.395)	(0.416)	(0.398)	(0.367)	(0.401)	(0.412)	(0.406)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t} - \bar{D})$	0.039**	0.065***	0.041**	0.048***	0.039**	0.066***	0.050***	0.048***	0.049***	0.047***
	(0.015)	(0.022)	(0.017)	(0.017)	(0.018)	(0.016)	(0.019)	(0.016)	(0.016)	(0.016)
$D_{i,t}$	0.001**	0.002**	0.002***	0.001**	0.002***	0.001***	0.001**	0.001**	0.001**	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.446	0.371	0.397	0.405	0.389	0.441	0.395	0.378	0.451	0.375
N. Obs.	2374	2374	2374	2374	2374	2031	2374	2374	2031	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 per capita real ouput. In all regressions, the independent variables are the change in per capita government expenditures, $(G_{i,t} - G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (age 20-29) in total population, $D_{i,t}$, and the interaction between the change in per capita government expenditures 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 expenditures (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 expenditures (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. In regressions (1) - (5) we 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. In regressions (6) - (10) we include one additional state-level control to the benchmark specification. Regression (6) includes the log-difference of the real house price. Regression (7) includes per capita real households' income. Regression (8) includes per capita real households' federal taxes. Regression (9) includes the unemployment rate. Regression (10) includes per capita real unemployment benefits. 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 to a Government Shock across U.S. States - Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	National Controls					State Controls				
	Oil Price	Households' Debt	Federal Debt	Real Interest Rate	Ramey News	House Price	Households' Income	Personal Taxes	Unempl. Rate	Unempl. Benefits
	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.104***	1.070***	1.025***	1.069***	1.073***	0.416**	1.064***	1.071***	0.325	1.084***
	(0.207)	(0.013)	(0.216)	(0.211)	(0.222)	(0.220)	(0.207)	(0.218)	(0.220)	(0.217)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times (D_{i,t}-\bar{D})$	0.033***	0.040***	0.034***	0.032***	0.035***	0.043***	0.036***	0.035***	0.035***	0.035***
	(0.011)	(0.013)	(0.011)	(0.011)	(0.011)	(0.008)	(0.010)	(0.011)	(0.009)	(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
	(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	0.723	0.625	0.624	0.726	0.622
N. Obs.	2374	2374	2374	2374	2374	2031	2374	2374	2031	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 expenditures, $(G_{i,t} - G_{i,t-2})/Y_{i,t-2}$, the log-share of young people (age 20-29) in total population, $D_{i,t}$, and the interaction between the change in per capita government expenditures 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 expenditures (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 expenditures (as a fraction of national per capita GDP). The share of young people is instrumented with 20-30 year lagged birth rates. In regressions (1) - (5) we 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. In regressions (6) - (10) we include one additional state-level control to the benchmark specification. Regression (6) includes the log-difference of the real house price. Regression (7) includes per capita real households' income. Regression (8) includes per capita real households' federal taxes. Regression (9) includes the unemployment rate. Regression (10) includes per capita real unemployment benefits. 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.3: Local Fiscal Multipliers: Skilled Workers & Female Labor Participation

	(1)	(2)	(3)	(4)
	Skilled Workers	Young Skilled Workers	Female Workers	Young Female Workers
	IV	IV	IV	IV
	Panel A. Response of Output			
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	1.125**	1.177**	1.147**	1.138**
	(0.480)	(0.478)	(0.477)	(0.470)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times \left(D_{i,t} - \bar{D}\right)$	0.070***	0.070***	0.071***	0.067***
	(0.018)	(0.018)	(0.017)	(0.017)
$D_{i,t}$	0.001*	0.001**	0.001*	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.348	0.351	0.349	0.352
N. Observations	1982	1982	1982	1982
	Panel B. Response of Employment Rate			
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$	0.537*	0.611**	0.581*	0.591**
	(0.298)	(0.300)	(0.301)	(0.298)
$\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times \left(D_{i,t} - \bar{D}\right)$	0.045***	0.046***	0.046***	0.045***
	(0.010)	(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)
R^2	0.664	0.660	0.660	0.663
N. Observations	1982	1982	1982	1982

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 expenditures (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 (age 20-29) in total population, $D_{i,t}$, and the interaction between the change in per capita state government expenditures (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 expenditures (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 expenditures (as a fraction of per capita national GDP). The share of young people is instrumented with 20-30 year lagged birth rates. Regression (1) includes as an additional independent variables states' share of skilled workers. Regression (2) includes states' share of skilled workers compute over the young population. Regression (3) includes states' share of female workers. Regression (4) includes states' share of female workers compute over the young population. 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.

interacting the variable with the state fixed effects. Table A.2 reports a similar battery of robustness checks for the employment 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. Actually, the introduction of additional controls alters the level of fiscal multipliers but not the sensitivity of multipliers to states' age structure.

Table A.3 considers a further set of robustness check in which we include as additional controls the share of skilled workers and female workers in each state. We build these measures using CPS data from 1977 on. Again, the link between demographics and fiscal multipliers is not driven by recent trends in the U.S. labor market.

A.1 Cumulative Fiscal Multipliers

The econometric specification of the regression (1) in Section 2 computes a two-year impact output fiscal multiplier. Ramey and Zubairy (2017) argue that cumulative fiscal multipliers are than impact multipliers.

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

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

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 $D_{i,t}$. 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 follows

$$\frac{\left(\sum_{j=1}^{2} E_{i,t+1-j} - 2E_{i,t-2}\right)}{E_{i,t-2}} = \alpha_i + \delta_t + \beta \frac{\left(\sum_{j=1}^{2} G_{i,t+1-j} - 2G_{i,t-2}\right)}{Y_{i,t-2}} + \dots$$

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

where the dependent variable is the two-year cumulative change in the employment rate of state i.

In this case we instrument state-specific two-year cumulative changes in per capita state government expenditures (as a fraction of per capita state GDP) with the product of state fixed effects and two-year cumulative change in per capita national government expenditures (as a fraction of per capita national GDP), that is, we run the following first-stage regression:

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

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.4 shows that neither the estimate of β nor the one of γ change when we estimate two-year cumulative multiplier rather than two-year impact multiplier.

Table A.4: 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*** (0.405)	1.019*** (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*** (0.016)	0.033*** (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 expenditures (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 (age 20-29) in total population, $D_{i,t}$, and the interaction between the two-year cumulative change in per capita state government expenditures (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 both regressions, two-year cumulative state-specific changes in per capita state government expenditures (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 expenditures (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.2 Population Response to Government Spending Shocks

Table A.5 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), (*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 regression uses annual data from 1969 until 2015.

Table A.5: 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 (age 20-29). In Column (3) the dependent variable is the state white male mature population (age 30-64). In Column (4) the dependent variable is the state white male old population (age 65+). The independent variable is the change in per capita state government expenditures (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 expenditures (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.5 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 prime-age 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 patter could mask 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.

B National Fiscal Multipliers

Although we show that at the state level demographics have an effect on fiscal multipliers which is statistically and economically significant, our results do not necessarily hold 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.[9] 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

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

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. Anyway, results do not depend on the choice of the lag. 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: 8 countries with high shares of young people in total population, and 11 countries with low

[9] 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.

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 12 countries with high shares of young people and 13 countries with low shares.[10,11]

Finally, we follow Ilzetzki et *al.* (2013) and define the impact output fiscal multiplier as $\frac{\Delta Y_{i,0}}{\Delta G_{i,0}}$ and 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 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 impact fiscal multiplier and 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.

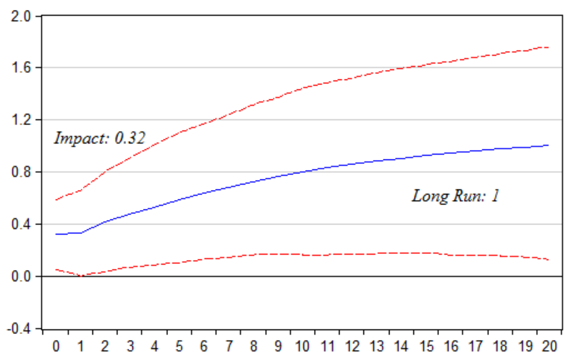
Although the impact fiscal multiplier is similar across groups, in countries with low shares of young people the fiscal multipliers becomes statistically insignificant from zero from the first quarter on, leading to a long-run multiplier of -0.023. Instead, in countries with high shares of young people the fiscal multiplier is always statistically significant and the long-run multiplier equals 1.

[10] 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. Hence, cross-country SVARs do not allow a perfect and clean identification of how national fiscal multipliers vary with demographics.

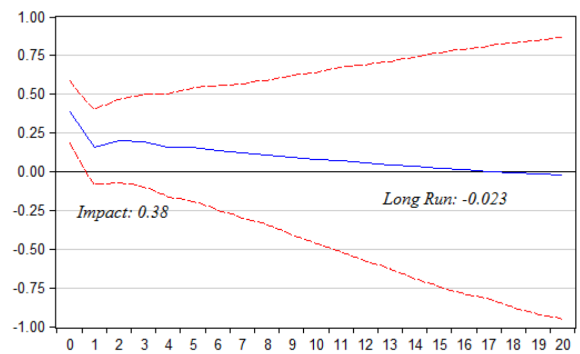
[11] Table B.6 reports countries' average share of young people (age 14-34) over total population computed from 1970 to 2010. We show how we group the countries in the set with high shares of young people and the set with low shares of young people. In the case of developed countries, the eight countries with high shares of young people have shares in the range of 30.1%-32.0%. Instead, the eleven countries with low shares of young people have shares in the range of 27.1%-29.3%. In the case of developing countries, the twelve countries with high shares of young people have shares in the range of 33.0%-35.6%. Instead, the thirteen countries with low shares of young people have shares in the range of 28.2%-32.0%.

Figure B.1: National Fiscal Multipliers and Demographics.

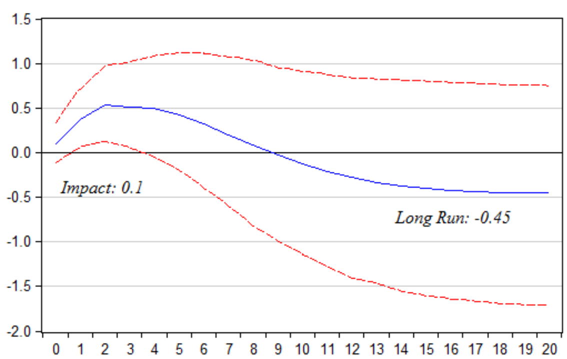
(a) High Income Countries - High Share of Young



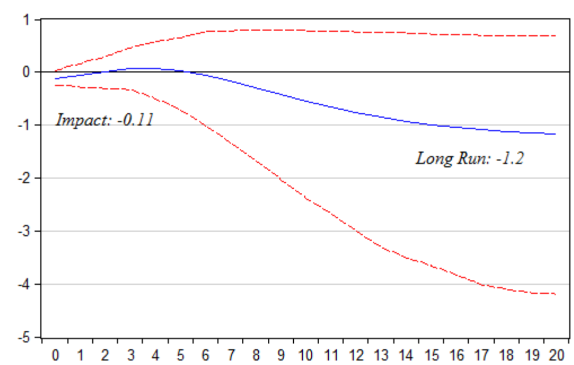
(b) High Income Countries - Low Share of Young



(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 twelve low income countries with high shares of young people in total population. Panel (d) plots the cumulative national fiscal multipliers in a panel of thirteen 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).

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. Nevetheless, 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 multiplier is positive and equals 0.1, while the long-run multiplier is -0.45. Interestingly, the point estimate of the cumulative fiscal multiplier after two quarters is around 0.5, and is statistically different from zero. In the panel of developing countries with low shares of young people fiscal multipliers are much smaller. On impact the multipliers equals -0.11, and in the long-run the multiplier drops down to -1.2

Table B.6: 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
Australia 31.1%	Belgium 28.3%	Botswana 35.2%	Argentina 31.2%
Canada 31.9%	Denmark 28.4%	Brazil 35.3%	Bulgaria 28.2%
Iceland 32.0%	Finland 29.1%	Chile 34.4%	Croatia 28.8%
Ireland 30.9%	France 28.9%	Colombia 35.6%	Czech Republic 29.7%
Israel 31.8%	Germany 27.8%	Ecuador 34.5%	Estonia 28.9%
Netherlands 30.3%	Greece 28.5%	El Salvador 33.0%	Hungary 28.8%
Spain 30.1%	Italy 28.10%	Malaysia 35.0%	Latvia 28.9%
United States 31.1%	Norway 28.7%	Mexico 34.4%	Lithuania 30.0%
	Portugal 29.3%	Peru 34.6%	Poland 31.5%
	Sweden 27.1%	South Africa 35.3%	Romania 30.3%
	United Kingdom 28.2%	Thailand 34.8%	Slovakia 32.0%
		Turkey 34.9%	Slovenia 30.2%
			Uruguay 29.5%

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.