Fiscal Stimulus and Skill Accumulation over the Life-Cycle*

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Abstract

Using household level data for the U.S. from the Consumer Expenditure Survey, I document that age is a key driver of consumption adjustment to government spending shocks. Responses of young households are significantly higher, regardless of their income level or debt position. Further evidence using micro data from the Current Population Survey reveals greater responsiveness of productivity, wages and hours worked to government spending shocks among young workers. I propose a new transmission channel of fiscal policy that can account for these heterogeneous effects across age groups, based on differences in skill accumulation over the life-cycle. To illustrate the mechanism, I develop a parsimonious New Keynesian life-cycle model where young agents accumulate skills on-the-job through a learning-by-doing process. As individuals work more following a fiscal stimulus, the young raise their productivity faster than their prime-age counterparts. The ensuing increase in the relative labor demand for young workers boosts their wages, stimulating their consumption.

Keywords: fiscal policy, heterogeneity, consumption, productivity, life-cycle

JEL Codes: D12, D15, E21, E62, J11, J24

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1 Introduction

There is ample evidence that changes in government expenditures affect consumers unevenly depending on their characteristics such as age, income, wealth, or education.[1] Understanding the channels that drive these heterogeneous effects across households is crucial to implement better designed and targeted policies. It is also important for assessing how the evolution of the population composition, in terms of demographic or socio-economic characteristics, may affect the effectiveness of fiscal policy. A large literature argues that financial constraints play a major role in shaping these differential outcomes.[2] Specifically, financially constrained agents are more responsive to fiscal shocks as they have a higher marginal propensity to consume out of current disposable income.

In this paper, I show that age is a key determinant of consumption adjustment to government spending shocks and I propose a new transmission channel that can account for the heterogeneous effects of fiscal policy across age groups. Using household level data for the U.S. from the Consumer Expenditure Survey (CEX), I document that the young increase their consumption after a government spending shock while the prime-aged are more negatively affected. My analysis suggests that this result is not primarily driven by financial constraints. I also bring evidence, using micro data from the Current Population Survey (CPS), that productivity, wages and hours worked increase relatively more for young workers. I rationalize these findings with a parsimonious life-cycle model where I introduce a learning-by-doing process for young agents. Young workers accumulate skills on-the-job at a fast rate, while the productivity of their prime-age counterparts remains roughly stable. Then, by raising hours worked, a fiscal stimulus can generate higher wage increases for young individuals, stimulating their consumption.

First, I examine consumption responses to a fiscal expansion for different groups of households, aggregated into pseudo-cohorts according to their characteristics. I estimate impulse responses using a VAR approach. Fiscal shocks are identified with a forecast-based measure using the Survey of Professional Forecasters. Consistent with the existing literature, I find that households more likely to be credit constrained tend to raise their consumption after a government spending shock, while unconstrained households tend to lower it. However, after conditioning on age, income or wealth do not appear to

[1] See, e.g., De Giorgi and Gambetti (2012), Anderson et al. (2016), Cloyne and Surico (2016).

[2] See, e.g., Galí et al. (2007), Jappelli and Pistaferri (2014), Kaplan and Violante (2014), Misra and Surico (2014), Brinca et al. (2016), Ferriere and Navarro (2018), Kaplan et al. (2018), Hagedorn et al. (2019).

be the main drivers of heterogeneity in consumption responses. Specifically, my evidence suggests that the young strongly increase their consumption after a positive shock, while the prime-aged reduce it, regardless of their income level or debt position. This finding sheds light on the importance of demographics for the transmission of fiscal policy and suggests the age-related heterogeneity in consumption responses could potentially affect the effectiveness of fiscal policy as the population ages.

I propose a new and distinct transmission channel of fiscal policy that can account for this heterogeneity across the life-cycle. Fiscal policy affects more young agents because it enhances human capital accumulation. It is well documented that the age-productivity profile is steep for young workers and becomes flat for the prime-aged.[3] This implies that the return to learning is high for young individuals, but falls to zero for the prime-aged, which may induce age-related heterogeneity in adjustment to shocks. According to my proposed mechanism, a fiscal stimulus induces a surge in labor demand that increases hours worked. In turn, young workers raise their skill level through learning-by-doing, while the productivity of the prime-aged remains roughly stable.

To investigate this channel, I explore empirically the dynamics of human capital accumulation for young and prime-age workers after a fiscal stimulus. To do so, I use micro-level data from the CPS and build a measure of age-specific productivity. I follow the wage-based approach of Bowlus and Robinson (2012) which allows me to identify the number of supplied efficiency units from the hourly wage. The impact of government spending shocks on these productivity series is then estimated using a similar VAR specification to that used in the analysis of consumption responses. I find that an increase in government spending raises significantly the productivity of young workers, while the response for prime-age workers is statistically insignificant. Turning to the responses of other labor market variables, micro evidence indicates that hours worked and wages increase relatively more for young individuals. I confirm the evidence on the effects of fiscal policy on the productivity of the young in macro-level data using a structural vector autoregression approach for a panel of countries. After a positive shock in government spending, labor productivity significantly increases only in the group of countries with a high share of young in the population.

[3] The concave shape of the age-productivity profile, as predicted by Ben-Porath (1967) model, is documented for instance in Bowlus and Robinson (2012) who build human capital profiles using a wage-based approach. See also other studies which estimate productivity-tenure profiles using employer-employee matched data, such as Hellerstein and Neumark (1995), Hellerstein et al. (1999), Fukao et al. (2006), Hellerstein and Neumark (2007).

To rationalize my empirical findings, I develop an overlapping generations model in the spirit of Gertler (1999) that illustrates how the different dynamics of human capital accumulation across the life-cycle can shape the heterogeneity observed. The model embeds a tractable demographic structure, with three stages of life (young, prime-aged, and retiree), within a dynamic stochastic general equilibrium framework where I introduce price and wage rigidities, as well as segmentation in labor markets. The key feature in this model is a learning-by-doing (LBD) mechanism for young workers, as originally developed in Chang et al. (2002) in a standard real business cycle model and extended to a New Keynesian framework by d'Alessandro et al. (2019). This mechanism implies that young workers accumulate skills as they work, increasing their labor productivity in subsequent periods. Prime-age workers, in contrast, have already reached their highest level of efficiency which remains stable.

Due to pricing frictions, a fiscal stimulus generates an increase in aggregate demand, which leads to higher labor demand. Through the learning-by-doing mechanism, young workers raise their skill level. Due to wage rigidities, this translates into a greater demand of firms for young workers, which boosts their wages. In addition, the increase in productivity, if sufficiently powerful, pushes down marginal costs, and thus expected inflation falls.[4] The Central Bank reacts by lowering the nominal interest rate, which induces a fall in the real interest rate by the Taylor principle. Therefore, the fiscal stimulus operates through two channels. On one hand, lower real interest rates stimulate consumption expenditure for all individuals via intertemporal substitution. On the other hand, the fiscal stimulus also generates asymmetric effects across age groups through redistribution, which a model without heteregeneous agents cannot capture. In particular, young borrowers gain from lower real interest rates, at the expense of prime-age savers, since the real value of nominal assets declines. More importantly, young workers, who primarily finance their consumption through labor income, benefit from higher wage increases. As a result, the young win, while the prime-aged partly lose from the fiscal expansion.

Since most of the existing literature has focused on the importance of financial constraints to explain the heterogeneous responses to fiscal shocks, I compare the predictions of the life-cycle model with LBD to a model with "hand-to-mouth" young agents, who fully consume their current disposable income. Both models are able to

[4]The negative effect of government spending shocks on inflation was already documented in several papers. See Jørgensen and Ravn (2018) and d'Alessandro et al. (2019) for recent examples.

explain the increase in consumption for young individuals and the decrease for prime-age individuals after a positive government spending shock. However, the models strongly differ regarding the effects of the fiscal expansion on wages. Specifically, in the model with LBD, the growth in wages tracks the increase in skills, thus is more pronounced for young individuals than for the prime-aged, consistent with the data. In contrast, the model with "hand-to-mouth" young predicts that wage growth remains subdued for both young and prime-age workers.

This study provides important policy implications. Given the accelerating demographic transition towards an older population in the U.S. and other developed countries, results in this paper indicate that fiscal stimulus measures could become increasingly less effective in boosting the economy. On the other hand, policies which promote human capital formation may increase the effectiveness of fiscal policy, in particular if they are targeted at young individuals.

The remainder of the paper is structured as follows. Section 2 provides an overview of existing literature. Section 3 documents the heterogeneous effects of unexpected government spending shocks on households' consumption. Section 4 presents evidence on the effects of government spending shocks on productivity and other labor market variables by age groups. Section 5 introduces the life-cycle model with learning-by-doing, its parametrization and describes the transmission mechanism. Finally, Section 6 concludes.

2 Related Literature

The effects of fiscal policy shocks on households' consumption are still debated, as mainstream theoretical models make different predictions and empirical evidence is mixed.[5] This paper contributes to this debate by complementing other studies which analyze the effects of government spending shocks at the household level.[6] These papers typically document important heterogeneity in consumption responses to fiscal policy shocks across groups of households with different characteristics, such as income, age and wealth. The most prominent explanation is the presence of liquidity

[5] See Ramey (2016) for a survey of the literature.

[6] See, e.g., Johnson et al. (2006), De Giorgi and Gambetti (2012), Agarwal and Qian (2014), Jappelli and Pistaferri (2014), Misra and Surico (2014), Anderson et al. (2016), Cloyne and Surico (2016), Baugh et al. (2018), Ferriere and Navarro (2018), Zidar (2019).

constraints. Financially constrained households behave in a non-Ricardian fashion as their consumption depends on their current disposable income, while unconstrained households base their consumption decisions on their lifetime resources.[7] As a result, the former tend to increase their consumption after a government spending shock that raises labor income, while the latter reduce it due to ensuing higher taxes. In this paper I instead document that age is a key determinant of households' adjustment to these shocks. In particular, my results suggest that after controlling for age, financial constraints account for limited heterogeneity in consumption responses to changes in government expenditure. Furthermore, I extend my analysis to variables which have received less attention in this literature, notably labor market variables.

This paper also adds to the literature that studies the role of demographics for the transmission of fiscal policy and how it affects aggregate outcomes.[8] Basso and Rachedi (2019) exploit the heterogeneity in age structure across U.S. states to estimate the effects of government spending shocks on output and employment and how they depend on demographics. They find that higher local fiscal multipliers are associated with a higher share of young people in total population. My results, based both on micro and macro data, are broadly in line with this finding. The authors emphasize the role of credit constraints and capital-experience complementarity in explaining the link between demographics and fiscal multipliers. In this paper, I provide an alternative rationale based on the different dynamics of human capital accumulation along the life-cycle and document the importance of this channel in shaping heterogeneous outcomes in response to government spending shocks. In particular, I argue that the evolution of skill accumulation over the life-cycle is able to generate age-specific differences in labor demand, similar to capital-experience complementarity as shown in Jaimovich et al. (2013).

Lastly, this paper relates to the strand of literature which studies the interaction between fiscal policy and productivity.[9] Most of these papers document a positive response of TFP or labor productivity after an increase in government spending. A potential explanation for this finding, studied in d'Alessandro et al. (2019), is that a

[7]See, e.g., Heathcote (2005), Galí et al. (2007), Kaplan and Violante (2014), Kaplan et al. (2018) for theoretical contributions.

[8]See, e.g., Fiori et al. (2016), Janiak and Monteiro (2016), Basso and Rachedi (2019) for recent contributions.

[9]See, e.g., Evans (1992), Ramey (2011), Bachmann and Sims (2012), Aghion et al. (2014), Ben Zeev and Pappa (2015), Jørgensen and Ravn (2018), d'Alessandro et al. (2019).

government spending shock induces an increase in hours worked leading to future human capital improvement. The authors build a New Keynesian model with a learning-by-doing mechanism as originally proposed by Chang et al. (2002) in a real business cycle framework. They show that it can generate an increase in real wages, TFP and consumption in response to a government spending shock. In this paper I provide evidence of the importance of demographics in the transmission of government spending shocks to productivity. Specifically, my results suggest that the increase in productivity in response to fiscal shocks is driven by young workers. The model I develop features a similar skill accumulation mechanism, but I emphasize its age-dependence and introduce it within a heterogeneous agents framework with a life-cycle structure. I show that this transmission channel also leads to important redistributive effects of government spending which cannot be captured in an economy without heterogeneity.

3 Heterogeneous Effects on Consumption: Age Matters

In this section, I explore the heterogeneous effects of government spending shocks on consumption using household-level data. First I group consumers by a single characteristic, such as age, income, or housing tenure. Then I refine the grouping strategy by splitting the sample further in order to jointly inspect the role of two characteristics. I document heterogeneity in consumption responses depending on age or financial constraints, in line with the literature. However, the bivariate heterogeneity analysis reveals that, after conditionning on age, financial constraints only account for little heterogeneity in consumption responses, in contrast to previous studies.

3.1 Data description

For government spending shocks, I use the forecast-based measure developped by Ramey (2011), based on the Survey of Professional Forecasters (SPF).[10] Government spending refers to government purchases, thus does not include transfer payments. Household level data on consumption and hours worked is from the Consumer

[10] As showed by Ramey (2011), this measure has good explanatory power for government spending over the time period considered.

Expenditure Survey (CEX) conducted by the Bureau of Labor Statistics (BLS). The empirical analysis covers the period from 1981Q4 to 2008Q4 with quarterly data.[11]

Government spending shocks

To identify government spending shocks, I follow Anderson et al. (2016) and use a measure based on the Survey of Professional Forecasters (SPF), constructed by Ramey (2011).[12] The shock is measured as the difference between the actual real government spending growth and the forecast of government spending growth made one quarter earlier.[13] Ramey (2011) shows these shocks have good explanatory power for government spending for the recent period considered in my analysis. Since professional forecasts implicitly contain a very rich information set, including anticipated changes in fiscal policy and other economic and policy variables, using this forecast error measure allows to control for all available information and anticipated future policy actions.[14] Thus it effectively deals with the issue of fiscal foresight, namely that most government spending is anticipated by economic agents prior to implementation. Another major advantage of this approach is that the shock is directly identified using information outside the VAR. Therefore the shocks are model-independent, they are unaffected by potential misspecifications of the VAR or by identification assumptions. This makes it particularly appealing for estimation techniques like local projections and distributed lag models, which require a series of previously identified structural shocks.[15]

[11]The starting date of the sample is determined by the availability of SPF data. The sample is restricted to 2008 to avoid nonlinearities caused by the Fed funds rate being constrained by the zero lower bound.

[12]Ramey (2011) first develops a narrative time series of estimates of changes in the expected present value of government defense spending, using information from articles in several newspaper sources such as the Business Week magazine. However, she finds that this defense news shock variable has very low predictive power if both WWII and the Korean War are excluded from the sample.

[13]Following Ramey (2011), the difference in the growth rates is preferred to the difference in the levels as the base year changed multiple times during the sample period.

[14]As showed in Coibion and Gorodnichenko (2012), although there appears to be more disagreement among households compared to other economic agents, their rate of information acquisition and processing is similar to the one of professional forecasters or firms, supporting that the forecasts from the SPF can be used as proxy for agents expectations about government spending.

[15]The shocks are plotted in Figure 9.

Household survey data

Household level data on consumption and hours worked is from the Interview portion of the Consumer Expenditure Survey (CEX) conducted by the Bureau of Labor Statistics (BLS). The survey records information on detailed categories of consumption expenditures over the preceding quarter for all households interviewed, as well as detailed demographic characteristics for all household members, and information on income and hours worked. The household is identified by its head. Hours worked correspond to weekly hours by the head of household. Nondurable consumption expenditures are measured in log of real per capita terms, and hours worked are measured in log terms.[16] All variables are seasonally adjusted by X-12 ARIMA. Given the short panel dimension of the dataset, I follow the strategy described in Deaton (1985) and use a grouping estimator to build pseudo-panels. This consists in aggregating individual observations into pseudo-cohorts of consumers with different characteristics and computing averages for each period. An advantage of this approach is that it attenuates the attrition problem and reduces measurement error since it aggregates across agents. I focus my analysis on the role of the following characteristics: age, defined by the age of the head of household, income level, where the measure used is household's income after taxes for the past 12 months, and housing tenure, used as proxy for households' debt position, as in Cloyne and Surico (2016). See Appendix A for more details on this dataset and the construction of the pseudo-cohorts.

3.2 Empirical Specification

To compute the responses to exogenous government spending shocks, I estimate the following VAR model where the shocks are explicitely treated as an exogenous variable, in line with the empirical literature which uses narrative measures of fiscal shocks.

$$X_{i,t} = \alpha_i + \beta_i \text{trend} + \gamma_i \text{qtrend} + A_i(L) X_{i,t-1} + B_i(L) u_t^G + \varepsilon_{i,t} \tag{1}$$

where $X_{i,t}$ is a vector of endogenous variables, α_i, β_i and γ_i control for a constant, a linear trend and a quadratic trend, $A_i(L)$ is a P-order lag polynomial, $B_i(L)$ and

[16] Household consumption expenditures data is divided by the number of family members and deflated by the nondurables price deflator.

$C_i(L)$ are (R+1)-order lag polynomials, i represents the group each household belongs to. The vector X_t includes the log of real government spending per capita, the log of real non-durable consumption per capita, as well as the three month Treasury bill rate and the average marginal income tax rate from Barro and Redlick (2011) to control for monetary policy shocks and tax shocks respectively. u_t^G denotes the series of SPF shocks. Finally, I assume that R=7 and P=2.[17] Standard errors are estimated using a wild bootstrap with 10,000 replications.

3.3 Results

In this subsection, I investigate the presence of heterogeneous effects of government spending shocks across different groups of consumers. I first examine the responses when households are grouped according to a single characteristic. Then I conduct a bivariate heterogeneity analysis to study the responses of consumption by income level or wealth, conditioning on age. I document that age is a key driver of the heterogeneity in consumption responses to government spending shocks. The young increase significantly their consumption, while the prime-aged are more negatively affected. My analysis suggests that this result is not primarily driven by financial constraints.

A large body of literature has strongly advocated an important role for income or wealth in understanding the effects of transitory fiscal shocks on consumption behavior.[18] Households who are credit constrained or lack access to financial markets have a high marginal propensity to consume out of transitory income changes, thus raise their consumption after a government spending shock that leads to an increase in wages. In contrast, unconstrained households behave in a Ricardian fashion, lowering their consumption as the net present value of their life-time resources decreases after the shock from the associated higher taxes. Figure 10, Figure 11, and Figure 12 display the responses to government spending shocks of households grouped according to their age, income level and their housing tenure respectively.[19] As can be observed, the responses are

[17]The results are robust to assuming longer lag structures.

[18]See, e.g., Johnson et al. (2006), Galí et al. (2007), De Giorgi and Gambetti (2012), Jappelli and Pistaferri (2014), Kaplan and Violante (2014), Misra and Surico (2014), Anderson et al. (2016), Cloyne and Surico (2016).

[19]As explained in Cloyne and Surico (2016), housing tenure status is an effective proxy for household debt position. It allows to distinguish between households with mortgage debt and those without (outright owners, renters). Specifically, the authors document that for nearly half of mortgagors, their net liquid wealth represents less than 50% of their monthly income, thus they appear far more likely to be liquidity

broadly in line with these predictions. Specifically, the prime-age group, highest income group and non-mortgagors behave in a Ricardian fashion lowering their consumption, while the young, lowest income group and mortgagors, more likely to be financially constrained, behave in a non-Ricardian fashion with positive consumption responses.

Next, I further investigate what drives the heterogeneity in consumption responses by splitting each age group by income level or by housing tenure.[20,21,22] Figure 24 displays the responses of consumption to a government spending shock for the young (first row) and the prime-aged (second row) grouped by their income level (Panel (a)) and by their housing tenure (Panel (b)), respectively. Regardless of being mortgagors or not, the young increase their consumption in response to a positive shock, while the prime-aged decrease or do not adjust their consumption. The same conclusion applies when analyzing the responses of age groups by level of income. The impulse responses of the ratio of consumption between young and prime-age groups split by housing tenure or income level, depicted in Figure 2, confirm that the young tend to adjust their consumption relatively more than prime-age consumers. Therefore households do not react in a homogeneous way by housing tenure or income level as can be inferred from the literature. In contrast, they rather react homogeneously by age group.

To inspect this further, I perform a descriptive analysis of income tertiles and housing tenure groups, with a focus on the age composition of each group. The distributions of age across housing tenure groups and income tertiles are plotted in Figure 13. Homeowners with mortgage are mainly young and working-age (25-55) while homeowners without mortgage are mainly over 55. The lowest income tertile consists mainly of young and old, while the highest tertile includes mainly working-age individuals (35-55). These statistics help explain the responses obtained when households are grouped depending on their housing tenure or their income level. For instance, positive consumption responses are found for the low income group and for renters, which are characterized by the largest share of young.[23] Similarly, negative consumption responses are found for the high income

constrained than outright owners.

[20]The average cell size for each group is documented in Table 1.

[21]For income level, I split households in two groups, depending on whether their after-tax income is below or above the 35th percentile. Results are robust to other income percentile splits.

[22]Given the limited number of observations per cell for young outright owners, I define a broad category of "non-mortgagors" which merges outright owners and renters. Results are robust to considering outright owners and renters separately, with less precise estimates for young outright owners.

[23]Households above 65, who represent the largest share of the low income group together with the young, increase their consumption as well in response to positive government spending shocks. The analysis of this group, mainly composed of retirees, is however outside the scope of this paper.

group which is characterized by the largest share of prime-age households. Furthermore, the response of consumption for mortgagors is not significant as it pools together young and prime-age households who adjust their consumption in opposite ways.

To sum up, I find substantial heterogeneity in consumption responses to government spending shocks across households with different characteristics. Consistent with existing literature, households more likely to be credit constrained tend to raise their consumption after a government spending shock, while unconstrained households tend to lower it. However, after conditioning on age, income or wealth provide less compelling explanations for the heterogeneity in consumption responses than age does. The young increase their consumption after a government spending shock while the prime-aged tend to decrease it, regardless of their income level or their housing tenure. Thus, in contrast with previous literature, my results suggest that age is a stronger predictor of significant heterogeneity in consumption responses to changes in government expenditure than traditional dimensions related to liquidity constraints. In the next section, I provide new evidence on a potential underlying transmission channel accounting for this heterogeneity.

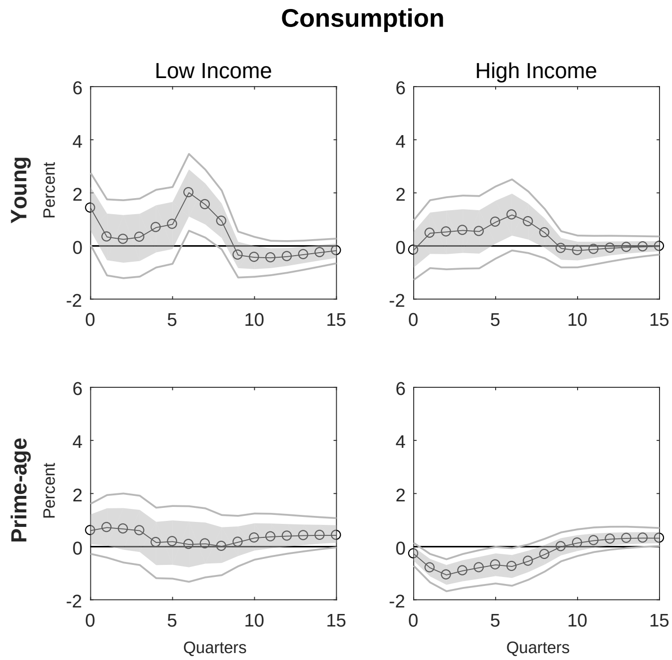
3.4 Robustness and Extensions

Previous results hold when considering other proxies for financial constraints, such as educational attainment and financial market participation. As proxy for financial market participation, I define a dummy variable that takes the value one for households that report non-zero financial wealth from savings accounts, stocks, bonds, mutual funds or other financial assets, and zero otherwise.[24] In addition, the results are also robust to using a broader definition of consumption that includes purchases of small durables, imputed services from vehicles, rents, imputed rents for home owners, mortgage payments, pensions, and cash contributions. I also considered restricting the sample to employed households, for which added hours worked of head and spouse are strictly positive. The results are similar. All related figures can be found in Appendix E.1.

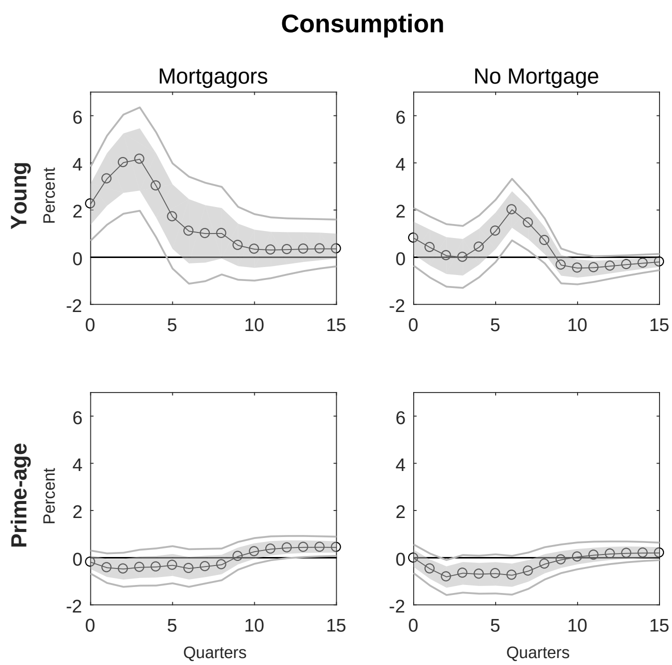
[24] Using non-zero income from financial assets instead of non-zero financial wealth leads to similar results.

Figure 1: Impulse responses to government spending shocks

(a) By age and income level



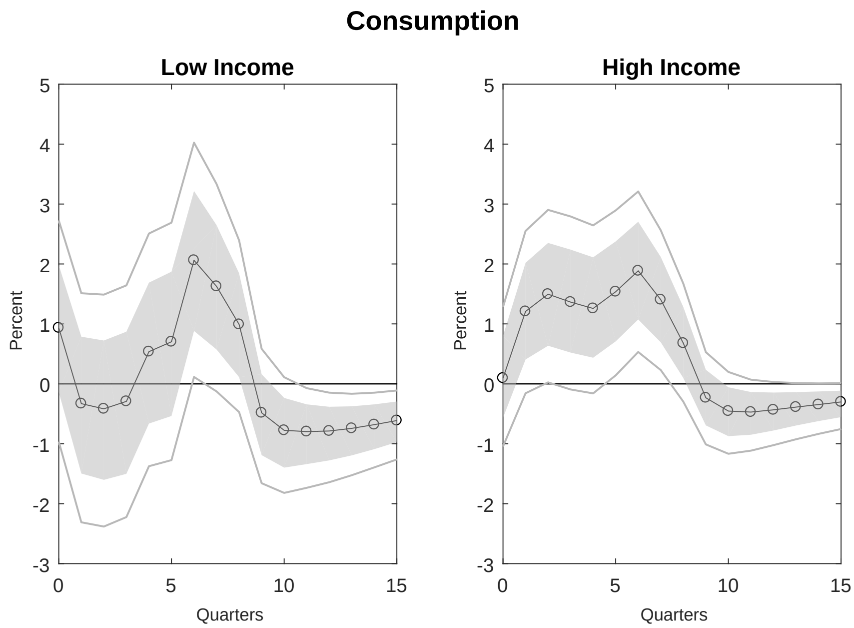
(b) By age and housing tenure



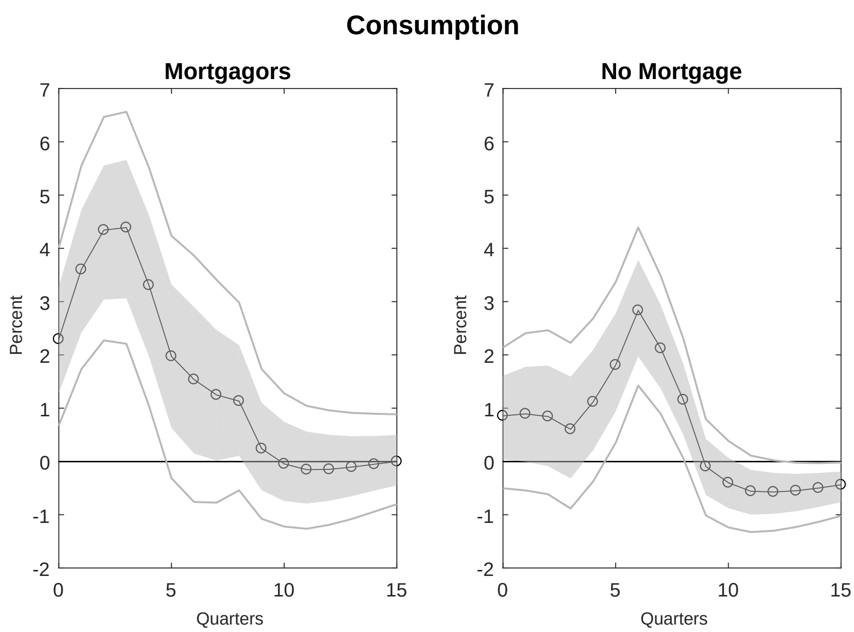
Notes: These graphs show the impulse responses of nondurable consumption for young and prime-age households by their income level in Panel (a) and by their housing tenure in Panel (b) to an exogenous government spending shock leading to an initial 1% increase in government expenditures. The impulse responses for the young (below 30) are depicted on the first row, for the prime-aged (30-64) on the second row. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 2: Impulse responses of consumption ratios between young and prime-age groups

(a) By income level



(b) By housing tenure



Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their income level in Panel (a) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

4 Towards a Human Capital Channel of Fiscal Policy: Some Evidence

In this section, I explore the role of human capital accumulation in shaping the heterogeneity in consumption responses to government spending shocks across the age dimension. I provide evidence both at the micro and at the macro level. In Section 4.1, I build age-specific measures of productivity using a wage-based approach which allows me to identify efficiency from labor income. These series are used to estimate the impulse responses of productivity to a spending shock for young and prime-age workers. In Section 4.2, I estimate the dynamic response of productivity using a structural vector autoregressive approach on a panel of countries split according to the share of young people in total population. Both analyses suggest that the impact of government spending shocks on productivity is age-dependent.

4.1 Micro-based Evidence

In this subsection I provide evidence that government spending shocks affects young and prime-age workers' productivity differently. My approach proceeds in two steps. First, I identify the number of supplied efficiency units from the real hourly wage for each age group. I use these efficiency time series as proxy for the productivity of workers. Then, I estimate the impact of government spending shocks on this measure of productivity for young and prime-age workers separately, using the same VAR approach and the same identification of shocks as in the previous section. I also use these efficiency series to build life-cycle productivity profiles for different cohorts.

To identify the number of efficiency units from the wage, I follow the wage-based approach of Bowlus and Robinson (2012), inspired by Ben-Porath (1967) model of optimal life-cycle production of human capital and its extensions.[25] As is standard in the human capital literature, the hourly wage can be defined as the product of a quantity of human capital, i.e. the number of supplied efficiency units, and its price, both unobservable. It is assumed that there are different "types" of human capital, associated with different education levels, implying different prices. At each period, the prices are assumed to

[25] Bowlus and Robinson (2012) extend Ben-Porath framework by incorporating two sources of cohort effects, namely selection on ability in education choices, as well as technological change.

be identical for all workers in a given education group, irrespectively of their age or experience. The key strategy to identify prices from observed wages, based on human capital theory, is that towards the end of working life, supplied efficiency units are constant. This implies that the change between two periods in the wage of workers on their "flat spot" only reflects changes in the price. This assumption offers a way to construct price series for each education group. Then, the worker's productivity can be calculated by dividing the real hourly wage by the price.

To construct the productivity series, I use individual-level data on wages for the United States from the Current Population Survey (CPS) for the period from 1979 to 2016.[26] I restrict the sample to full-time male workers, i.e. who usually work at least 35 hours a week.[27] Individuals pursuing studies, self-employed and individuals with zero or missing wage are also excluded from the sample. I consider two education levels: low-educated are defined as workers with at most a high-school degree, and high-educated as those with some college and above. I choose the flat spot age regions for high-educated to be 48-57, and for low-educated 44-53, which is in line with Bowlus and Robinson (2012).[28] Then, to build age-specific productivity series, I compute the average productivity across the two education levels for each age group, weighted by their share in this age group. Lastly, the impact of government spending shocks on productivity is estimated for young and prime-age groups using the same specification and for the same sample period as in the previous section. Specifically, the regression model is given by Equation (1), where the shocks are identified by the SPF measure, and the vector of endogenous variables includes the log of real government spending per capita, the log of measured productivity, the three month Treasury bill rate and the average marginal income tax rate. I further use these productivity series to build estimates of the life-cycle human capital profiles for different cohorts.[29]

Figure 3 plots the estimated impulse response functions of this productivity measure,

[26] Bowlus and Robinson (2012) use the annual March supplement of the Current Population Survey, available since 1964, which reports households' income earned during the previous calendar year. To build productivity series at a quarterly frequency, I use instead monthly data from the CPS Merged Outgoing Rotation Group, which is available from 1979.

[27] As explained in Bowlus and Robinson (2012), females have experienced considerable changes in their labor force participation, as well as fluctuating discrimination, which raises selection issues, in particular to appropriately identify their flat spot regions. They are thus exluded from the sample.

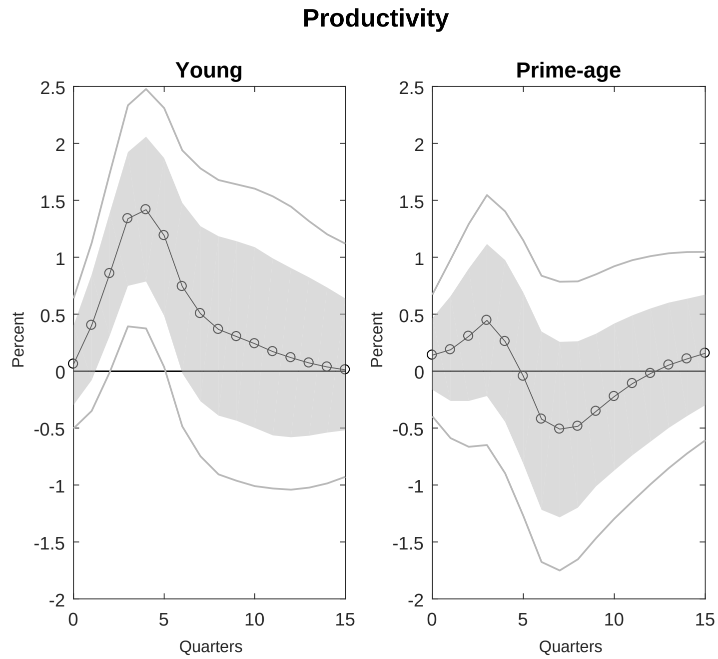
[28] Bowlus and Robinson (2012) consider four education levels, high-school dropouts, high-school graduates, some college and college graduates, with flat spot age ranges of 44-53, 46-55, 48-57 and 50-59 respectively.

[29] To build the life-cycle profile of productivity for different cohorts, I use CPS data over the period 1979-2016.

for young and prime-age workers, to a government spending shock. Productivity of the young significantly increases, with a peak of about 1.4% around 4 quarters after the shock. In contrast, the response for prime-age workers is not statistically different from zero. Thus, these results suggest that the young raise their skill level following a positive government spending shock. Results are robust to alternative specifications of the flat spot ranges (see Appendix E.2.1). Figure 4 depicts the life-cycle profile of productivity. As predicted by the Ben-Porath model, the profile is steep for young workers, then it gradually becomes flat for prime-age workers. Interestingly, the life-cycle profile is very similar across the different cohorts.

I further examine the effects on government spending shocks on wages and hours worked for young and prime-age agents. Still using CPS data, I build series of real hourly wages and hours worked per capita for young and prime-age groups, where individuals pursuing studies, self-employed and individuals with zero or missing wage are excluded from the sample. The impact of government spending shocks on these series is estimated using the same specification and for the same sample period as before. Impulse response functions of hours worked and hourly wages for young and prime-age workers can be found in Appendix C. They show that young wages increase significantly at 68% level, with hump-shaped pattern, while the response of the prime-age group is not statistically significant. In addition, hours worked strongly increase in the short-run for young people and, to a lesser extent, for the prime-aged. Figure 5 depicts the impulse response functions of the productivity, wage and hours worked ratios between young and prime-age groups. These estimates further confirm the greater responsiveness of productivity, wage and hours worked to positive government spending shocks for young workers.

Figure 3: Impulse responses of measured productivity to government spending shocks



Notes: These graphs show the impulse responses of measured productivity to a 1% shock to government expenditure for young and prime-age workers. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 4: Estimated productivity life-cycle profiles by cohort

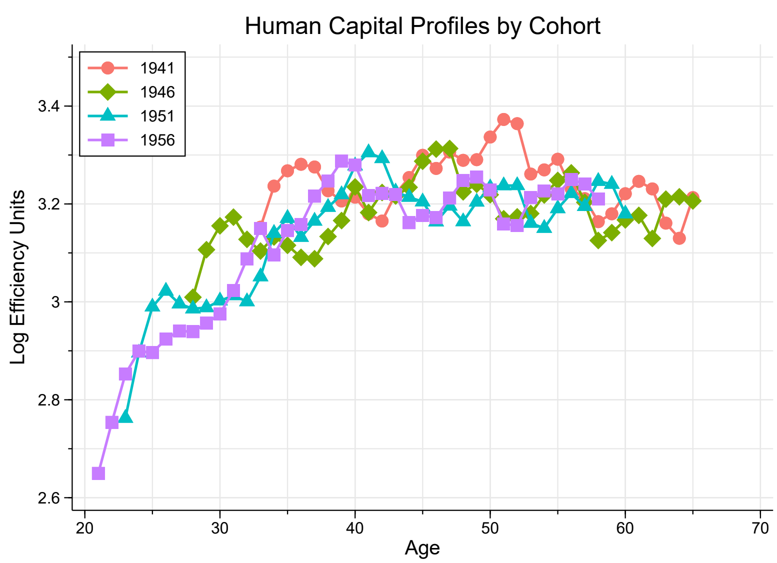
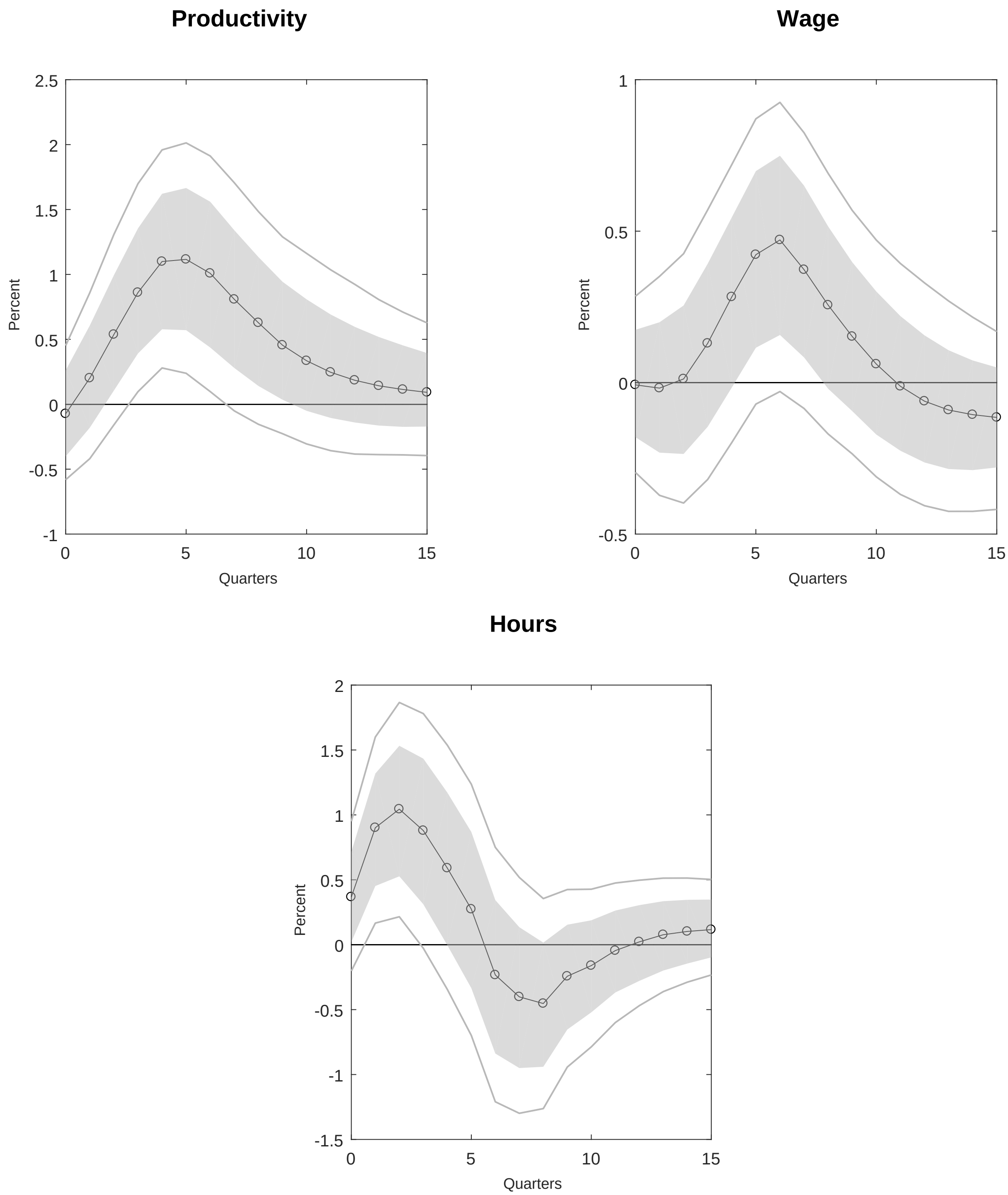


Figure 5: Impulse responses of productivity, wage and hours worked ratios to government spending shocks



Notes: These graphs show the impulse responses of the productivity ratio, the hourly wage ratio and the hours worked ratio between young and prime-age workers to a 1% shock to government expenditure. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

4.2 Macro-based Evidence

In this subsection, I provide further evidence on the effects of government spending shocks on productivity conditional on age using a structural vector autoregression approach for a panel of countries. For this analysis, I use the unique quarterly dataset compiled by Ilzetzki et al. (2013), covering government expenditure, output, consumption and other macroeconomic variables for 44 developing and developed countries from 1960 to 2007. I complement it with series on labor productivity and demographic data on the shares of young people (aged 15-29) in total population.[30] I estimate the following SVAR model:

$$AX_{j,t} = \sum_{k=1}^{K} C_k X_{j,t-k} + BU_{j,t} \quad (2)$$

where $Y_{j,t}$ is a vector of endogenous variables in country j at quarter t that consists of real government consumption expenditure, real GDP, real private consumption and labor productivity. Following Ilzetzki et al. (2013), government spending shocks are identified using Blanchard and Perotti (2002) identification strategy, and the model is estimated by panel OLS regression with fixed effects, with four lags included. This identification hinges on the assumption that there is no response of government spending to changes in other macroeconomic variables within a quarter due to decision and implementation lags.

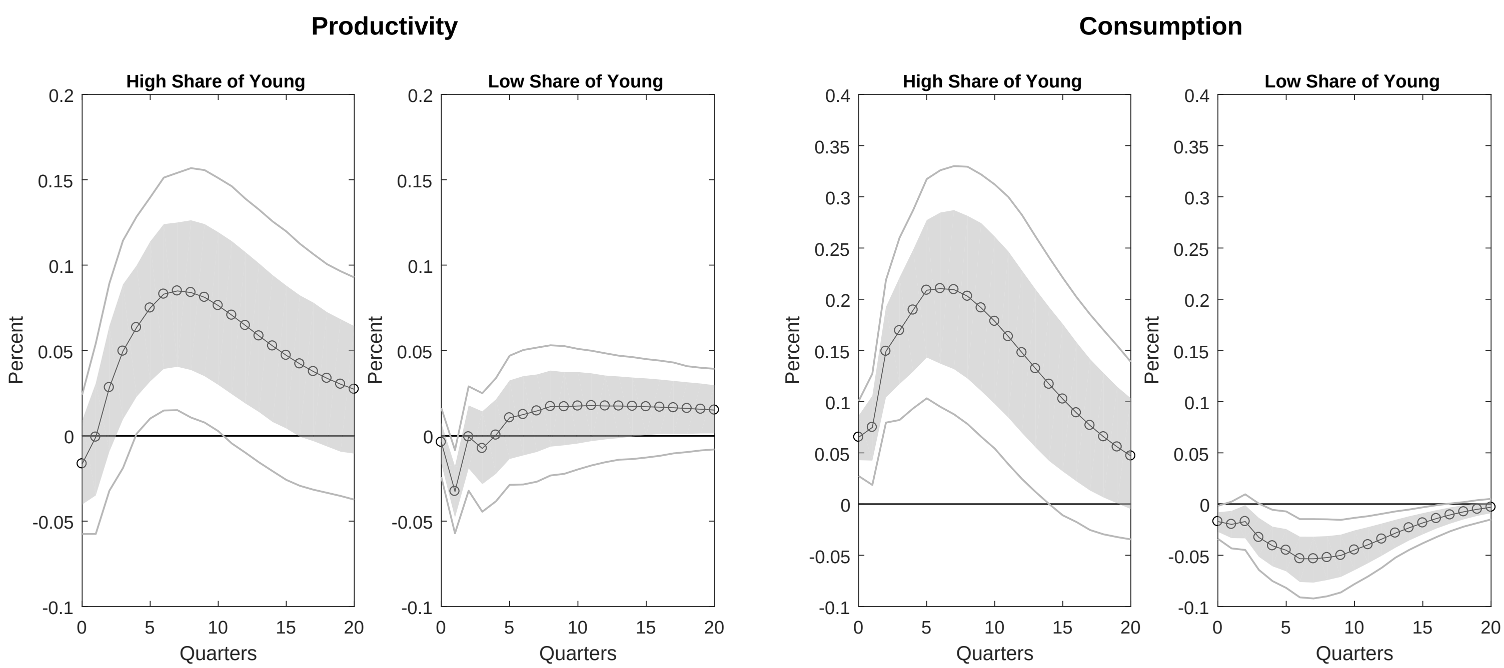
To inspect the role of demographics, I split the panel of countries in two groups, characterized by shares of young in total population above and below the sample mean. The VAR model is then estimated for the two groups separately in order to compare the impulse response functions of productivity and private consumption to government spending shocks in countries with high share of young and in those with low share of young.

As can be observed in Figure 6, countries with high share of young display very different responses of productivity and consumption to government spending shocks compared to countries with low share of young. Specifically, in the group of countries with high share of young, there is a strong and significant increase in both productivity and consumption after a positive shock in government spending. In contrast, in the group

[30] See Appendix A for more details on the data.

with low share of young, productivity remains virtually unchanged while consumption significantly drops after the shock. These results are in line with findings from the household level analysis reported in the previous subsection, confirming the importance of demographics in the transmission of government spending shocks to productivity and aggregate variables. Results are similar when the current account and the real exchange rate are included as controls (see Appendix E.2.2).

Figure 6: Impulse responses of productivity and consumption to government spending shocks in countries with high vs. low shares of young in total population



Notes: These graphs show the impulse responses of labor productivity (left panels) and private consumption (right panels) to a 1% shock to government consumption expenditure in countries with low share of young (aged 15-29) vs. high share of young in total population. 90% and 68% confidence intervals are shown in all cases.

5 A Life-Cycle Model with Learning-By-Doing

In this section, I build a New Keynesian DSGE model with a parsimonious life-cycle structure that rationalizes the empirical findings documented in Sections 3 and 4. The key feature is a learning-by-doing (LBD) mechanism which I introduce for young workers.

The model illustrates how different dynamics of human capital accumulation across the life-cycle after a fiscal stimulus lead to redistribution effects that differentially affect young and prime-age workers' incentives to consume.

5.1 Model

The model features a life-cycle structure in the spirit of Gertler (1999), where individuals face three stages of life: young, prime-age and retirement. Prime-age individuals cannot insure against retirement risk and retirees against longevity risk. The incompleteness of financial markets leads to life-cycle saving behavior, with prime-age workers accumulating assets to finance consumption during retirement. On the other hand, young agents borrow as they expect higher income when prime-aged. I further incorporate life-cycle human capital accumulation. Young workers accumulate skills on the job while prime-age workers have reached their highest level of efficiency which remains stable. To model skill accumulation, I specify a learning-by-doing mechanism as originally proposed by Chang et al. (2002) in a real business cycle model and adapted recently to a New Keynesian framework by d'Alessandro et al. (2019).

As is standard in the New Keynesian literature, the supply side of the economy consists of a continuum of firms under monopolistic competition facing staggered price setting à la Calvo. They produce differentiated intermediate goods that are used as inputs by a perfectly competitive firm to produce a final good for private and public consumption. Wages are set by representative unions for young and prime-age workers on segmented labor markets, subject to adjustment costs. The central bank sets the nominal interest rate following a standard Taylor rule. The Treasury finances its expenditures by issuing one-period bonds and collecting lump-sum taxes from young and prime-age individuals.

Aggregation is typically challenging in this type of heterogeneous agents models, notably because the wealth distribution responds endogenously to aggregate shocks. Gertler (1999) proposes a tractable overlapping generations setup which allows to derive closed-form aggregate consumption and savings functions while preserving life-cycle behavior. However, this framework requires the use of specific nonexpected utility preferences and the assumption of risk neutrality. To make the model more flexible, I incorporate a transfer to new young and to new prime-age agents that aims at removing heterogeneity in wealth among each age group. This strategy, motivated by evidence that heterogeneity in wealth plays a smaller role than age in the transmission of government spending shocks, allows in particular to incorporate wage rigidity and to specify standard preferences. Although there is no within-group heterogeneity in this model, heterogeneity across the age dimension, i.e. between-group, is preserved. The model can be solved with standard linearization methods, using the certainty equivalence property of the first order approximation.[31]

5.1.1 Households and Life-cycle Structure

The economy is populated by a continuum of households, who belong to three different age groups: young (y), prime-aged (p) and retiree (r). At each period, young agents face a constant probability of becoming prime-aged ω_p. Similarly, prime-age households face a constant probability of becoming retiree ω_r, and retirees face a time-invariant death probability ω_x. The population size is normalized to one and its composition remains constant over time.

The share of each age group in total population can be computed using the fact that the number of new prime-age agents is equal to the number of prime-age retiring, i.e. $\omega_p N_y = \omega_r N_p$, and the number of prime-age retiring is equal to the number of deaths in the economy, i.e. $\omega_r N_p = \omega_x N_r$, where N_y, N_p and N_r are the number of young, prime-aged and retirees, respectively. Therefore, denoting ν_y, ν_p and ν_r the shares of each age group, we get:

$$\begin{aligned} \nu_y &= \frac{1}{1 + \frac{\omega_p}{\omega_r} + \frac{\omega_p}{\omega_x}} \\ \nu_p &= \frac{1}{1 + \frac{\omega_r}{\omega_p} + \frac{\omega_r}{\omega_x}} \\ \nu_r &= 1 - \nu_y - \nu_p \end{aligned} \tag{3}$$

Individual i in age group j derives utility from consumption $C^i_{j,t}$ and disutility from hours worked $L_{j,t}$. In period t, this individual chooses consumption $C^i_{j,t}$ and asset holdings

[31] Details of the derivations are provided in Appendix G.

$A^i_{j,t+1}$ which solve the following optimization problem

$$\max \ V^i_{j,t} = \left(\log(C^i_{j,t}) - \chi_j \frac{{L^i_{j,t}}^{1+\varphi_j}}{1+\varphi_j} \mathbb{I}_{\{j=y,p\}} + \beta \mathbb{E}\left(V^i_{j',t+1}|j\right) \right)$$

s.t.

$$\begin{cases} P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} + W^i_{j,t} L^i_{j,t} - P_t \tau^i_{j,t} + \text{bq}^i_{j,t} + P_t {\tau^G_{NY,t}}^i & \text{if } j = \{y\} \\ P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} + W^i_{j,t} L^i_{j,t} - P_t \tau^i_{j,t} + (1-\tau_d)\text{div}^i_{j,t} + P_t {\tau^G_{NP,t}}^i & \text{if } j = \{p\} \\ P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} & \text{if } j = \{r\} \end{cases} \tag{4}$$

$$\begin{cases} A^i_{j,t+1} = (R_{n,t} + \zeta) B^i_{j,t} & \text{if } j = \{y\} \\ A^i_{j,t+1} = R_{n,t} B^i_{j,t} & \text{if } j = \{p, r\} \end{cases}$$

where β denotes the subjective discount factor, φ_j the inverse of the Frisch elasticity of labor supply, and χ_j the weight of the disutility of labor.

Households have access to bonds $B_{j,t}$ which yield a nominal return given by $R_{n,t}$, where $R_{n,t}$ is the gross nominal interest rate. To avoid overborrowing from young agents, it is assumed that they face a constant risk premium ζ. P_t is the price level. Young and prime-age individuals supply labor services to firms for a nominal wage $W_{j,t}$. Workers take wages and hours as given. Wages are fixed by unions, and hours worked are determined by intermediate goods firms' labor demand. Retirees have no labor income and consume only out of asset income. The wealth of deceased retirees is equally distributed as bequests $\text{bq}^i_{j,t}$ among young individuals. Prime-age agents earn nominal dividends $\text{div}_{j,t}$, taxed at proportional rate τ_d, from imperfectly competitive intermediate firms. Young and prime-age individuals pay the same amount of lump-sum taxes, i.e. $\tau^i_{y,t} = \tau^i_{p,t}$. Finally, the newborns and new prime-age individuals receive government transfers ${\tau^G_{NY,t}}^i$ and ${\tau^G_{NP,t}}^i$, respectively.[32]

5.1.2 Firms

The supply side of the economy is composed of a continuum of firms under monopolistic competition which produce differentiated intermediate goods, indexed by $z \in [0, 1]$, that are used as inputs by a perfectly competitive firm to produce a final good.

[32] As explained in Section 5.1.4, this assumption aims at making the model tractable.

Final goods firm. The production of final goods by the representative firm is given by

$$Y_t = \left(\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}} \tag{5}$$

where Y_t correspond to the quantity of the final good and $Y_t(z)$ to the quantity of intermediate good z at time t. ϵ denotes the elasticity of substitution across varieties.

Profit maximization under perfect competition yields the following set of demand schedules for intermediate goods and zero-profit condition

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\epsilon} Y_t \tag{6a}$$

$$P_t = \left(\int_0^1 P_t(z)^{1-\epsilon} dz \right)^{\frac{1}{1-\epsilon}} \tag{6b}$$

where $P_t(z)$ and P_t denote the price of intermediate good z and the price of the final good, respectively.

Intermediate goods firms. Each intermediate goods firm produces good z with a technology that is linear in labor

$$Y_t(z) = L_t(z) \tag{7}$$

Each firm hires both young and prime-age workers, aggregated into a labor input index $L_t(z)$ using CES technology.

$$L_t(z) = \left(\nu_y (X_{y,t} L_{y,t}(z))^{\frac{\eta-1}{\eta}} + \nu_p (X_{p,t} L_{p,t}(z))^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{8a}$$

$$L_{y,t}(z) = \left(\frac{1}{\nu_y} \int_0^{\nu_y} L_{y,t}(z,k)^{\frac{\varepsilon_w-1}{\varepsilon_w}} dk \right)^{\frac{\varepsilon_w}{\varepsilon_w-1}} \tag{8b}$$

$$L_{p,t}(z) = \left(\frac{1}{\nu_p} \int_{\nu_y}^{\nu_y+\nu_p} L_{p,t}(z,k)^{\frac{\varepsilon_w-1}{\varepsilon_w}} dk \right)^{\frac{\varepsilon_w}{\varepsilon_w-1}} \tag{8c}$$

where η denotes the elasticity of substitution between young and prime-age labor inputs, and ε_w the elasticity of substitution between different varieties of labor.[33] $X_{y,t}$ and $X_{p,t}$ correspond to the skill level of young and prime-age workers, respectively. $L_{y,t}(z)$ is the quantity of young labor hired by the firm to produce good z, and $L_{y,t}(z,k)$ is the quantity

[33] For $\eta = 0$, the two labor inputs are perfect complements. $\eta = 1$ corresponds to the Cobb-Douglas case. As $\eta \to \infty$, the two labor inputs become perfect substitutes.

of young labor of variety k. The same notation holds for prime-age workers. The skill level of young workers $X_{y,t}$, i.e. their productivity, evolves according to a learning-by-doing mechanism as proposed by Chang et al. (2002). Hours worked in a given period induce an increase in skills in the next period, with an elasticity μ, which persists over time at rate ϕ. On the other hand, prime-age agents are assumed to have reached their maximum level of efficiency which remains stable. Following d'Alessandro et al. (2019), firms take productivity levels as given.

$$X_{y,t} = X_{y,t-1}^{\phi} L_{y,t-1}^{\mu} \tag{9a}$$

$$X_{p,t} = X_{p,t-1} \tag{9b}$$

Each firm minimizes costs taking nominal wages $W_{y,t}(k)$ and $W_{p,t}(k)$ as given, which leads to the following set of demand schedules for young and prime-age labor inputs

$$L_{j,t}(z,k) = \left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w} L_{j,t}(z) \qquad \text{for} \quad j \in \{y,p\} \tag{10}$$

where the wage indexes for young and prime-age workers are given by

$$W_{y,t} = \left(\frac{1}{\nu_y}\int_0^{\nu_y} W_{y,t}(k)^{1-\varepsilon_w} dk\right)^{\frac{1}{1-\varepsilon_w}} \tag{11a}$$

$$W_{p,t} = \left(\frac{1}{\nu_p}\int_{\nu_y}^{\nu_y+\nu_p} W_{p,t}(k)^{1-\varepsilon_w} dk\right)^{\frac{1}{1-\varepsilon_w}} \tag{11b}$$

Finally, taking the wage indexes $W_{y,t}$ and $W_{p,t}$ as given, each firm minimizes labor costs subject to Equation (8a). The optimality conditions with respect to $L_{y,t}(z)$ and $L_{p,t}(z)$ yield

$$MC_t = \left(\nu_y\left(\frac{W_{y,t}}{X_{y,t}}\right)^{1-\eta} + \nu_p\left(\frac{W_{p,t}}{X_{p,t}}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{12a}$$

$$\frac{L_{y,t}}{L_{p,t}} = \left(\frac{W_{y,t}}{W_{p,t}}\right)^{-\eta}\left(\frac{X_{y,t}}{X_{p,t}}\right)^{\eta-1} \tag{12b}$$

where MC_t is the nominal marginal cost.

Intermediate goods firms face staggered price setting à la Calvo. Each period, only a fraction $1-\theta_p$ of them are able to reset their prices. These firms maximize expected discounted real profits with respect to prices

$$\max_{P_t^*(z)} \mathbb{E}_t \left(\sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} \left[P_t^*(z) - MC_{t+s} \right] Y_{t+s}(z) \right) \tag{13}$$

subject to the final goods firm's demand constraint Equation (6a) for each variety z. $Q_{t,t+s}$ corresponds to the stochastic discount factor of prime-age agents between period t and $t+s$. This optimization problem implies that the optimal reset price and the dynamics of the aggregate price level are given by

$$P_t^*(z) = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} P_{t+s}^{\epsilon-1} Y_{t+s}(z) MC_{t+s}}{\mathbb{E}_t \sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} P_{t+s}^{\epsilon-1} Y_{t+s}(z)} \tag{14a}$$

$$P_t = \left((1-\theta_p) P_t^*(z)^{1-\epsilon} + \theta_p P_{t-1}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} \tag{14b}$$

5.1.3 Unions

To model wage stickiness, I follow the literature and assume that wages are set by unions. These unions act as monopolistic suppliers of differentiated labor services provided by workers. These labor services are bundled into a composite labor input by intermediate goods firms as specified in Section 5.1.2. To allow young and prime-age workers to get different wages, it is assumed that labor markets are segmented, so that there is one union for young workers and one for prime-age workers.

Each type of union chooses the nominal wage $W_{j,t}$ for an effective unit of labor so that $W_{j,t}(k) = W_{j,t}$ for all varieties k of workers, with $j \in \{y, p\}$, to maximize profits taking into account its members' utility and some wage adjustment costs, subject to the labor demand function for the workers it represents. The profits correspond to the difference between the wage income and the disutility of work, where $\lambda_{j,t}$ denotes the marginal utility of consumption. The wage adjustment cost is proportional to the total wage bill and is a quadratic function of the change in wages decided by the union, similar to Rotemberg (1982) for prices.[34] The adjustment cost parameter θ_w is the same for

[34] Another way to model wage stickiness would be to assume that the union is able to reset its wage rate at each period with probability $1 - \theta_w$, similar to Calvo (1983). In the case of a Calvo type of friction, the wage setting problem of the union would imply maximizing the present value of its members expected lifetime utility, which makes it difficult to adapt to this life-cycle setup. Consequently, the Rotemberg adjustment-cost version is preferred here.

young and prime-age workers.

$$V_t^{w_j}(W_{j,t-1}(k)) = \max_{W_{j,t}(k)} \int \left(\frac{W_{j,t}(k)}{P_t} L_{j,t}(k) - \chi_j \frac{L_{j,t}(k)^{i^{1+\varphi_j}}}{1+\varphi_j} \frac{1}{\lambda_{j,t}} \right) dk$$
$$- \int \frac{\theta_w}{2} \left(\frac{W_{j,t}(k)}{W_{j,t-1}(k)} - 1 \right)^2 \frac{W_{j,t}}{P_t} L_{j,t} dk + \beta \mathbb{E} V_{t+1}^{w_j}(W_{j,t}(k))$$

subject to

$$L_{j,t}(k) = \left(\frac{W_{j,t}(k)}{W_{j,t}} \right)^{-\varepsilon_w} L_{j,t} \qquad j \in \{y, p\}$$

Solving this wage setting problem gives the following wage inflation equation for each type of worker, where $MRS_{j,t}$ is the marginal rate of substitution and $\Pi_{j,t}^w \equiv \frac{W_{j,t}}{W_{j,t-1}}$ is the wage inflation rate.[35]

$$(1-\varepsilon_w)\frac{W_{j,t}}{P_t} = -\varepsilon_w MRS_{j,t} + \theta_w(\Pi_{j,t}^w - 1)\Pi_{j,t}^w \frac{W_{j,t}}{P_t} - \beta \mathbb{E}_t \theta_w (\Pi_{j,t+1}^w - 1)\Pi_{j,t+1}^w \frac{L_{j,t+1}}{L_{j,t}} \frac{W_{j,t+1}}{P_{t+1}} \qquad j \in \{y, p\} \tag{16}$$

I follow Hagedorn et al. (2019) and assume that the wage adjustment process does not lead to actual costs, so as to avoid distortions due to large fluctuations in these costs after a government spending shock.[36]

5.1.4 Fiscal Policy

The government purchases consumption goods G_t and makes transfers to new young and new prime-age agents. These expenditures are financed by issuing debt, which consists of one-period non-contingent bonds $B_{G,t}$ yielding a nominal gross interest rate $R_{n,t}$, and by collecting lump-sum taxes T_t from young and prime-age households, as well as taxes on dividends from prime-age households.

$$B_{G,t} = R_{n,t-1}B_{G,t-1} + P_t G_t - P_t T_t + P_t(\nu_y \omega_x \tau_{NY,t}^G + \nu_p \omega_p \tau_{NP,t}^G) - \tau_d \nu_p \mathrm{div}_t \tag{17}$$

[35] See details in Appendix G.

[36] As explained by Hagedorn et al. (2019), not making this assumption may lead to different results compared to using a price setting à la Calvo.

The government follows a fiscal rule which dictates the response of debt and taxes to a change in government expenditures. The parameters Φ_B and Φ_G determine the response of deficits to debt and the extent of deficit financing, respectively.

$$P_t T_t = \Phi_B B_{G,t} + \Phi_G P_t G_t \tag{18}$$

Government expenditures evolve exogenously and follow a first order autoregressive process.

$$G_t = \rho_G G_{t-1} + \varepsilon_{G,t} \tag{19}$$

Total transfers to the new young and new prime-age agents are given by $\nu_y \omega_x \tau^G_{NY,t}$ and $\nu_p \omega_p \tau^G_{NP,t}$ respectively. These transfers are introduced to make the model tractable. In particular, these transfers are aimed at removing inequality in wealth between new young and pre-existing young, as well as between new prime-aged and pre-existing prime-aged. This ensures that all young agents solve the same optimization problem, and similarly for all prime-age agents. Thus the groups of young and prime-age individuals can be reduced to a representative young agent and a representative prime-age agent. Note that this assumption removes heterogeneity among young individuals and among prime-age individuals, but it preserves heterogeneity across the life-cycle, and among retirees. The transfers are given by

$$\begin{aligned} P_t \tau^G_{NY,t} &= A_{y,t} \\ A_{y,t} + P_t \tau^G_{NP,t} &= A_{p,t} \end{aligned} \tag{20}$$

where $A_{y,t}$ and $A_{p,t}$ denote the average wealth among pre-existing young agents, and among pre-existing prime-age agents, respectively.

5.1.5 Monetary Policy

The nominal interest rate is set by the monetary authority and follows the Taylor rule

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\gamma} \left[\left(\frac{\Pi_t}{\Pi_{ss}}\right)^{\phi_\pi}\right]^{1-\gamma} \tag{21}$$

where R_{ss} stands for the steady-state gross nominal interest rate, Π_{ss} is the steady-state inflation. ϕ_π measure the reaction of monetary policy to current inflation. γ denotes the degree of interest rate smoothing.

5.1.6 Aggregation and Market Clearing

Aggregate assets of young individuals correspond to the sum of bequests left by deceased retirees and of the asset holdings of the fraction of young who do not become prime-aged. The laws of motion of assets held by prime-age and retired agents can be defined similarly.

$$A_{y,t} = (1-\omega_p)\left((R_{n,t-1}+\zeta)B_{y,t-1}\right) + \omega_x\left(R_{n,t-1}B_{r,t-1}\right) \tag{22a}$$

$$A_{p,t} = (1-\omega_r)\left(R_{n,t-1}B_{p,t-1}\right) + \omega_p\left((R_{n,t-1}+\zeta)B_{y,t-1}\right) \tag{22b}$$

$$A_{r,t} = (1-\omega_x)\left(R_{n,t-1}B_{r,t-1}\right) + \omega_r\left(R_{n,t-1}B_{p,t-1}\right) \tag{22c}$$

Similarly, the aggregate levels of skills of young and prime-age workers respectively follow the laws of motion

$$X_{y,t} = (1-\omega_p)\left(X^{\phi}_{y,t-1}L^{\mu}_{y,t-1}\right) + \omega_x X_{y,0} \tag{23a}$$

$$X_{p,t} = (1-\omega_r)X_{p,t-1} + \omega_p\xi_p X_{y,t-1} \tag{23b}$$

where $X_{y,0}$ is the initial level of skills of newborns, and ξ_p aims at replicating the life-cycle productivity profile.

Finally, total consumption is given by the sum of each age group's consumption, weighted by their respective share in total population, and similarly for total taxes. Markets for bonds and goods clear.[37]

$$C_t = \nu_y C_{y,t} + \nu_p C_{p,t} + \nu_r C_{r,t} \tag{24a}$$

$$T_t = \nu_y \tau_{y,t} + \nu_p \tau_{p,t} \tag{24b}$$

$$B_{G,t} = \nu_y B_{y,t} + \nu_p B_{p,t} + \nu_r B_{r,t} \tag{24c}$$

$$Y_t = C_t + G_t \tag{24d}$$

5.2 Calibration

In this section I discuss the parametrization of the model. One period corresponds to one quarter. Parameter values are summarized in Table 2.

[37] The goods market clearing condition is redundant by Walras' law.

Demographic structure. As in the empirical analysis, the young are defined as individuals aged between 15 and 29, and the prime-aged between 30 and 64. This implies a probability of transition from young to prime-age $\omega_p = 0.0167$ and a probability of retirement $\omega_r = 0.0071$. The probability of death for retirees is defined to match the average share of individuals aged 65 and above in total population over the sample, approximately 17%, which yields $\omega_x = 0.0243$.

Preferences. The disutility of labor of young and prime-age agents are fixed to match a fraction of hours worked in steady state of 0.4 for prime-age workers, and 0.35 for young workers. The value for young workers is obtained by multiplying steady hours of the prime-age by the relative employment rates of young and prime-age workers in the data.[38] The Frisch elasticities are set to $\psi_y = 0.5$ and $\psi_p = 0.5$, in line with conventional micro estimates.[39] The subjective discount factor is fixed to match an annualized interest rate at steady state of 2%, which leads to $\beta = 0.97$. The risk premium faced by young agents is calibrated to match the consumption ratio of prime-age relative to young in the data, which is approximately equal to 1.4.

Production. The elasticity of substitution across varieties and the price stickiness parameter are calibrated to standard values used in the New Keynesian literature. Specifically, the elasticity of substitution across varieties ϵ is set to 10, which implies a price markup of 10%. The price stickiness parameter is set to $\theta_p = 0.75$, which implies that firms can reset their prices once every 4 quarters. Following Erceg et al. (2000), the elasticity of substitution across labor types is fixed to $\epsilon_w = 4$, which implies a wage markup of 1/3. To calibrate the adjustment cost on wages, I set the slope of the wage Phillips curves to 0.0066, which is the benchmark value used in Schmitt-Grohé and Uribe (2006). This implies $\theta_w \approx 500$. As regards the elasticity of substitution between age groups, I choose $\eta = 5$, which is in line with estimates reported in micro empirical studies such as Welch (1979), Card and Lemieux (2001) or Ottaviano and Peri (2012).[40] The profits are fully taxed.

[38] The average employment rate of young and prime-age individuals is approximately 65% and 74% respectively over the sample period 1981-2007.

[39] See in particular Chetty et al. (2011) for a meta-analysis of existing micro and macro evidence on labor supply elasticities.

[40] Welch (1979) finds a value between 4.6 and 12.5 for the elasticity of substitution across experience groups. Card and Lemieux (2001) estimate the value of the elasticity of substitution between different age groups in the range of 4 to 6 for both low and high education workers. Estimates reported in Ottaviano and Peri (2012) imply values in the range of 3.2 to 7.7.

Learning-by-doing. The parameters of the LBD are obtained from Chang et al. (2002) who estimate them using PSID data and find $\phi = 0.797$ and $\mu = 0.111$. The parameter ξ_p in the aggregate law of motion of skills for prime-age workers is calibrated to match the wage ratio of prime-aged relative to young in the data, which is approximately equal to 1.4. The initial level of skills of newborn young $X_{y,0}$ is normalized to 0.5.

Fiscal and monetary policy. The government spending to output ratio is set to 0.2, consistent with the sample average. The parameters of the fiscal rule are set to $\Phi_G = 0.1$ and $\Phi_B = 0.33$, following Galí et al. (2007). The persistence of the fiscal shock is set to 0.8, as in Christiano et al. (2011). The parameters of the Taylor rule are set to $\rho = 0.85$ and $\phi_\pi = 2.4$, in line with Christiano et al. (2014).

5.3 Results

Figure 7 displays the impulse responses of key aggregate and disaggregate variables for young and prime-age workers to an expansionary government spending shock, both in the standard model without LBD (dashed black lines) and in the model with LBD (blue lines). Responses are measured in quarterly percent deviations from steady state values, except for the responses of inflation and interest rates which are measured as annualized percentage-point deviations from steady state.

Let's first consider the responses of aggregate variables (panel (a)). A positive government expenditure shock leads to a negative wealth effect as the present value of taxes paid by households increases to finance the fiscal expansion. This translates into a reduction of consumption and leisure which are normal goods. As prices are sticky, firms increase their production to meet higher demand since some of them cannot adjust their prices, hence an outward shift of the labor demand curve which raises real wages. In the standard model without LBD, productivity of workers is unresponsive to the shock, so the increase in real wages generates a surge of marginal costs. This in turn leads to higher inflation since it depends on current and expected future marginal costs.[41] The Central Bank responds by raising the nominal interest rate, which translates into higher real interest rates by the Taylor principle, encouraging households to postpone consumption. This intertemporal substitution effect thus amplifies the drop in consumption. In contrast, in the model with LBD, young workers raise their skill level as they work more, boosting

[41] This is a key implication of the New Keynesian Phillips Curve. Iterating forward this equation yields that current inflation is determined by the discounted sum of expected future real marginal costs.

the future productivity of the firms, which in turn dampens the increase in marginal costs. If wages are sticky enough, marginal costs can actually fall. This leads to a decrease in expected inflation, and through the monetary policy rule, to a decline in real interest rates which boosts consumption by intertemporal substitution. The increase in aggregate consumption and productivity, along with a reduction in inflation and the nominal interest rate, is in line with my estimates based on aggregate data, displayed in Appendix B, and with evidence reported notably in Jørgensen and Ravn (2018) and d'Alessandro et al. (2019).[42]

Turning to disaggregate variables (panel (b)), we can observe that the responses of aggregate variables mask substantial heterogeneity between young and prime-age groups in the model with LBD. In particular, the surge of aggregate consumption appears to be mainly driven by the increase in young individuals' consumption while prime-age agents tend to reduce it, in line with empirical results. In contrast, the standard model without LBD predicts a decrease in consumption for both age groups. In the model with LBD, the fiscal expansion operates not only through intertemporal substitution effects but also through redistribution effects which shift resources from prime-age individuals (and retirees) to young households. First, the decline in real interest rates favors borrowers but penalizes savers. As a consequence, the young increase borrowing, while prime-age agents, who rely heavily on interest income, incur losses on their financial assets. Second, heterogeneity in skill accumulation further induces redistribution effects through the impact on wages. Specifically, although prime-age workers are more productive, the relative productivity of young workers increases, through the LBD mechanism, as they supply more hours. However, their productivity growth in only partially reflected in the growth of their labor income due to wage stickiness, which implies that young workers become relatively more profitable for firms compared to prime-age workers. As a result, labor demand increases relatively more for young workers, which translates in stronger wage increases for those who primarily finance their consumption from labor income, compared to prime-age workers. Remarkably, the model with LBD generates hump-shaped responses for consumption, hours, wage and productivity for the young, in line with empirical evidence.

To sum up, young workers benefit from redistribution effects due to changes in interest rates and wages, as well as from intertemporal substitution effects, hence the surge of

[42]In addition, several other papers document a fall in inflation after a positive government spending shock, such as Fatás and Mihov (2001), Mountford and Uhlig (2009), Hall and Thapar (2018).

their consumption. However, for prime-age individuals, the negative redistribution effects generated by the fiscal expansion tend to offset the positive effect from intertemporal substitution, leading to a small reduction of their consumption.

5.4 Sensitivity Analysis

In this section I provide a sensitivity analysis of my findings with respect to some key parameters in the life-cycle model with LBD. All related figures are displayed in Appendix F.

First, it is worth noting that price and wage rigidities are critical in generating an increase in consumption for the young. Figure 28 shows the impulse responses to a government spending shock in the baseline case with nominal frictions, compared to the case with flexible price and wages. Without price rigidities, firms adjust prices and not quantities in response to a rise in government demand. This leads to a reduced increase in hours worked, and thus in productivity and wage growth for the young. Under flexible wages, the rise in productivity of young workers is fully reflected in the increase of their real wage, which implies a surge in marginal costs. In turn, inflation and real rates strongly increase, leading to a crowding-out of consumption.[43] However, as showed in Figure 29 and Figure 30, the response of consumption is still positive for the young when the degree of price rigidity falls to 0.4, or when the wage adjustment cost falls to 300.

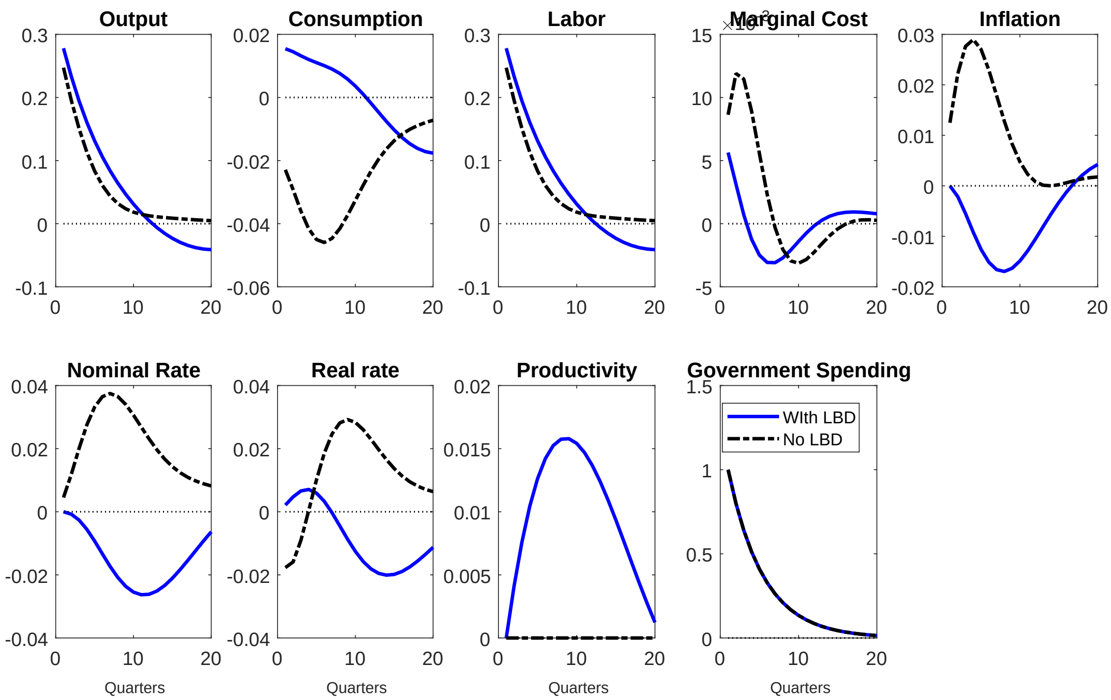
Figure 31 considers variations in the value of the Taylor rule inflation parameter ϕ_π. The stronger the response of the Central Bank to inflation, the larger the drop in the real interest rate. This reinforces the positive intertemporal substitution effect and, to a lesser extent, the redistribution effect from savers to borrowers. Therefore, as the Taylor rule inflation parameter increases, the response of consumption is larger for the young, and becomes less negative for the prime-age. In particular, the prime-age response becomes slightly positive on impact for values of ϕ_π greater than 1.5, although their response at 12 quarter horizon remains negative.

Figure 32 displays the responses of consumption for young and prime-aged at different horizons for different values of the persistence of the government spending shock. The young increase their consumption for values of the persistence ρ_G up to 0.9. For higher values, the negative wealth effect from higher taxes more than offsets the positive

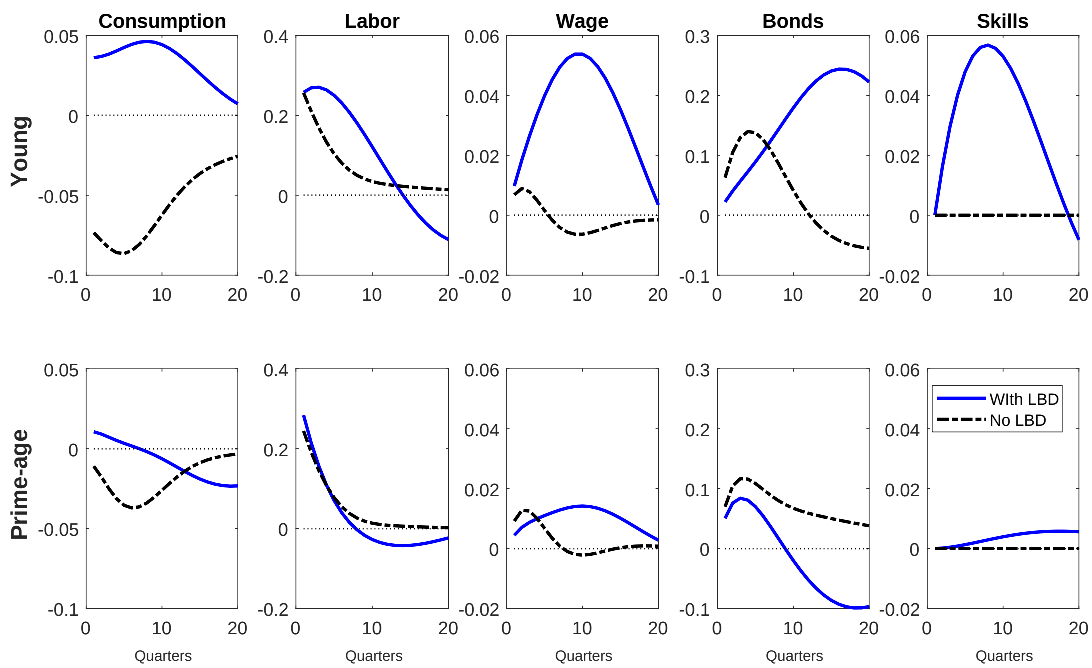
[43] Marginal costs and inflation are unchanged in the case of flexible prices.

Figure 7: Impulse responses of selected variables to an expansionary government spending shock in the life-cycle model with and without LBD

(a) IRFs of aggregate variables



(b) IRFs of disaggregate variables



Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD (blue solid lines) and without LBD (black dashed lines).

redistribution effect from higher wages and lower real interest rates. As a result, the young also reduce their consumption for high values of the persistence.

Figure 33 reports the sensitivity of consumption responses for young and prime-aged to the learning-by-doing parameters at different horizons. The figure shows that the consumption response of the young is positive for a reasonably large range of values, while it is broadly negative for the prime-aged. Note that in this life-cycle model the LBD mechanism does not lead to indeterminacy issues as in a representative agent model. Indeed, d'Alessandro et al. (2019) show that, if the LBD process is too strong, an increase in the nominal interest rate can lead to a rise in inflation due to the fall in productivity which pushes up marginal costs. As a result, inflation expectations become self-fulfilling. However, in this life-cycle model, this mechanism is not powerful enough to generate instability as only a fraction of the population is learning.

In the baseline analysis, it is assumed that young and prime-age workers have the same labor supply elasticity, in order to emphasize the importance of differences in skill accumulation over the life-cycle in shaping heterogeneous outcomes. Potential age differences in labor supply elasticity have received some attention in the litterature, in particular to partially account for the greater volatility of young hours relative to the prime-aged observed in the data.[44] Figure 34 thus considers variations in values of labor supply elasticity for young and prime-age workers. The figure shows that baseline results are preserved and reinforced when assuming higher labor supply elasticity for young individuals.

5.5 Discussion: Age vs. Financial Constraints

A key mechanism to generate asymmetric consumption responses of government spending shocks across agents is the introduction of "hand-to-mouth" agents, who fully consume their current disposable income. Galí et al. (2007) show that these households, who do not borrow or save due to a lack of access to financial markets or borrowing constraints, increase their consumption after a government spending shock in presence of price stickiness and under the assumption of imperfectly competitive labor market. Indeed, the surge in labor demand puts upward pressure on real wages, which stimulates consumption of these rule-of-thumb agents. Furlanetto (2011) shows that this result is

[44]See, e.g., Ríos-Rull (1996), Jaimovich et al. (2013), Janiak and Monteiro (2016). However, direct evidence that young workers have higher labor supply elasticity is scarce.

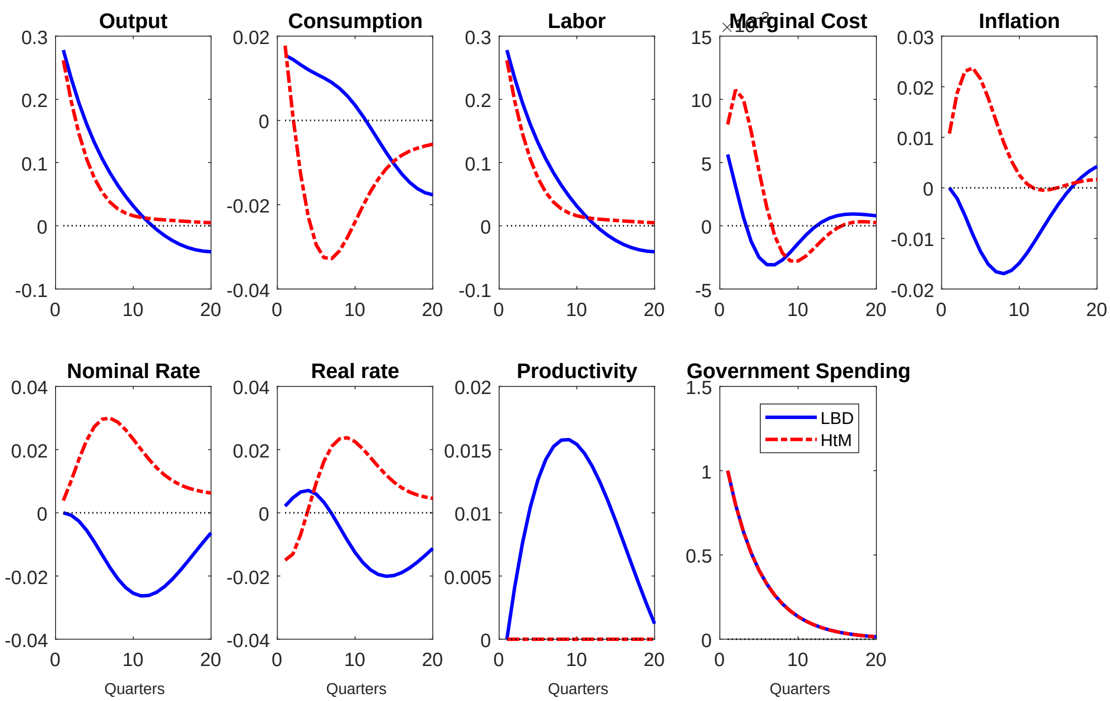
preserved and reinforced when assuming that wages are sticky. This theory could also justify why young agents, more likely to be financially constrained, tend to increase their consumption after a government spending shock.

I compare the predictions of the life-cycle model with LBD described in Section 5.1 to a life-cycle model where a share of young agents behave as hand-to-mouth. Figure 8 displays the impulse response functions of selected aggregate and disaggregate variables to a positive government spending shock in both models. The share of young hand-to-mouth is set equal to 0.5 in the model with financial constraints. At the aggregate level, both models predict an increase in labor, output and consumption. However, the model with financial constraints predicts an increase in marginal costs due to the surge in real wages which is not counteracted by a rise in productivity. This drives up expected inflation, to which the monetary authority reacts by raising interest rates. In contrast, in the model with LBD, the shift in government spending triggers an increase in TFP that puts downward pressure on marginal costs and inflation, leading instead to a reduction in the nominal interest rate, which is consistent with the existing evidence as discussed in Section 5.3.

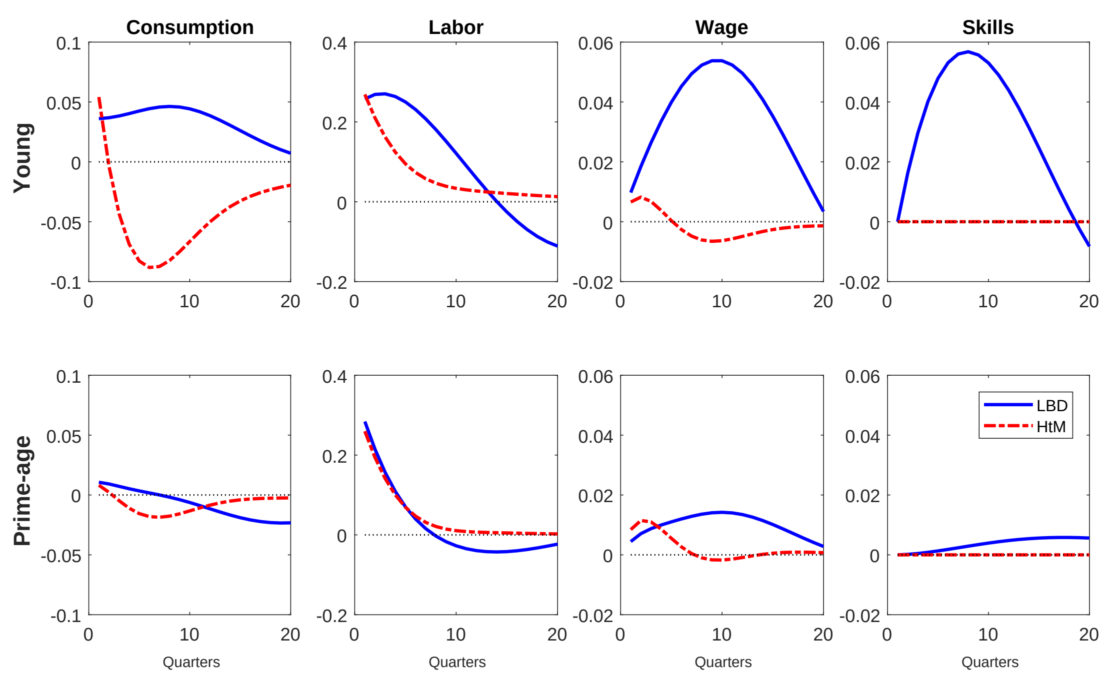
Turning to disaggregated variables, consumption strongly increases for young individuals in both models, while it remains flat or decreases for the prime-age. The increase in consumption for the young is more pronounced on impact in the model with financial constraints, but is less persistent as the response becomes negative after a couple of quarters. In addition, both models predict a similar increase in hours worked for young and prime-age workers, albeit more persistent for young individuals in the model with LBD. As pointed out by Furlanetto (2011), wage stickiness strongly reduces the heterogeneity in the adjustment of hours worked between Ricardian and hand-to-mouth agents. However, the models differ regarding the effects of a positive government spending shock on wages. The model with LBD predicts that wage growth for young agents is stronger than for the prime-age, reflecting the increase in skills, while the response of wages is nearly flat for both young and prime-age individuals in the model with financial constraints. As showed in Section 4.1, evidence suggests that the growth in real wages is more pronounced for young workers, as predicted by the model with LBD.

Figure 8: Impulse responses of selected variables to an expansionary government spending shock in the life-cycle model with LBD vs. with financial constraints

(a) IRFs of aggregate variables



(b) IRFs of disaggregate variables



Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD (blue solid lines) and with a share of Hand-to-Mouth young agents (red dashed lines).

This analysis suggests that the model with LBD manages to replicate qualitatively the age-specific effects of a fiscal expansion on labor market variables observed in the data, which a model with hand-to-mouth young does not capture. However, heterogeneity in skill accumulation and heterogeneity in marginal propensity to consume over the life-cycle likely interact. Quantifying the contribution of each of these channels in shaping these differential outcomes across age groups would likely yield interesting insights.

6 Conclusion

This paper provides a new perspective on the transmission of government spending shocks by uncovering a key interaction between fiscal policy, demographics and productivity. First, I present new evidence that age is a strong predictor of consumption adjustment to shifts in government expenditures. Young households increase their consumption after an unexpected increase in government spending, while prime-age households tend to reduce it. My analysis suggests that this result is not primarily driven by financial constraints.

The second contribution of this paper is to propose and study an alternative channel of fiscal policy transmission able to generate heterogeneous responses across age groups. Government spending enhances human capital accumulation, and thus affects more young agents who have a steep age-productivity profile. To illustrate the mechanism, I build a life-cycle New Keynesian model with learning-by-doing for young individuals. As a government spending shock stimulates hours, young workers accumulate skills faster than their prime-age counterparts. Relative labor demand for the young increases, boosting their wages. The rise in the productivity of the firm leads to a reduction in marginal costs and inflation, and thus in the real interest rate through the monetary policy rule. As a result, the fiscal stimulus tends to crowd in consumption via intertemporal substitution, but also generates redistribution effects which benefit the young. Specifically, consumption of the young is stimulated by lower real interest rates which encourage borrowing, and by higher labor income. Finally, I provide both micro- and macro-level evidence that corroborates this mechanism.

Given the accelerating demographic transition towards an older population in the U.S. and other developed countries, results in this paper indicate that fiscal stimulus measures could become increasingly less efficient in boosting the economy. On the other hand, policies which promote human capital formation may increase the effectiveness of fiscal policy, in particular if they are targeted at young individuals.

References

Agarwal, S. and W. Qian (2014). Consumption and debt response to unanticipated income shocks: Evidence from a natural experiment in singapore. *American Economic Review 104*(12), 4205–30.

Aghion, P., D. Hemous, and E. Kharroubi (2014). Cyclical fiscal policy, credit constraints, and industry growth. *Journal of Monetary Economics 62*, 41–58.

Aguiar, M. and M. Bils (2015). Has consumption inequality mirrored income inequality? *American Economic Review 105*(9), 2725–56.

Aguiar, M. and E. Hurst (2013). Deconstructing life cycle expenditure. *Journal of Political Economy 121*(3), 437–492.

Anderson, E., A. Inoue, and B. Rossi (2016). Heterogeneous consumers and fiscal policy shocks. *Journal of Money, Credit and Banking 48*(8), 1877–1888.

Bachmann, R. and E. R. Sims (2012). Confidence and the transmission of government spending shocks. *Journal of Monetary Economics 59*(3), 235–249.

Barro, R. J. and C. J. Redlick (2011). Macroeconomic effects from government purchases and taxes. *The Quarterly Journal of Economics 126*(1), 51–102.

Basso, H. and O. Rachedi (2019). The young, the old and the government: Demographics and fiscal multipliers. *Mimeo*.

Baugh, B., I. Ben-David, H. Park, and J. A. Parker (2018). Asymmetric consumption response of households to positive and negative anticipated cash flows. *NBER Working Paper No. 25086*.

Ben-Porath, Y. (1967). The production of human capital and the life cycle of earnings. *Journal of political economy 75*(4, Part 1), 352–365.

Ben Zeev, N. and E. Pappa (2015). Multipliers of unexpected increases in defense spending: An empirical investigation. *Journal of Economic Dynamics and Control 57*, 205–226.

Blanchard, O. and R. Perotti (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *The Quarterly Journal of Economics 117*(4), 1329–1368.

Bowlus, A. J. and C. Robinson (2012). Human capital prices, productivity, and growth. *American Economic Review 102*(7), 3483–3515.

Brinca, P., H. A. Holter, P. Krusell, and L. Malafry (2016). Fiscal multipliers in the 21st century. *Journal of Monetary Economics 77*, 53–69.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary Economics 12*(3), 383–398.

Card, D. and T. Lemieux (2001). Can falling supply explain the rising return to college for younger men? a cohort-based analysis. *The Quarterly Journal of Economics 116*(2), 705–746.

Chang, Y., J. F. Gomes, and F. Schorfheide (2002). Learning-by-doing as a propagation mechanism. *American Economic Review 92*(5), 1498–1520.

Chetty, R., A. Guren, D. Manoli, and A. Weber (2011). Are micro and macro labor supply elasticities consistent? a review of evidence on the intensive and extensive margins. *American Economic Review 101*(3), 471–75.

Christiano, L., M. Eichenbaum, and S. Rebelo (2011). When is the government spending multiplier large? *Journal of Political Economy 119*(1), 78–121.

Christiano, L. J., R. Motto, and M. Rostagno (2014). Risk shocks. *American Economic Review 104*(1), 27–65.

Cloyne, J. S. and P. Surico (2016). Household debt and the dynamic effects of income tax changes. *The Review of Economic Studies 84*(1), 45–81.

Coibion, O. and Y. Gorodnichenko (2012). What can survey forecasts tell us about information rigidities? *Journal of Political Economy 120*(1), 116–159.

d'Alessandro, A., G. Fella, and L. Melosi (2019). Fiscal stimulus with learning-by-doing. *International Economic Review 60*(3).

De Giorgi, G. and L. Gambetti (2012). The effects of government spending on the distribution of consumption. *Mimeo*.

Deaton, A. (1985). Panel data from time series of cross-sections. *Journal of econometrics 30*(1-2), 109–126.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics 46*(2), 281–313.

Evans, C. L. (1992). Productivity shocks and real business cycles. *Journal of Monetary Economics 29*(2), 191–208.

Fatás, A. and I. Mihov (2001). The effects of fiscal policy on consumption and employment: theory and evidence. *Mimeo*.

Ferriere, A. and G. Navarro (2018). The heterogeneous effects of government spending: It's all about taxes. *Mimeo*.

Fiori, G., D. Ferraro, et al. (2016). Aging of the baby boomers: Demographics and propagation of tax shocks. In *2016 Meeting Papers*, Number 359. Society for Economic Dynamics.

Fukao, K., R. Kambayashi, D. Kawaguchi, H. U. Kwon, Y. G. Kim, and I. Yokoyama (2006). Deferred compensation: evidence from employer-employee matched data from japan. *Hitotsubashi Institute of Economic Research*.

Furlanetto, F. (2011). Fiscal stimulus and the role of wage rigidity. *Journal of Economic Dynamics and Control 35*(4), 512–527.

Galí, J., J. D. López-Salido, and J. Vallés (2007). Understanding the effects of government spending on consumption. *Journal of the European Economic Association 5*(1), 227–270.

Gertler, M. (1999). Government debt and social security in a life-cycle economy. *Carnegie Rochester Conference Series on Public Policy 50*, 61–110.

Hagedorn, M., I. Manovskii, and K. Mitman (2019). The fiscal multiplier. *NBER Working Paper No. 25571*.

Hall, M. and A. Thapar (2018). The economic effects of government spending: The importance of controlling for anticipated information. *Mimeo*.

Heathcote, J. (2005). Fiscal policy with heterogeneous agents and incomplete markets. *The Review of Economic Studies 72*(1), 161–188.

Hellerstein, J. K. and D. Neumark (1995). Are earnings profiles steeper than productivity profiles? evidence from israeli firm-level data. *Journal of human resources*, 89–112.

Hellerstein, J. K. and D. Neumark (2007). Production function and wage equation estimation with heterogeneous labor: Evidence from a new matched employer-employee data set. In *Hard-to-measure goods and services: Essays in honor of Zvi Griliches*, pp. 31–71. University of Chicago Press.

Hellerstein, J. K., D. Neumark, and K. R. Troske (1999). Wages, productivity, and worker characteristics: Evidence from plant-level production functions and wage equations. *Journal of labor economics 17*(3), 409–446.

Ilzetzki, E., E. G. Mendoza, and C. A. Végh (2013). How big (small?) are fiscal multipliers? *Journal of monetary economics 60*(2), 239–254.

Jaimovich, N., S. Pruitt, and H. E. Siu (2013). The demand for youth: explaining age differences in the volatility of hours. *American Economic Review 103*(7), 3022–44.

Janiak, A. and P. S. Monteiro (2016). Towards a quantitative theory of automatic stabilizers: the role of demographics. *Journal of Monetary Economics 78*, 35–49.

Jappelli, T. and L. Pistaferri (2014). Fiscal policy and mpc heterogeneity. *American Economic Journal: Macroeconomics 6*(4), 107–36.

Johnson, D. S., J. A. Parker, and N. S. Souleles (2006). Household expenditure and the income tax rebates of 2001. *American Economic Review 96*(5), 1589–1610.

Jørgensen, P. L. and S. H. Ravn (2018). The inflation response to government spending shocks: A fiscal price puzzle? *Københavns Universitet*.

Kaplan, G., B. Moll, and G. L. Violante (2018). Monetary policy according to HANK. *American Economic Review 108*(3), 697–743.

Kaplan, G. and G. L. Violante (2014). A model of the consumption response to fiscal stimulus payments. *Econometrica 82*(4), 1199–1239.

Krueger, D. and F. Perri (2006). Does income inequality lead to consumption inequality? evidence and theory. *The Review of Economic Studies 73*(1), 163–193.

Lusardi, A. (1996). Permanent income, current income, and consumption: Evidence from two panel data sets. *Journal of Business & Economic Statistics 14*(1), 81–90.

Mertens, K. and J. L. Montiel Olea (2018). Marginal tax rates and income: New time series evidence. *The Quarterly Journal of Economics 133*(4), 1803–1884.

Misra, K. and P. Surico (2014). Consumption, income changes, and heterogeneity: Evidence from two fiscal stimulus programs. *American Economic Journal: Macroeconomics 6*(4), 84–106.

Mountford, A. and H. Uhlig (2009). What are the effects of fiscal policy shocks? *Journal of applied econometrics 24*(6), 960–992.

Ottaviano, G. I. and G. Peri (2012). Rethinking the effect of immigration on wages. *Journal of the European economic association 10*(1), 152–197.

Ramey, V. A. (2011). Identifying government spending shocks: it's all in the timing. *The Quarterly Journal of Economics 126*(1), 1–50.

Ramey, V. A. (2016). Macroeconomic shocks and their propagation. In *Handbook of Macroeconomics*, Volume 2, pp. 71–162. Elsevier.

Ríos-Rull, J.-V. (1996). Life-cycle economies and aggregate fluctuations. *The Review of Economic Studies 63*(3), 465–489.

Rotemberg, J. J. (1982). Sticky prices in the united states. *Journal of Political Economy 90*(6), 1187–1211.

Schmitt-Grohé, S. and M. Uribe (2004). Solving dynamic general equilibrium models using a second-order approximation to the policy function. *Journal of Economic Dynamics and Control 28*(4), 755–775.

Schmitt-Grohé, S. and M. Uribe (2006). Comparing two variants of calvo-type wage stickiness. *NBER Working Paper No. 12740*.

Welch, F. (1979). Effects of cohort size on earnings: The baby boom babies' financial bust. *Journal of Political Economy 87*(5, Part 2), S65–S97.

Zidar, O. M. (2019). Tax cuts for whom? heterogeneous effects of income tax changes on growth and employment. *Journal of Political Economy (forthcoming).*

Tables

Table 1: Average Cell Size by Groups - CEX dataset

Age	***15-29***	***30-64***	
	764.0	2933.5	
Housing tenure	***Mortgagors***	***Outright Owners***	***Tenants***
	1752.9	774.6	1510.4
Income level	***Low***	***High***	
	1387.5	2773.6	
Education	***Low***	***High***	
	1939.6	2221.5	
Financial market participation	***Limited***	***Not limited***	
	2863.8	1235.8	
Age and housing tenure	***15-29***	***30-64***	
Mortgagors	151.4	1516.5	
No mortgage	588.6	1331.1	
Age and income	***15-29***	***30-64***	
Low	387.1	714.6	
High	376.9	2218.8	
Age and education	***15-29***	***30-64***	
Low	304.5	1260.1	
High	459.5	1673.4	
Age and financial market participation	***15-29***	***30-64***	
Low	578.5	2002.6	
High	175.8	887.7	

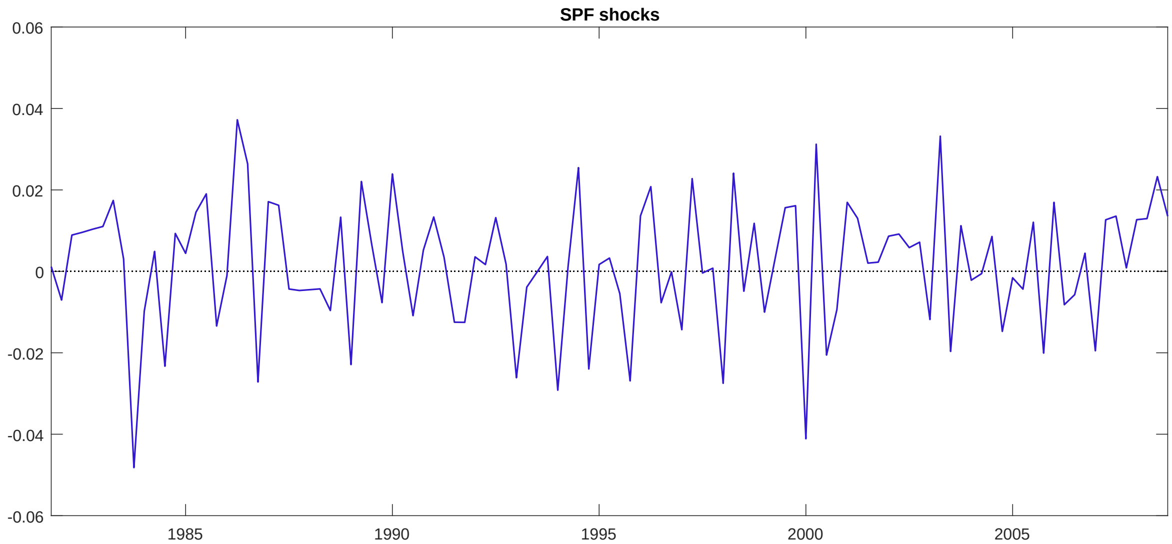
Notes: This table reports the average cell size for each group of consumers in the CEX dataset, where the cell size refers to the number of households used to make one quarterly observation.

Table 2: Calibration values

Parameter	Value	Description	Target/Source
β	0.97	Discount factor	Annualized interest rate 2%
ω_p	0.0167	Probability of becoming prime-age	Young for 15 years
ω_r	0.0071	Probability of retirement	Prime-age for 35 years
ω_x	0.0243	Probability of death	Share of 65+ in population
ϵ	10	Elasticity of substitution across varieties	Price mark-up of 10%
θ_p	0.75	Probability of fixed price	Average duration 4 quarters
ζ	0.035	Risk premium for young	Consumption ratio prime-age/young
ϕ	0.111	LBD: coefficient of hours impact	Chang et al. (2002)
μ	0.797	LBD: coefficient of auto-correlation	Chang et al. (2002)
ξ_p	0.6	Efficiency parameter of prime-aged	Wage ratio prime-age/young
$X_{y,0}$	0.5	Initial level of skills	Normalization
φ_y	0.45	Frisch elasticity of labor supply for young	Chetty et al. (2011)
φ_p	0.45	Frisch elasticity of labor supply for prime-age	Chetty et al. (2011)
χ_y		Disutility of labor for young	Fraction of hours worked 0.35
χ_p		Disutility of labor for prime-age	Fraction of hours worked 0.4
θ_w	500	Adjustment cost of wages parameter	Slope Phillips curve 0.006
ε_w	4	Elasticity of substitution across labor types	Erceg et al. (2000)
η	5	Elasticity of substitution between young and prime-age	Ottaviano and Peri (2012)
g_Y	0.2	Government spending to output ratio	Sample average
Φ_G	0.1	Degree of deficit financing	Galí et al. (2007)
Φ_B	0.33	Response of deficits to debt	Galí et al. (2007)
ρ_G	0.8	Persistence of government spending shock	Christiano et al. (2011)
ρ	0.85	Taylor rule: interest smoothing parameter	Christiano et al. (2014)
Φ_π	2.4	Taylor rule: coefficient of inflation	Christiano et al. (2014)

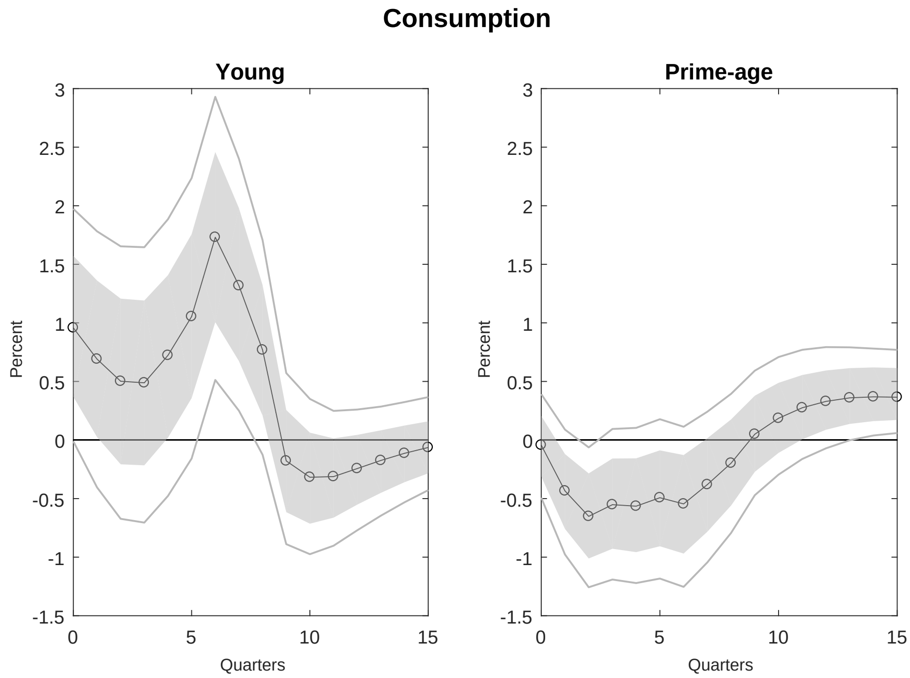
Figures

Figure 9: Government spending shocks



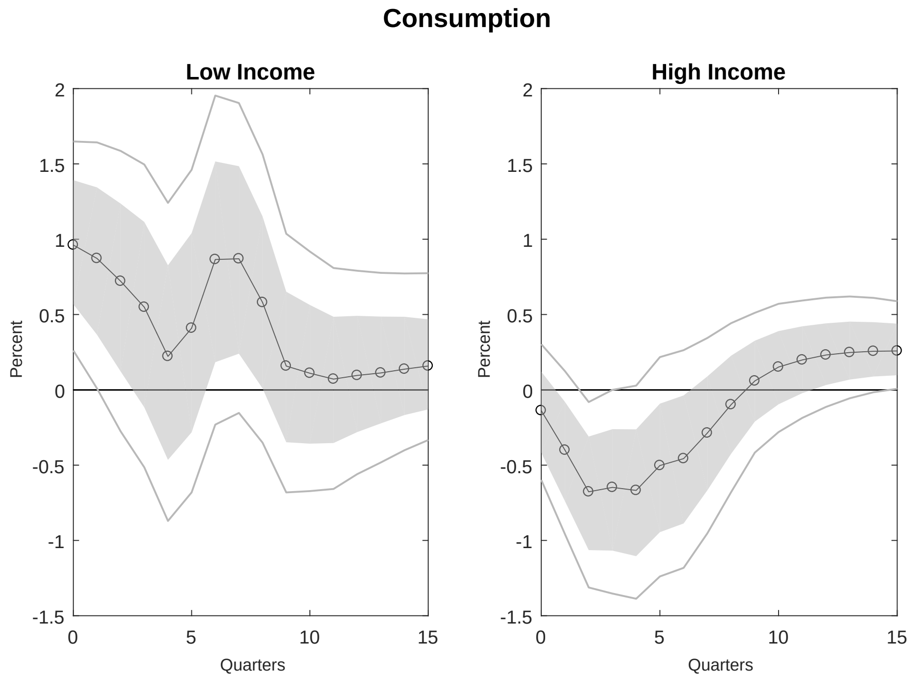
Notes: This graph displays the identified government spending shocks based on SPF forecasts.

Figure 10: Impulse responses to government spending shocks by age groups



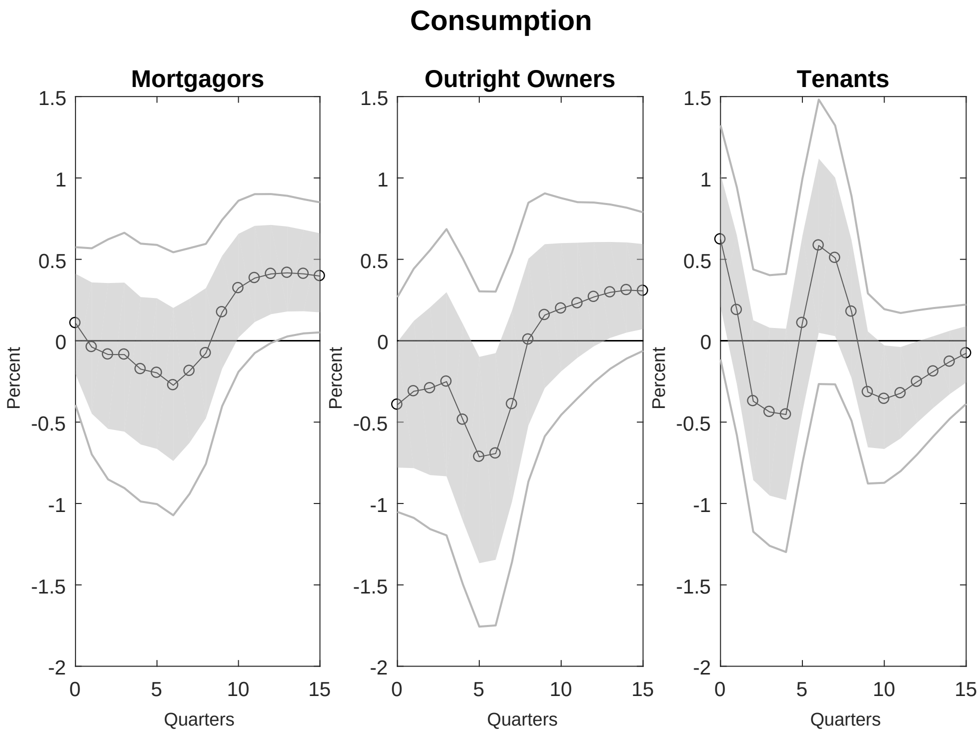
Notes: These graphs show the impulse responses of nondurable consumption for young (under 30) and prime-age (30-64) households to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 11: Impulse responses to government spending shocks by income group



Notes: These graphs show the impulse responses of nondurable consumption for each income tertile to an exogenous government spending shock leading to an initial 1% increase in government expenditures. "Low income" denotes the group of households with after-tax income below the 35th percentile, and "High income" the group with after-tax income above the 35th percentile. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

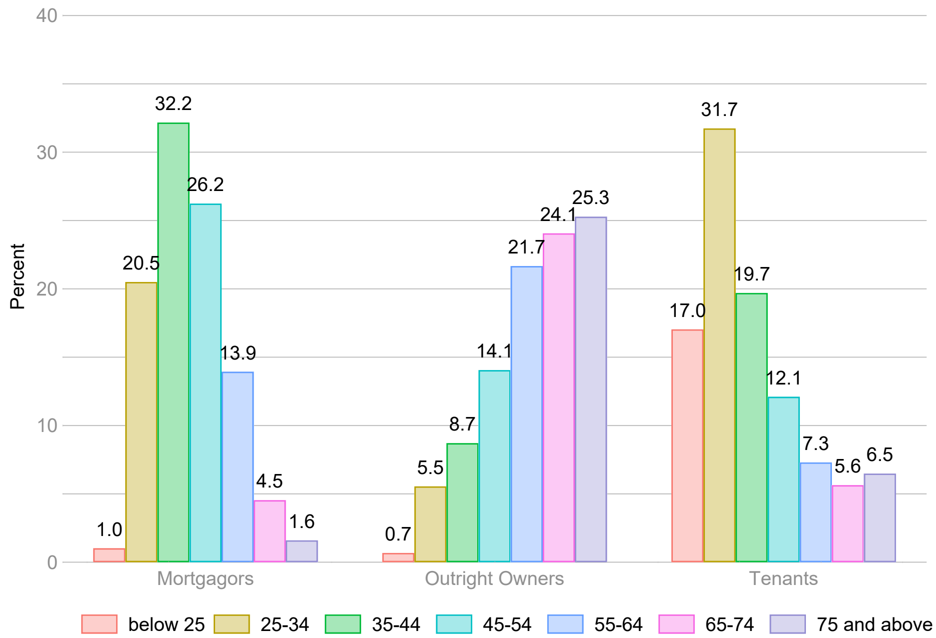
Figure 12: Impulse responses to government spending shocks by housing tenure



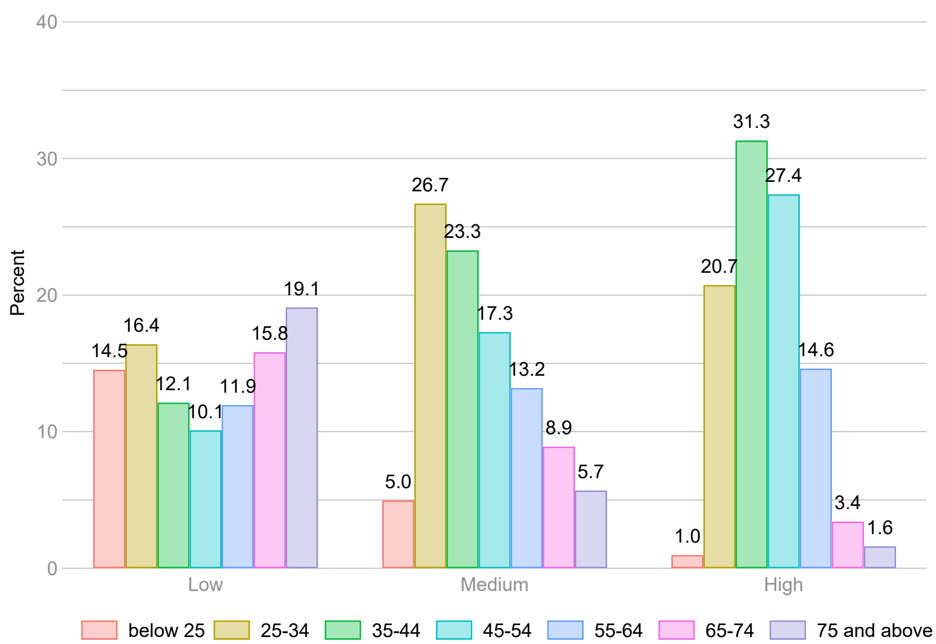
Notes: These graphs show the impulse responses of nondurable consumption for various housing tenure groups to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 13: Age composition of housing tenure groups and income tertiles

(a) By housing tenure



(b) By income tertile



Notes: These graphs show the proportion of each age group by housing tenure (upper graph) and by income tertile (lower graph).

Appendix

A Data

A.1 Aggregate U.S. Data

Time series for gross domestic product, non-durable consumption, wages, GDP price deflator, the three-month Treasury-Bill rate are available from the website of the Federal Reserve Board of St. Louis (FRED). Federal government expenditures include direct consumption and investment purchases, which excludes the imputed rent on government capital stocks. This data is from the Bureau of Economic Analysis, Table 3.2. The series for the average marginal income tax rate is taken from Mertens and Montiel Olea (2018) who update the measure of Barro and Redlick (2011) until 2012. Following Ramey (2011), the annual tax series are converted to quarterly assuming that the tax rate does not change during the fiscal year. For total factor productivity, I use the real-time, quarterly series on TFP for the U.S. business sector, adjusted for variations in factor utilization (labor effort and capital's workweek), constructed by John Fernald, which is available on the website of the Federal Reserve Bank of San Francisco. Total hours worked series is constructed as the product of average weekly hours in the nonfarm business sector and the civilian employment level, which are also available from FRED. Wages correspond to compensation per hour in the non-farm business sector. The inflation rate is constructed as the annualized rate of change of the GDP deflator. Nominal series for output, consumption, wages and government expenditures series are deflated using the GDP deflator. All quarterly series are seasonally adjusted and quantity variables are expressed in logs of per capita amounts.

A.2 SPF

To build a measure of government spending shocks, I follow the approach of Ramey (2011) and use data from the Survey of Professional Forecasters (SPF), which is available from the website of the Federal Reserve Bank of Philadelphia. In this survey, professional forecasters, mostly from the private sector, are asked to provide forecast values for a number of macroeconomic variables for the present quarter and up to four quarters ahead.

Regarding real federal government consumption expenditures and gross investment, which is the variable of interest to build the shock, individual forecasts are available from 1981Q3 onwards. As data on macroeconomic variables are released with a lag, when the forecasts are made, the forecasters only know the value of these variables in the previous quarter, but not in the current one. As is customary, to build the shock, the difference in the growth rates is preferred to the difference in the levels as the base year changed multiple times during the sample period.

A.3 CEX

Household level data on consumption and hours worked is from the Interview portion of the Consumer Expenditure Survey (CEX) conducted by the Bureau of Labor Statistics (BLS). The CEX Interview Survey is a rotating panel of approximately 7,000 households, selected to be representatives of the U.S. population, who are interviewed about their expenditures for up to four consecutive quarters. The survey records information on detailed categories of consumption expenditures over the preceding quarter for all households interviewed. In addition, the survey provides detailed demographic characteristics for all household members, as well as information on income and hours worked, which I exploit in my empirical analysis.

The household is identified with the head of the household. Following Anderson et al. (2016), all households with missing data or implausible consumption or income data are dropped, as well as households whose head is aged more than 75. My final sample contains 171,090 households over the period 1981Q3-2007Q4. Similar to Krueger and Perri (2006), nondurable consumption is defined as expenditures on food, alcoholic beverages, tobacco, apparel and services, personal care, household operations, public transportation, gas and motor oil, medical care, entertainment, reading material and education. Consumption expenditures are measured in log of real per capita terms, and hours worked are measured in log terms.[45] All variables are seasonally adjusted by X-12 ARIMA.

Given the short panel dimension of the dataset, I follow the strategy described in Deaton (1985) and build pseudo-panels, which consists in aggregating individual observations into pseudo-cohorts of consumers with different characteristics and computing averages for each period. Several concerns have been raised in the literature

[45] Household consumption expenditures data is divided by the number of family members and deflated by the consumer price index.

regarding CEX data, such as the presence of measurement error and underreporting by high-income households.[46] An advantage of this approach is that it attenuates the attrition problem and reduces measurement error since it aggregates across agents. Furthermore, income data, where measurement error is more salient, is only used to identify income tertiles.

A.4 CPS

To build measures of productivity for different age groups, I use data from the Uniform Extracts of the Current Population Survey (CPS) Merged Outgoing Rotation Group (MORG) from the CEPR. The CPS is the source of official US government statistics on employment, wages and unemployment, with interviewed households selected to be representative of the U.S. population. The extremely large sample size of the CPS dataset allows accurate analyses at a high degree of disaggregation. Furthermore, the survey records detailed information on hours worked, earnings, industry, occupation, education and unionization, as well as on demographic characteristics. Therefore I further use this dataset to build series of wages and hours worked by age groups to inspect the effects of government spending shocks on age-specific labor-market outcomes. Hours worked are computed as the product of usual weekly hours and the number of persons employed. About 60,000 households are interviewed for four consecutive months one year, then ignored for eight months, and interviewed again for four consecutive months. Individuals pursuing studies, self-employed and individuals with zero or missing wage are excluded from the sample. My final sample contains about 5 million observations over 1981Q3-2007Q4.

A.5 Cross-country Panel Data

The data series on real GDP, real government consumption expenditure, real private consumption, the current account and the real effective exchange rate used in Section 4.2 are taken from Ilzetzki et al. (2013). These quarterly series cover the period from 1960:1 to 2009:4 for 44 developing and developed countries. I extend this dataset by collecting series on labor productivity, measured as GDP per employed person. These series are

[46] See, e.g., Lusardi (1996), Aguiar and Hurst (2013) and Aguiar and Bils (2015) for a discussion of these issues.

obtained from the OECD (Main Economic Indicators), Eurostat and Oxford Economics. Five countries are excluded from the sample as there is no quarterly series available for labor productivity: Botswana, Ecuador, El Salvador, Peru, Uruguay. Similar to Ilzetzki et al. (2013), the productivity series are seasonally adjusted and analyzed as deviations from their quadratic trend.

The remaining 39 countries are split in two groups according to their share of young people in total population. Population shares by age groups are computed using annual data from the World Population Prospects prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. Table 3 lists the countries included in each group. Countries with high share of young in total population are characterized by an average share of people aged 15-29 over 1970-2010 above the sample mean of 23.6%, while the second group consists of countries with a share strictly below the sample mean. The distribution of countries in the two groups remains unchanged if the share of people aged 15-34 is considered instead of 15-29.

Table 3: Share of young people in total population across panel of 39 countries

High Share of Young		**Low Share of Young**	
Colombia	28.8%	Romania	23.1%
Malaysia	28.1%	Spain	22.8%
Mexico	28.1%	Slovenia	22.6%
Brazil	28.1%	Netherlands	22.6%
South Africa	28.0%	Lithuania	22.5%
Thailand	27.3%	Portugal	22.3%
Turkey	27.1%	Czech Republic	22.3%
Chile	26.9%	Greece	21.9%
Israel	25.1%	Finland	21.8%
Ireland	24.8%	France	21.7%
Iceland	24.7 %	Estonia	21.6%
Slovakia	24.5 %	Croatia	21.6%
Argentina	24.3%	Latvia	21.6%
Poland	24.3%	Hungary	21.6%
Canada	24.1%	Norway	21.5%
Australia	23.6%	Bulgaria	21.2%
United States	23.6%	United Kingdom	21.2%
		Belgium	21.1%
		Denmark	21.0%
		Italy	20.8%
		Germany	20.4%
		Sweden	20.1%
Mean	**26.0%**		**21.7%**

Notes: This table reports the average share of young people (aged 15-29) among total population over 1970-2010 across a panel of 39 countries. Using the average share of people aged 15-34 instead leads to the same distribution of countries across the two groups. Overall sample mean is 23.6%.

B Aggregate Results

In this Appendix, I present time series evidence on the effects of government spending shocks on macroeconomic variables for the U.S.

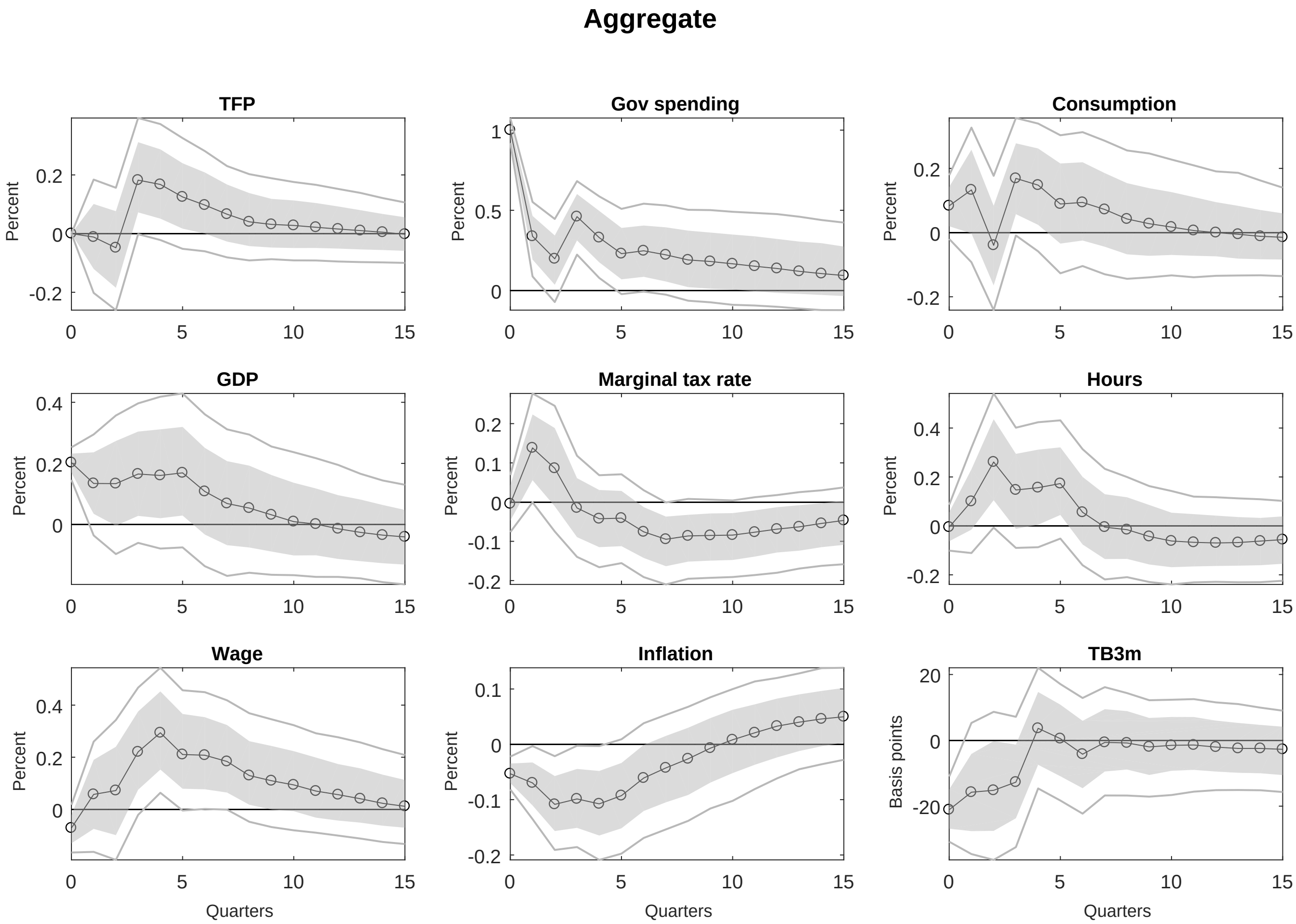
I use a structural vector autoregression approach, where the vector of endogenous variables includes, in this order, TFP, the SPF shock, log real per capita quantities of government spending, GDP, nondurable consumption and total hours worked, as well as log real wages, the average marginal income tax rate, the three-month T-Bill rate and the inflation rate. The model is estimated with two lags, a constant and a quadratic trend on the same sample as in the baseline analysis.

Using a standard Choleski decomposition, shocks to government spending are identified as innovations to the SPF forecast-based measure which are orthogonal to TFP movements on impact and pre-determined with respect to remaining variables. This specification controls for the measurement error component that may induce a bias in the impulse responses of output and TFP, following Ben Zeev and Pappa (2015).[47] Furthermore, following Blanchard and Perotti (2002), this specification implies that government spending cannot react to changes in remaining variables within the same quarter due to implementation lag.

Figure 14 displays the impulse responses of these variables to a shock that raises government spending by one percent. Following a fiscal expansion, output, hours worked, wages and consumption increase significantly, while the nominal interest rate and the inflation rate drop. TFP also rises significantly after a few quarters, and the marginal income tax rate increases during the first quarters after the shock. These findings are in line with empirical estimates already reported in the litterature, notably in d'Alessandro et al. (2019) and Jørgensen and Ravn (2018).

[47] Ben Zeev and Pappa (2015) find that the positive response of output and TFP to unexpected government spending shocks could be due to correlated measurement error in the two variables, and show that forcing the fiscal shocks to be orthogonal contemporaneously to TFP fluctuations enables to properly identify the true effects of the shocks on macroeconomic variables.

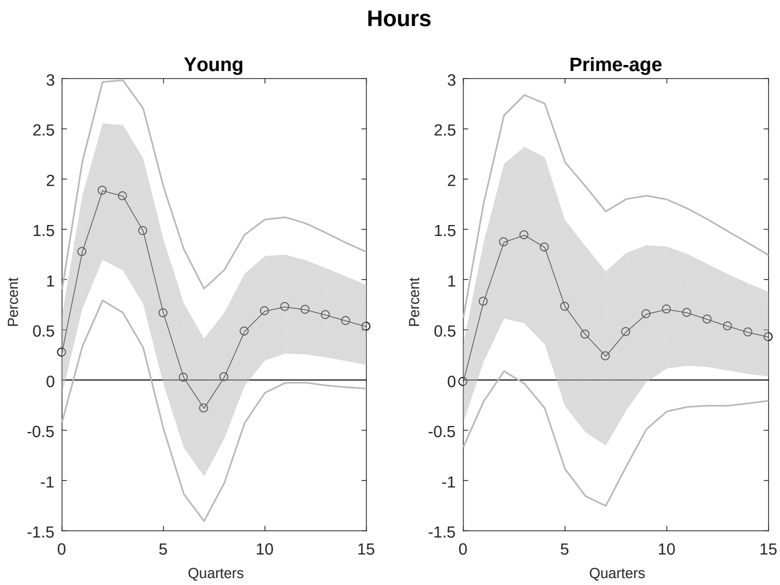
Figure 14: Impulse responses of aggregate variables to government spending shocks



Notes: These graphs show the impulse responses of aggregate variables to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

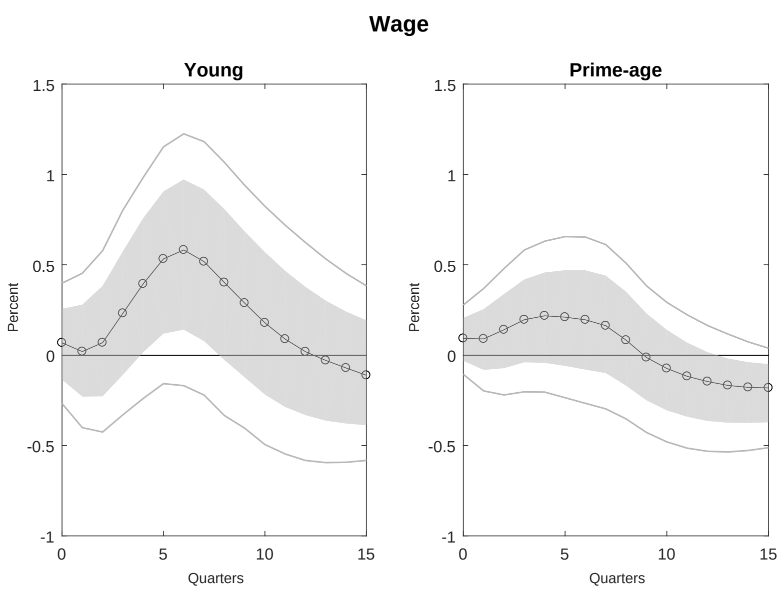
C Additional Micro-Level Evidence

Figure 15: Impulse responses of hours worked to government spending shocks



Notes: These graphs show the impulse responses of hours worked to a 1% shock to government expenditure for young and prime-age workers. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 16: Impulse responses of real hourly wages to government spending shocks

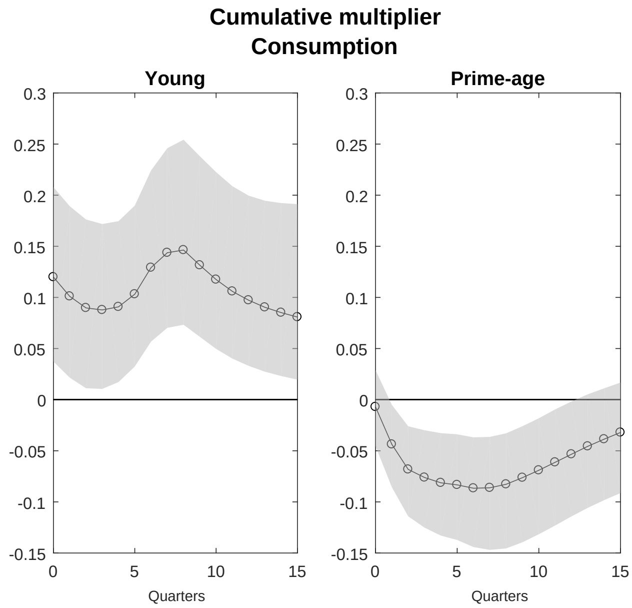


Notes: These graphs show the impulse responses of real hourly wages to a 1% shock to government expenditure for young and prime-age workers. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

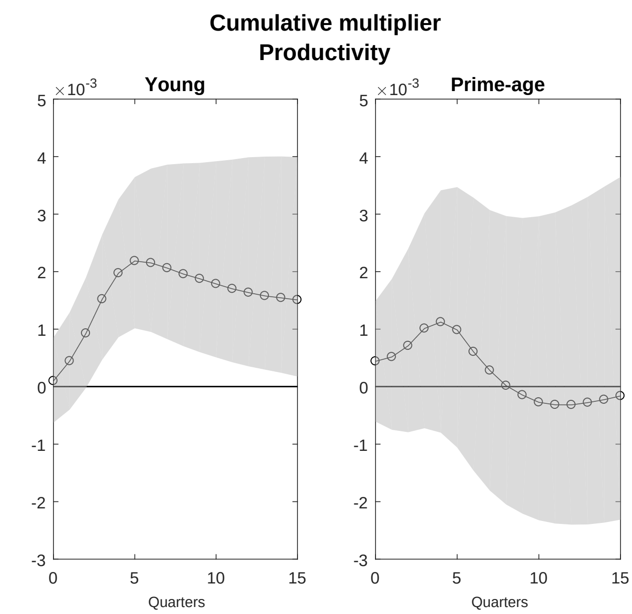
D Fiscal Multipliers

Figure 17: Cumulative Fiscal Multipliers

(a) Consumption



(b) Productivity



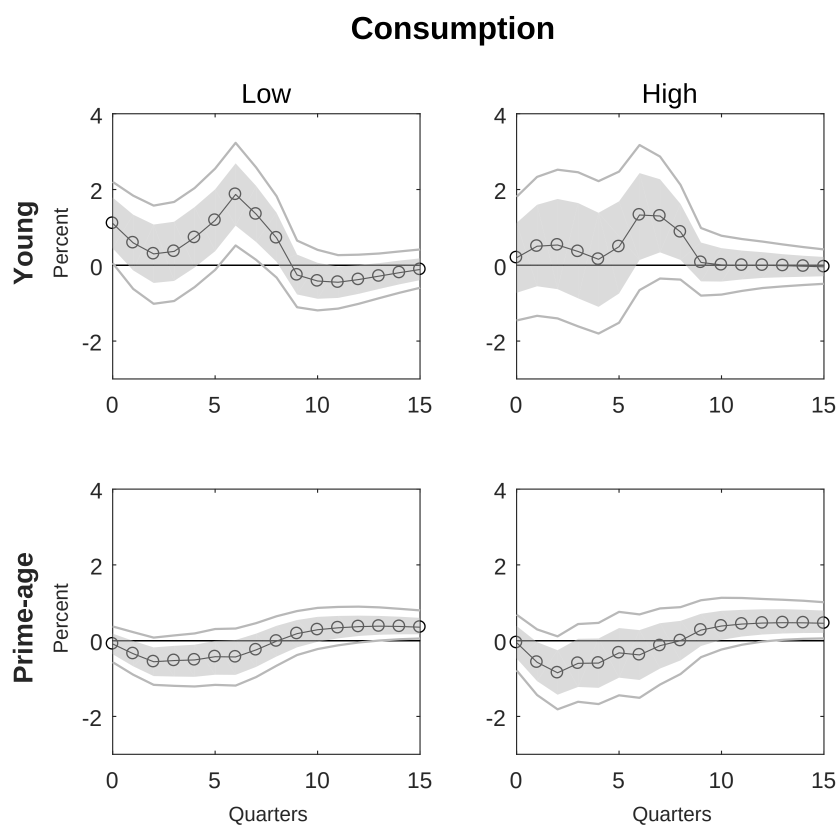
Notes: These graphs show the cumulative fiscal multipliers of nondurable consumption (Panel (a)) and productivity (Panel (b)) for young and prime-age households. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 68% confidence intervals are shown in all cases.

E Robustness

E.1 Heterogeneous Effects on Consumption: Robustness

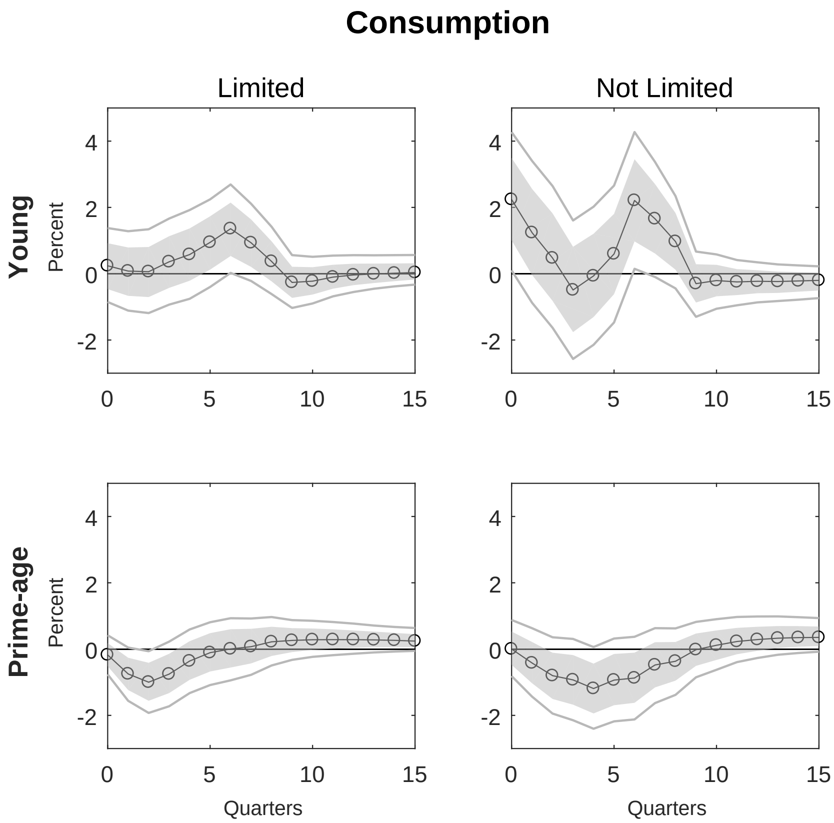
Using other proxies for financial constraints

Figure 18: Impulse responses to government spending shocks by age and education level



Notes: These graphs show the impulse responses of nondurable consumption for young and prime-age households, grouped by their education level ("Low": no college degree, "High": college degree) to an exogenous government spending shock leading to an initial 1% increase in government expenditures. The impulse responses for the young (below 30) are depicted on the first row, for the prime-age (30-64) on the second row. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

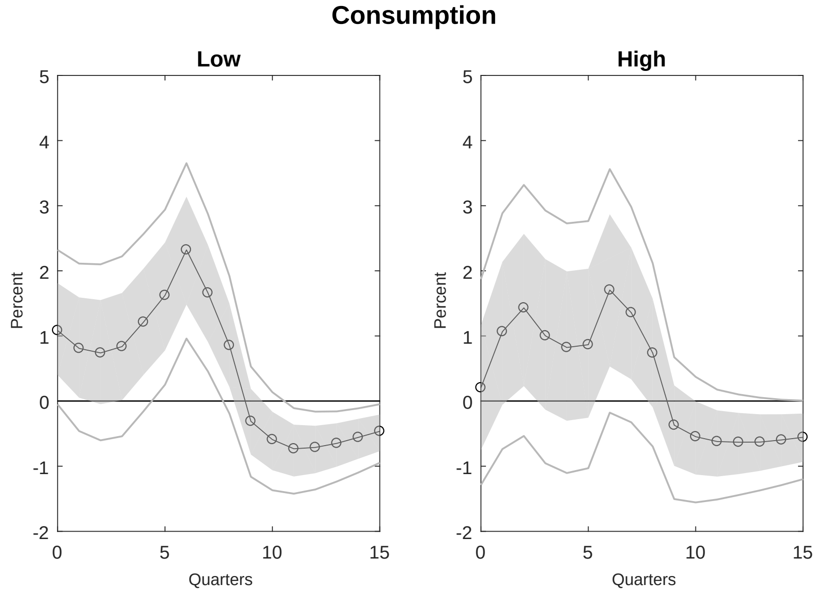
Figure 19: Impulse responses to government spending shocks by age and financial market participation



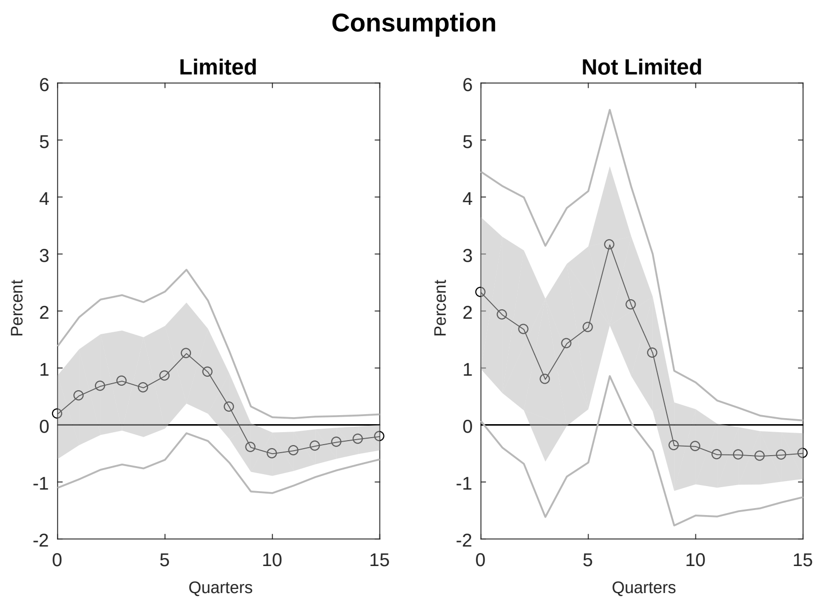
Notes: These graphs show the impulse responses of nondurable consumption for young and prime-age households, grouped by their financial market participation ("Limited": no income from financial assets, "Not Limited": non-zero income from financial assets) to an exogenous government spending shock leading to an initial 1% increase in government expenditures. The impulse responses for the young (below 30) are depicted on the first row, for the prime-age (30-64) on the second row. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 20: Impulse responses of consumption ratio between young and prime-age groups

(a) By education



(b) By financial market participation

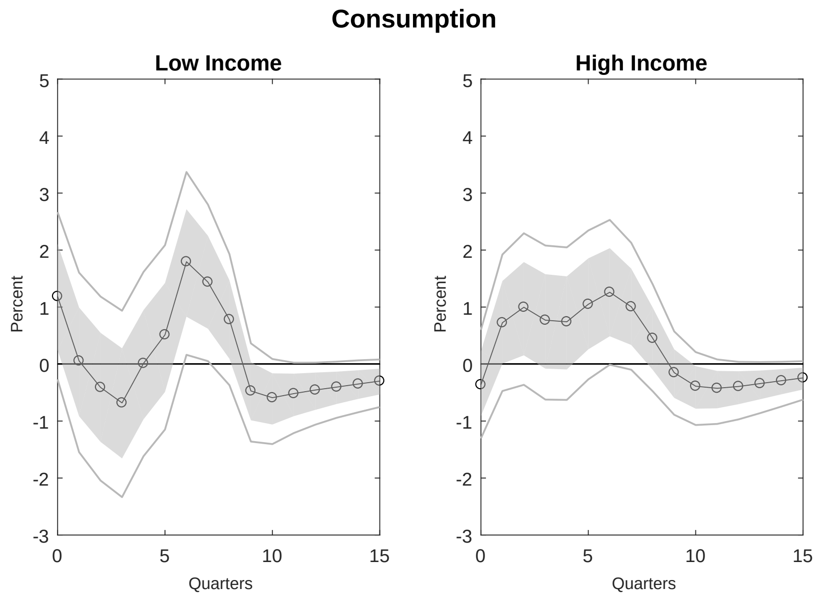


Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their education in Panel (a) ("Low": no college degree, "High": college degree) and by their financial market participation ("Limited": no income from financial assets, "Not Limited": non-zero income from financial assets) in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

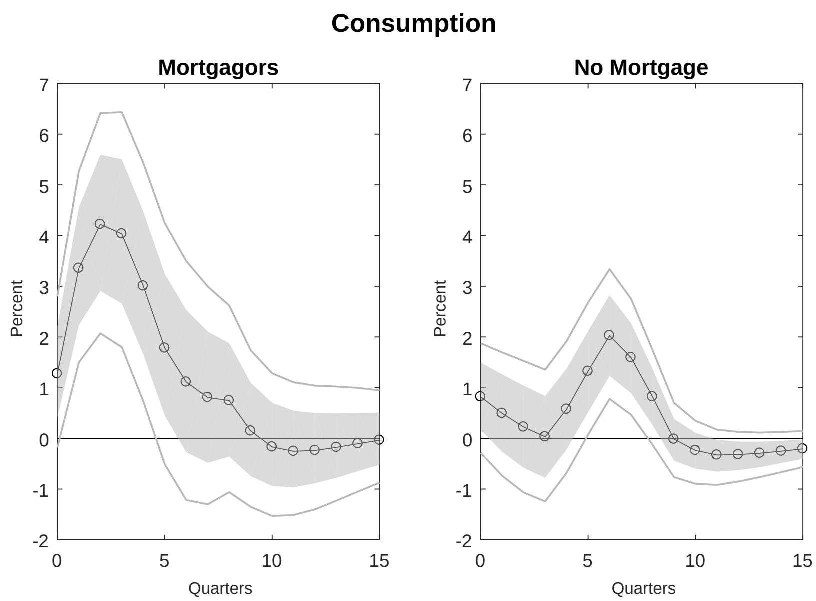
Using a broader definition of consumption

Figure 21: Impulse responses of consumption ratio between young and prime-age groups

(a) By income level



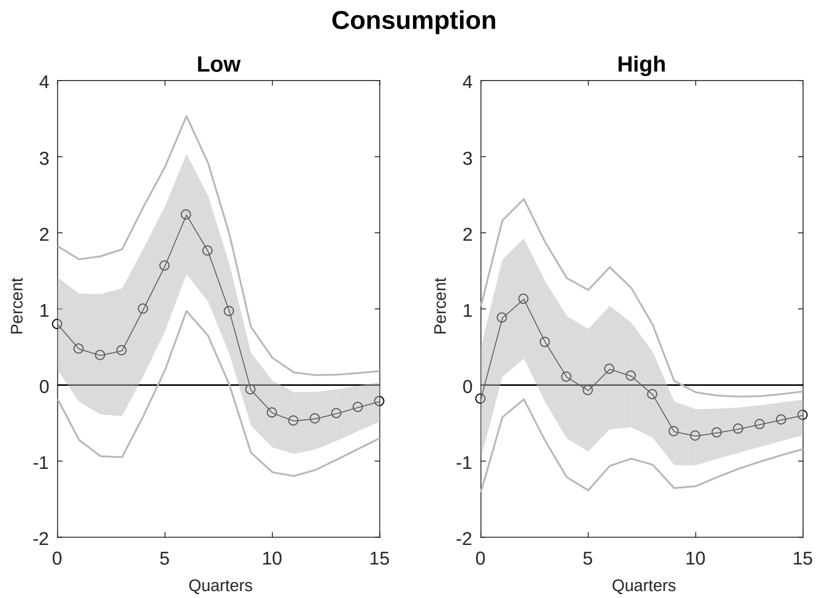
(b) By housing tenure



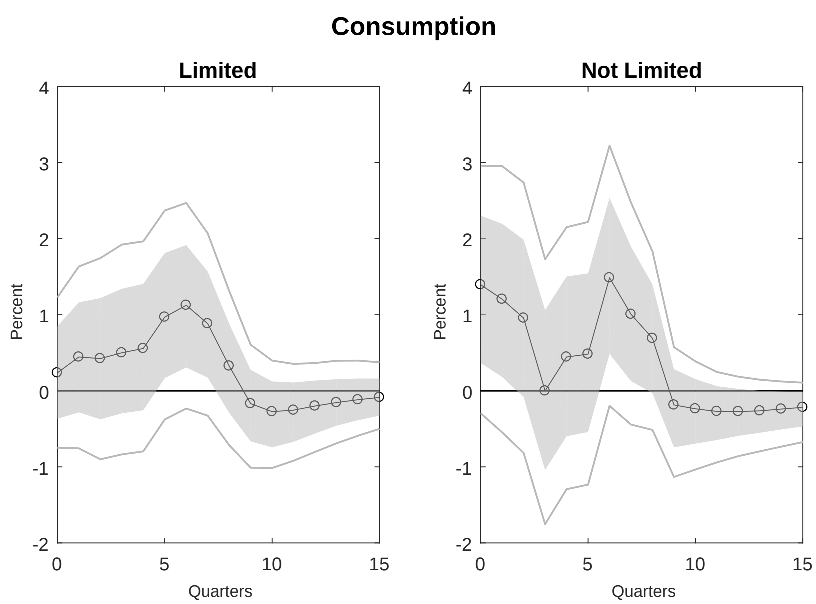
Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their income level in Panel (a) (lowest tertile on the left, highest on the right) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 22: Impulse responses of consumption ratio between young and prime-age groups

(a) By education



(b) By financial market participation

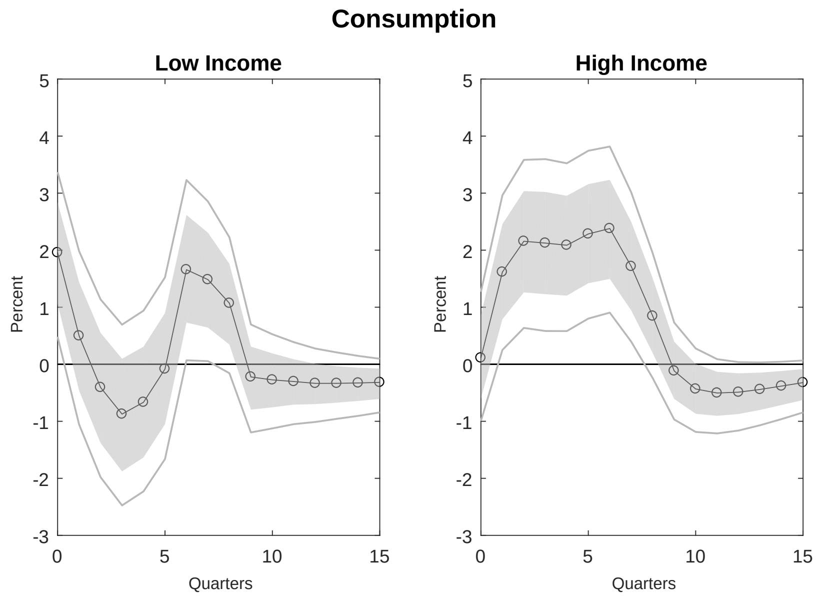


Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their income level in Panel (a) (lowest tertile on the left, highest on the right) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

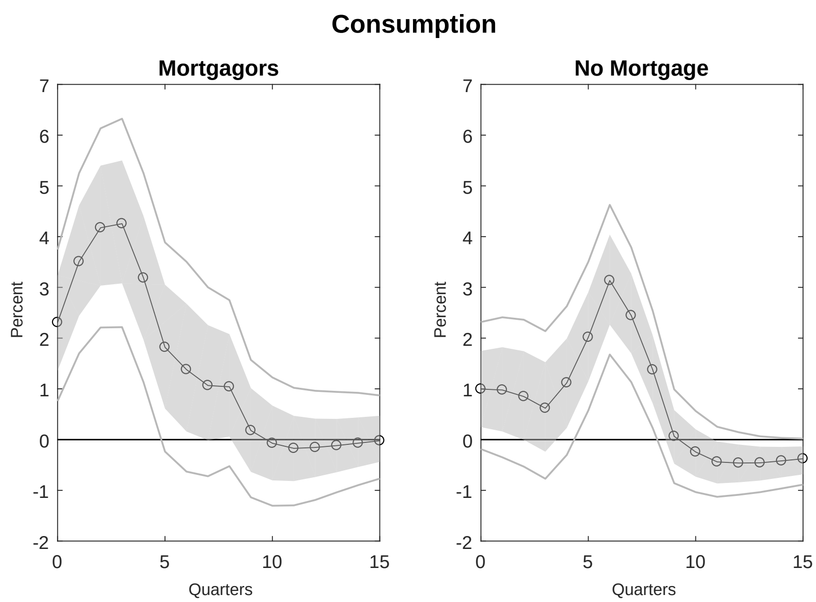
Restricting the sample to employed households

Figure 23: Impulse responses of consumption ratio between young and prime-age groups

(a) By income level



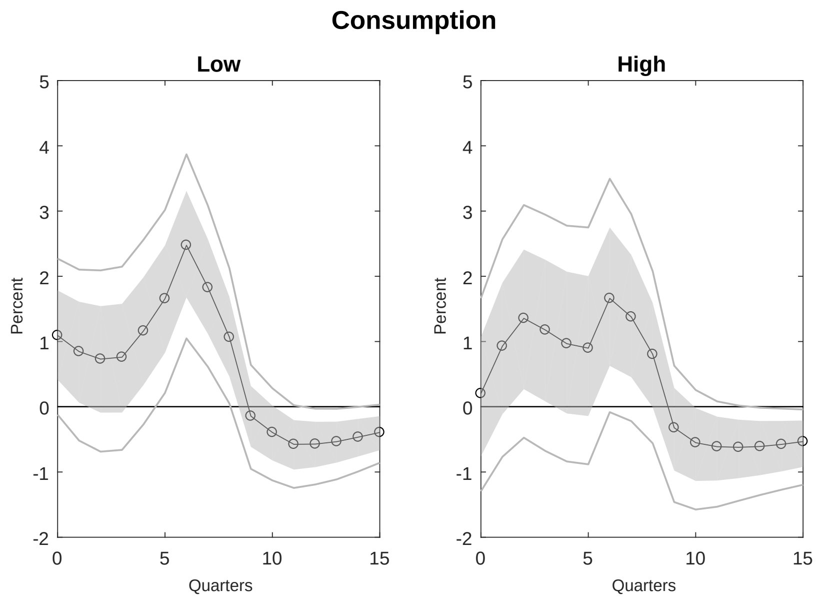
(b) By housing tenure



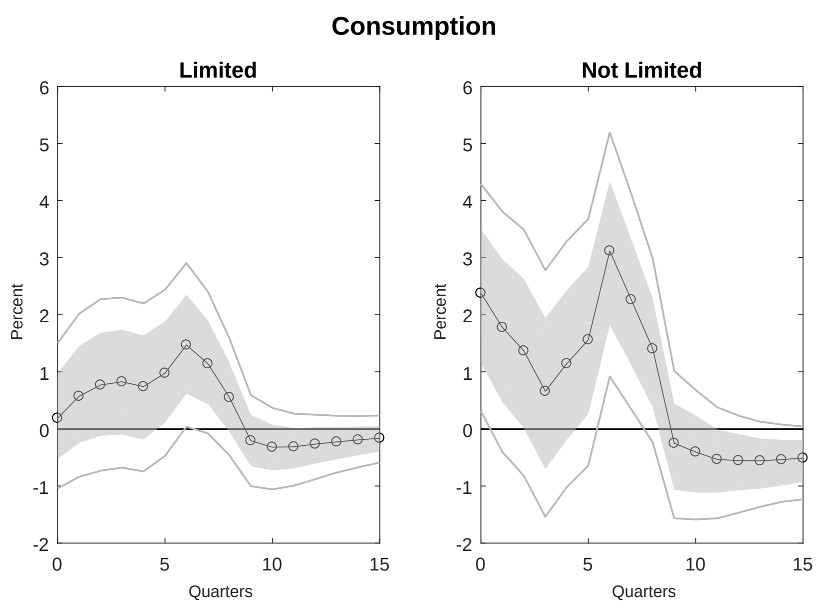
Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their income level in Panel (a) (lowest tertile on the left, highest on the right) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 24: Impulse responses of consumption ratio between young and prime-age groups

(a) By education



(b) By financial market participation

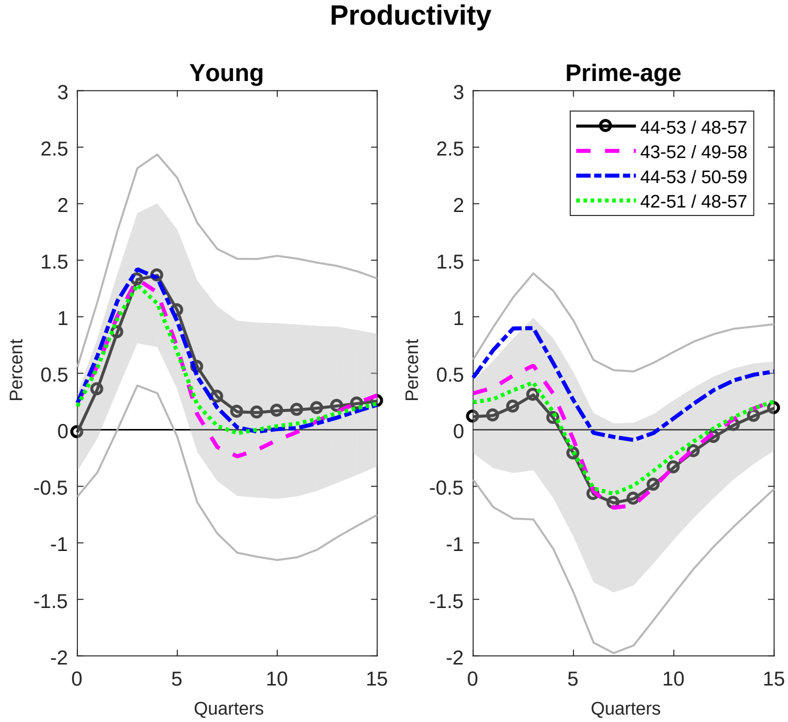


Notes: These graphs show the impulse response functions of the nondurable consumption ratio between young and prime-age households, by their income level in Panel (a) (lowest tertile on the left, highest on the right) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditures. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

E.2 Fiscal Policy and Human Capital: Robustness

E.2.1 Micro Evidence

Figure 25: Impulse responses of productivity to government spending shocks - sensitivity to the flat spot range

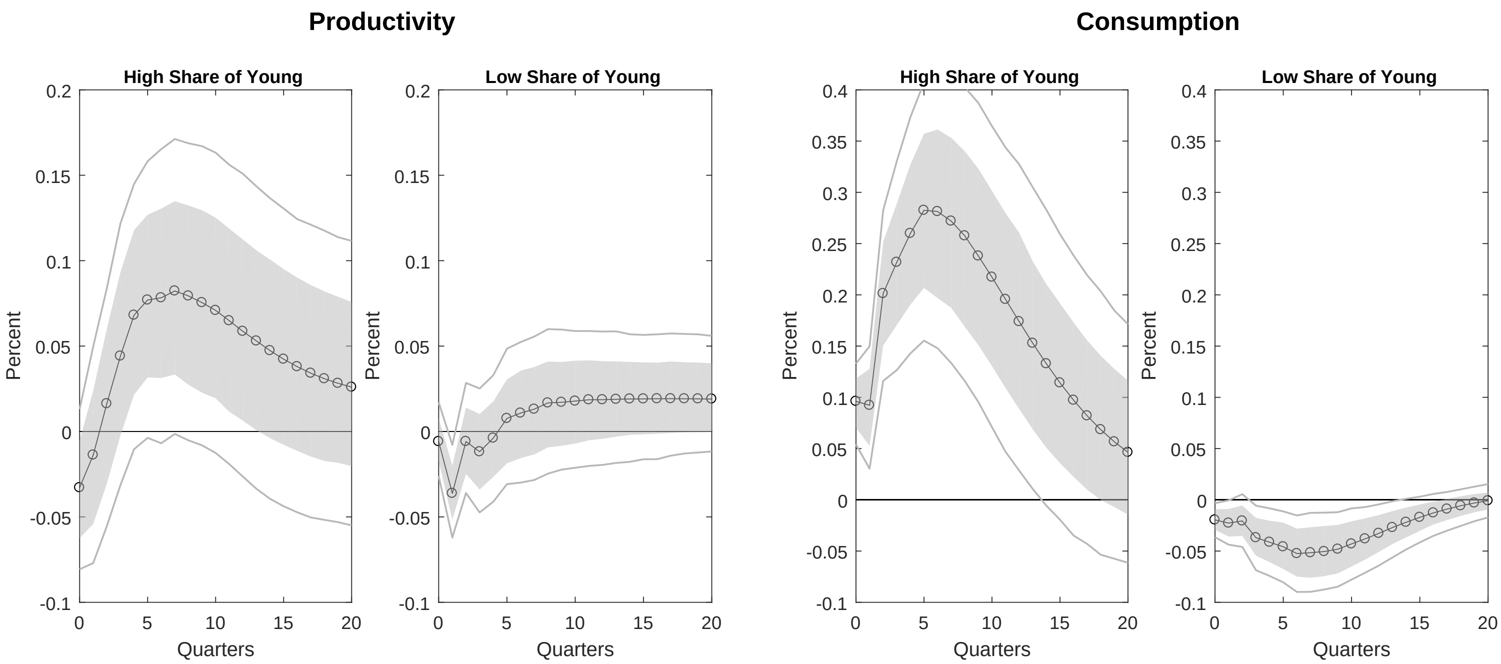


Notes: These graphs show the impulse responses of measured productivity to a 1% shock to government consumption expenditure for different values of the flat spot region for low- and high-educated groups. 90% and 68% confidence intervals are shown for the baseline impulse response function (flat spot: 43-52 / 48-57).

E.2.2 Panel Evidence

Additional controls

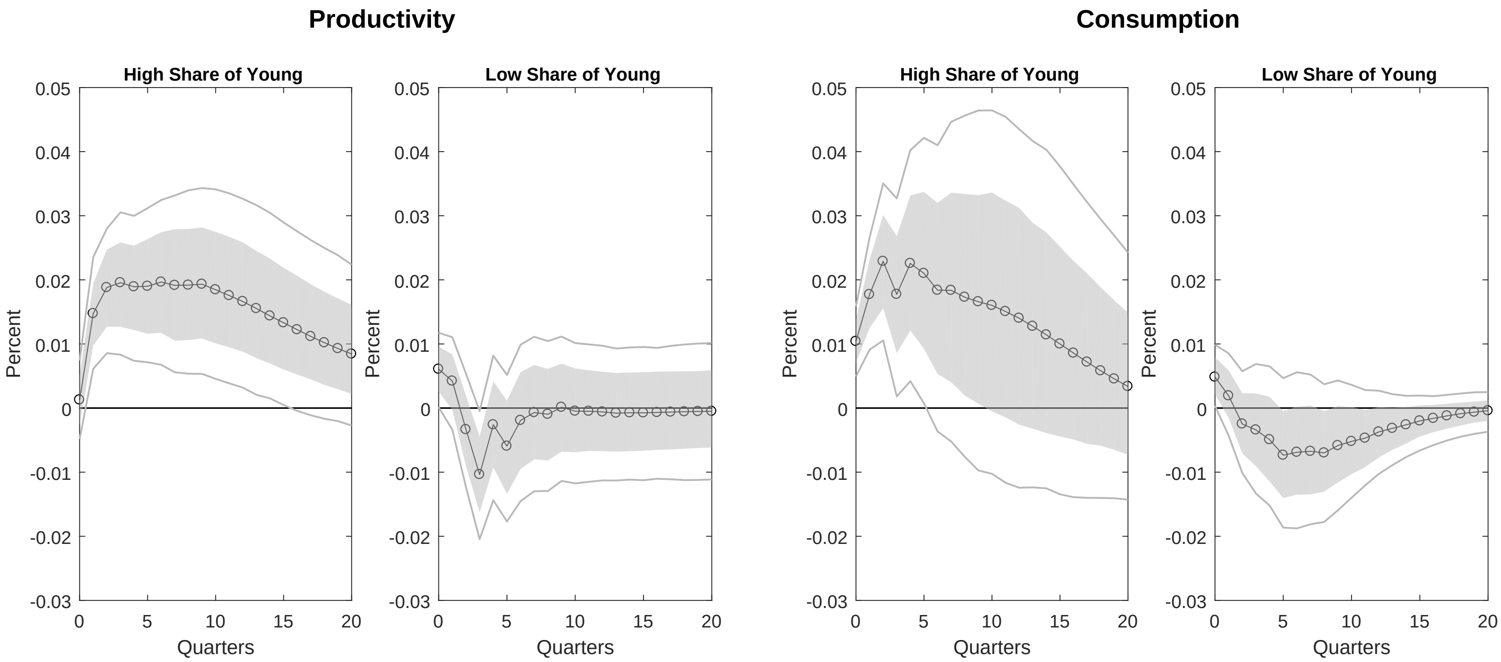
Figure 26: Impulse responses of productivity and consumption to government spending shocks in countries with high vs. low shares of young in total population - controlling for current account and real exchange rate



Notes: These graphs show the impulse responses of labor productivity (left panels) and private consumption (right panels) to a 1% shock to government consumption expenditure in countries with low share of young (aged 15-29) in total population vs. high share of young. 90% and 68% confidence intervals are shown in all cases.

Government investment shocks

Figure 27: Impulse responses of productivity and consumption to government investment shocks in countries with high vs. low shares of young in total population

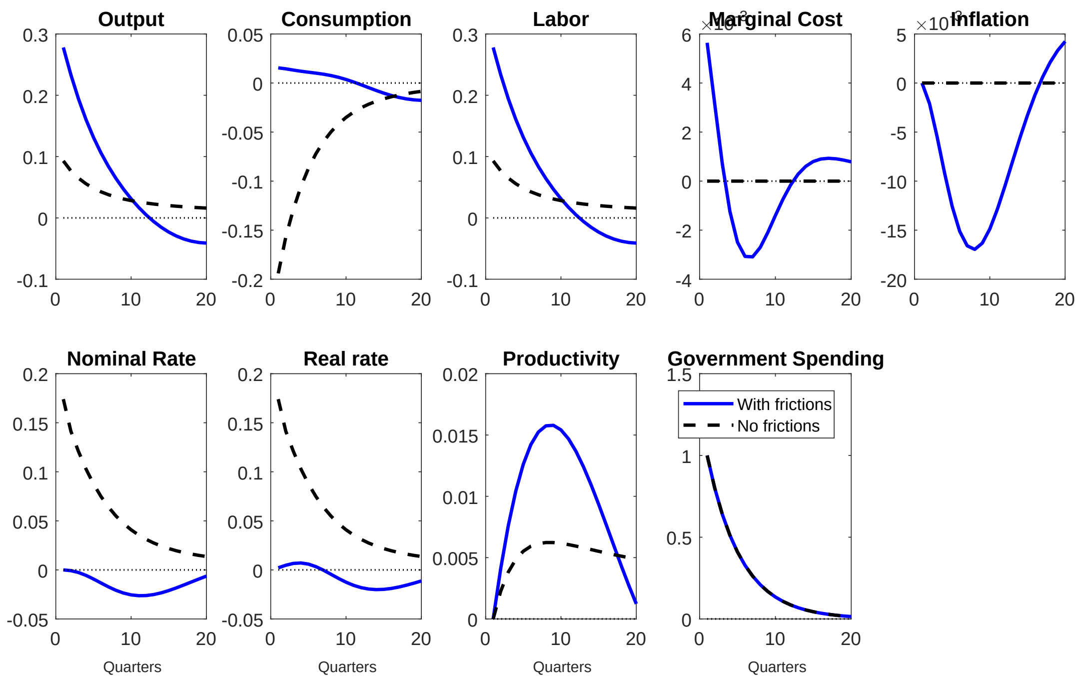


Notes: These graphs show the impulse responses of labor productivity (left panels) and private consumption (right panels) to a 1% shock to government investment expenditure in countries with low share of young (aged 15-29) in total population vs. high share of young. 90% and 68% confidence intervals are shown in all cases.

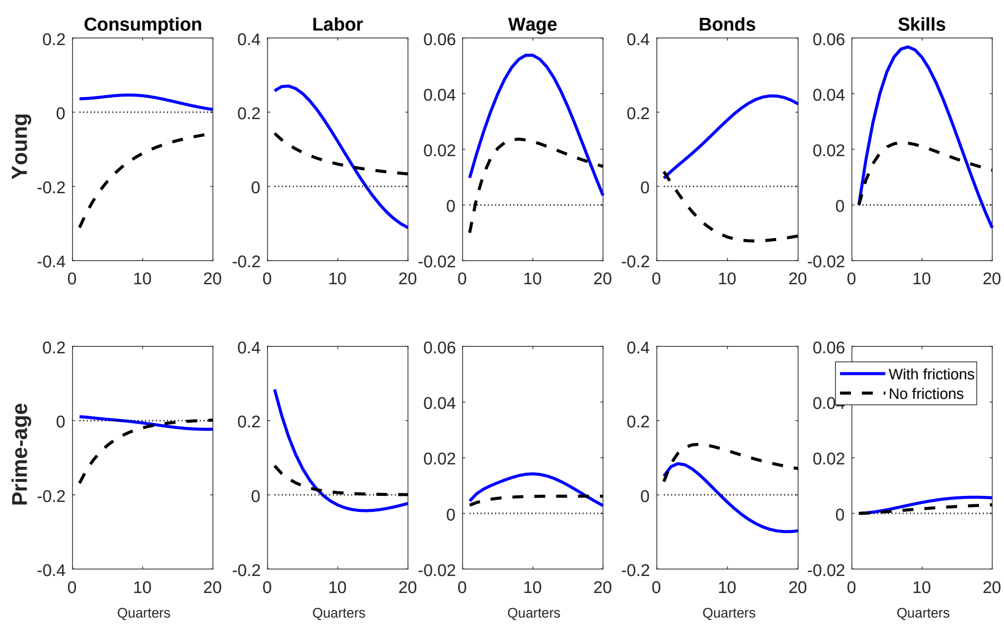
F Model: Sensitivity Analysis

Figure 28: Impulse responses to a government spending shock - With vs. without nominal rigidities

(a) IRFs of aggregate variables



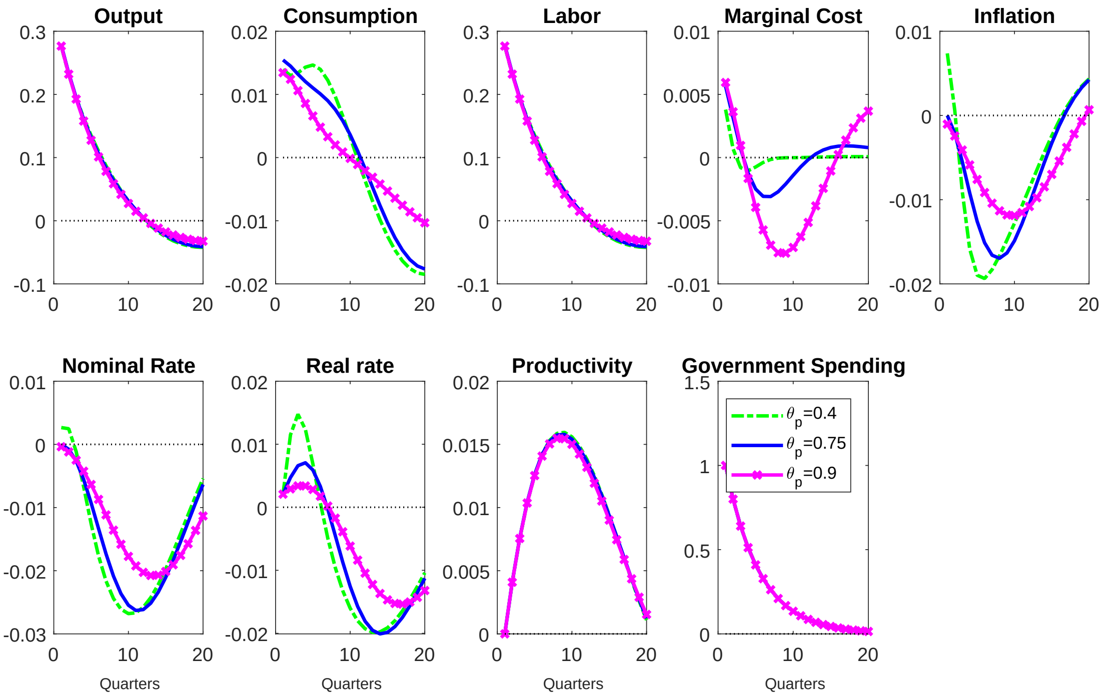
(b) IRFs of disaggregate variables



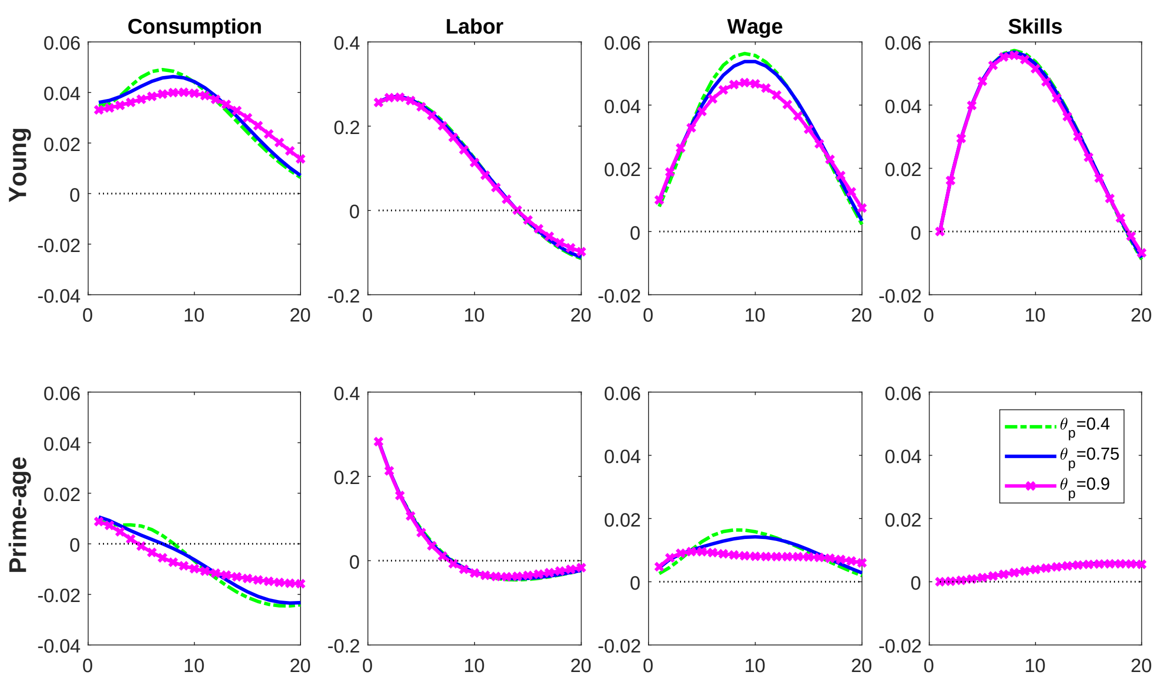
Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD, with and without nominal rigidities.

Figure 29: Impulse responses to a government spending shock - Sensitivity to price stickiness

(a) IRFs of aggregate variables



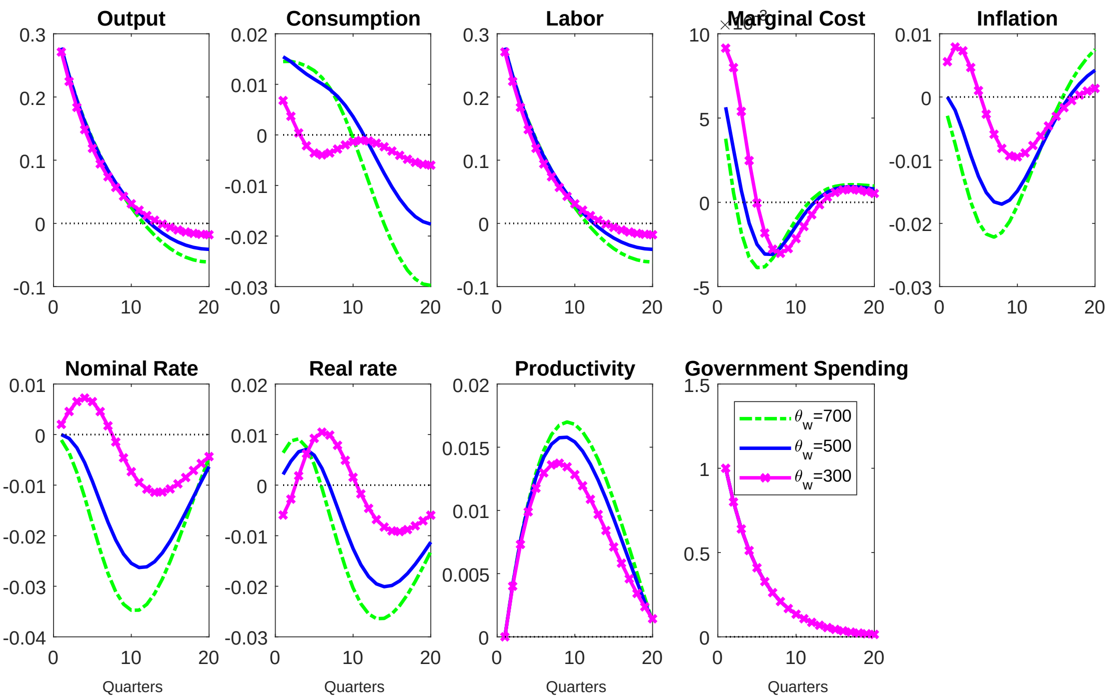
(b) IRFs of disaggregate variables



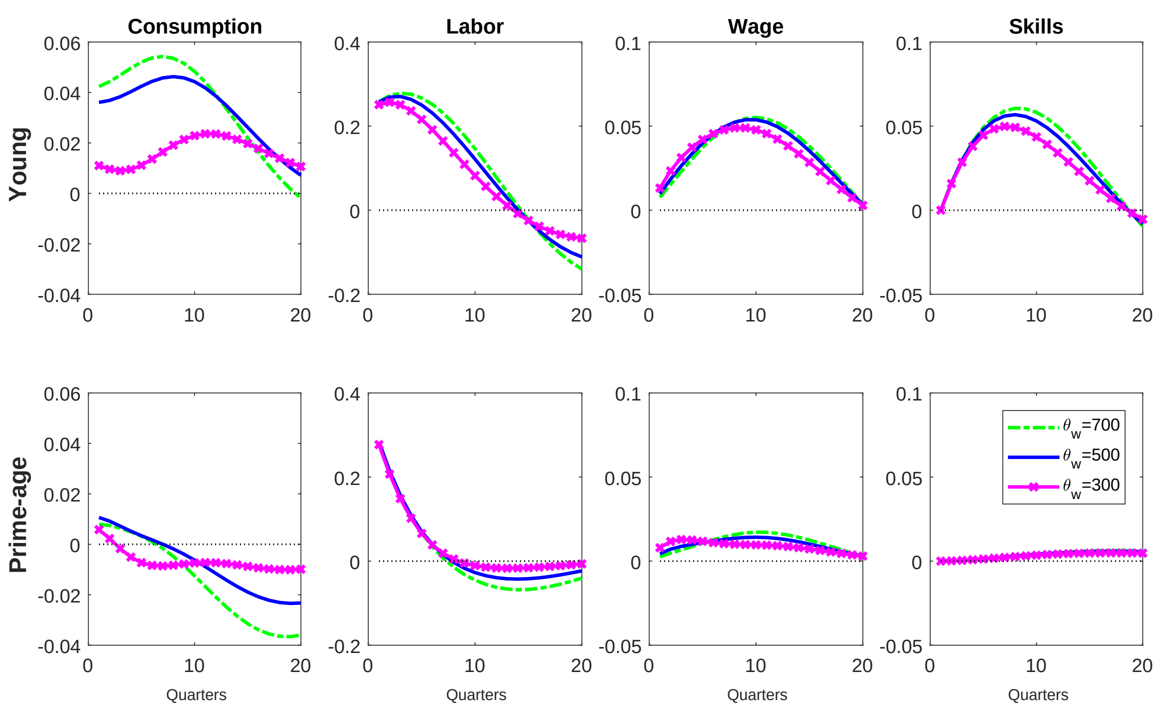
Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the price stickiness parameter θ_p.

Figure 30: Impulse responses to a government spending shock - Sensitivity to wage stickiness

(a) IRFs of aggregate variables

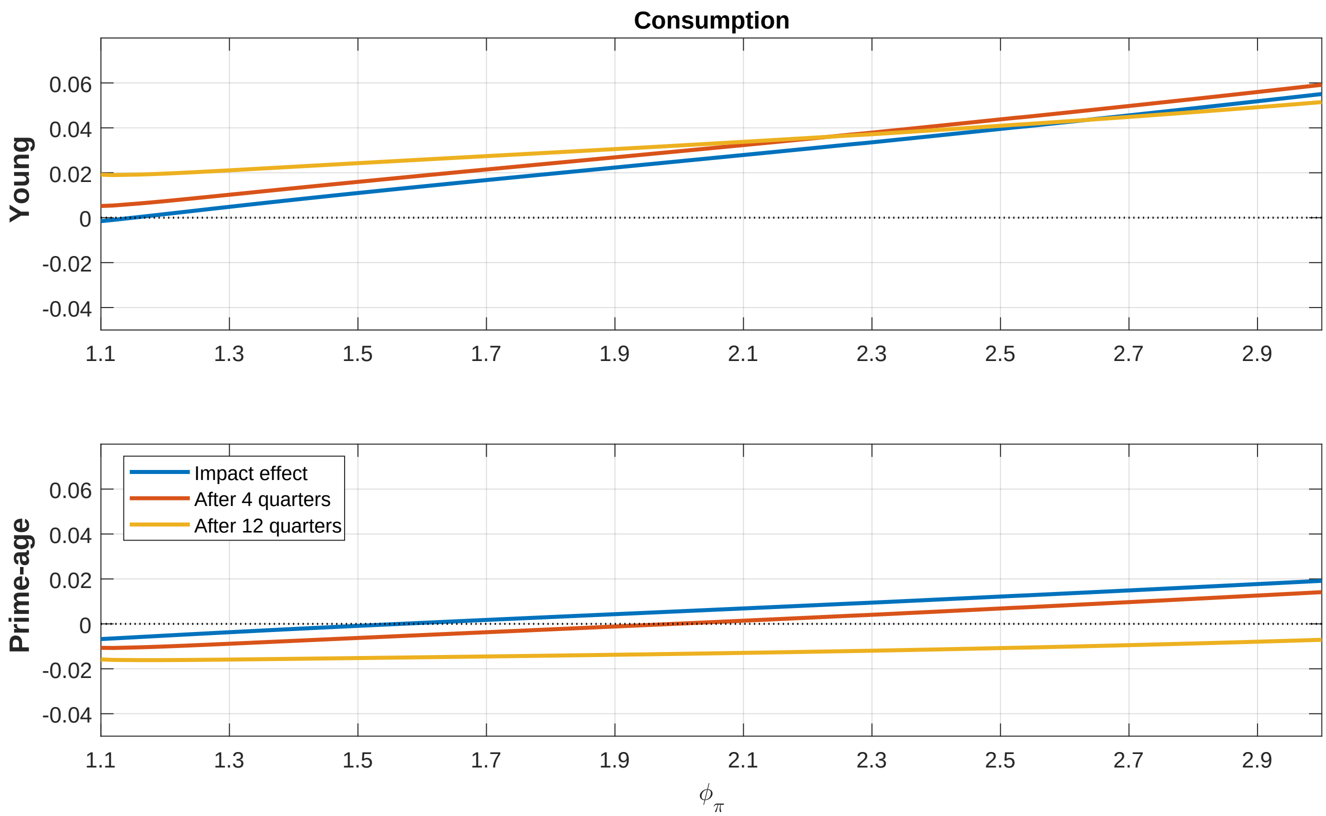


(b) IRFs of disaggregate variables



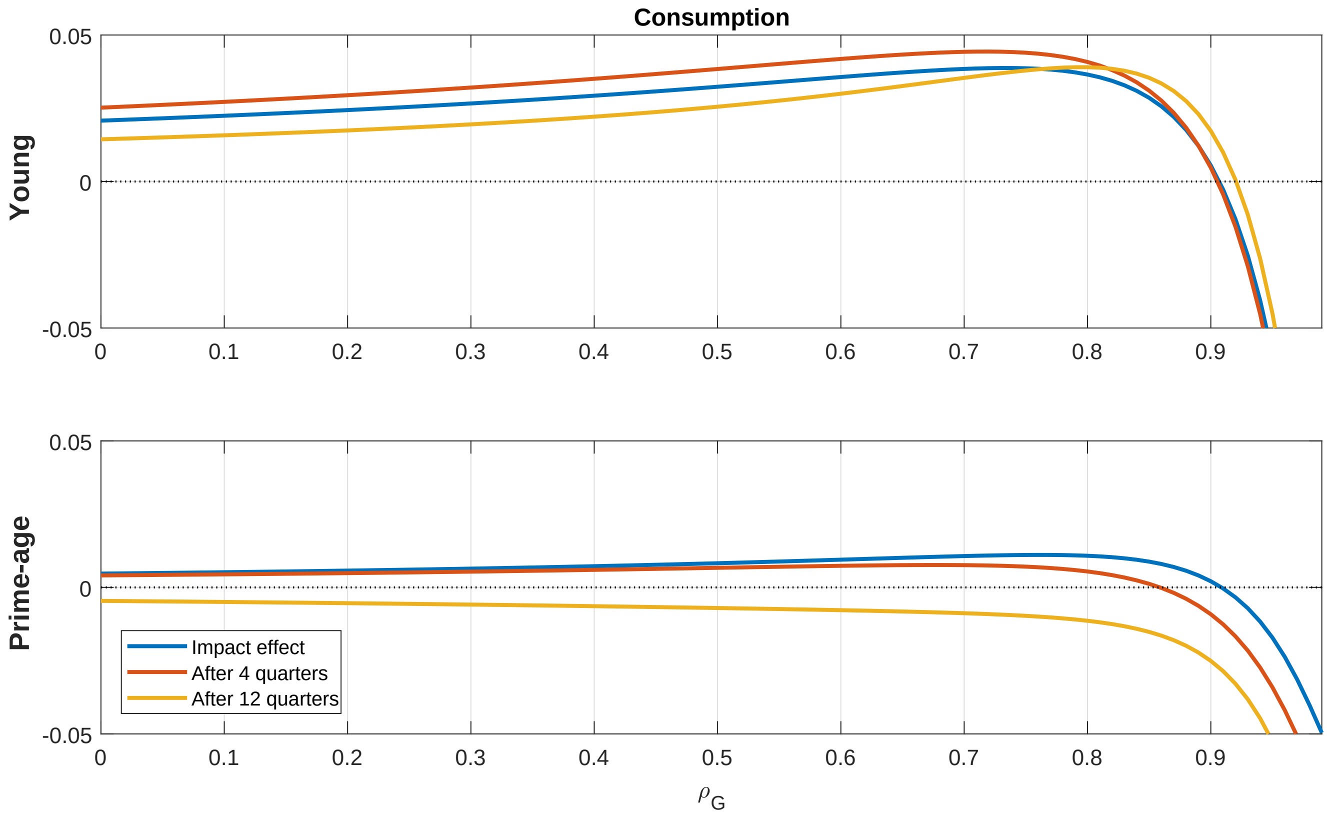
Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the wage adjustment cost parameter θ_w.

Figure 31: Impulse responses to a government spending shock - Sensitivity to monetary policy parameter ϕ_π



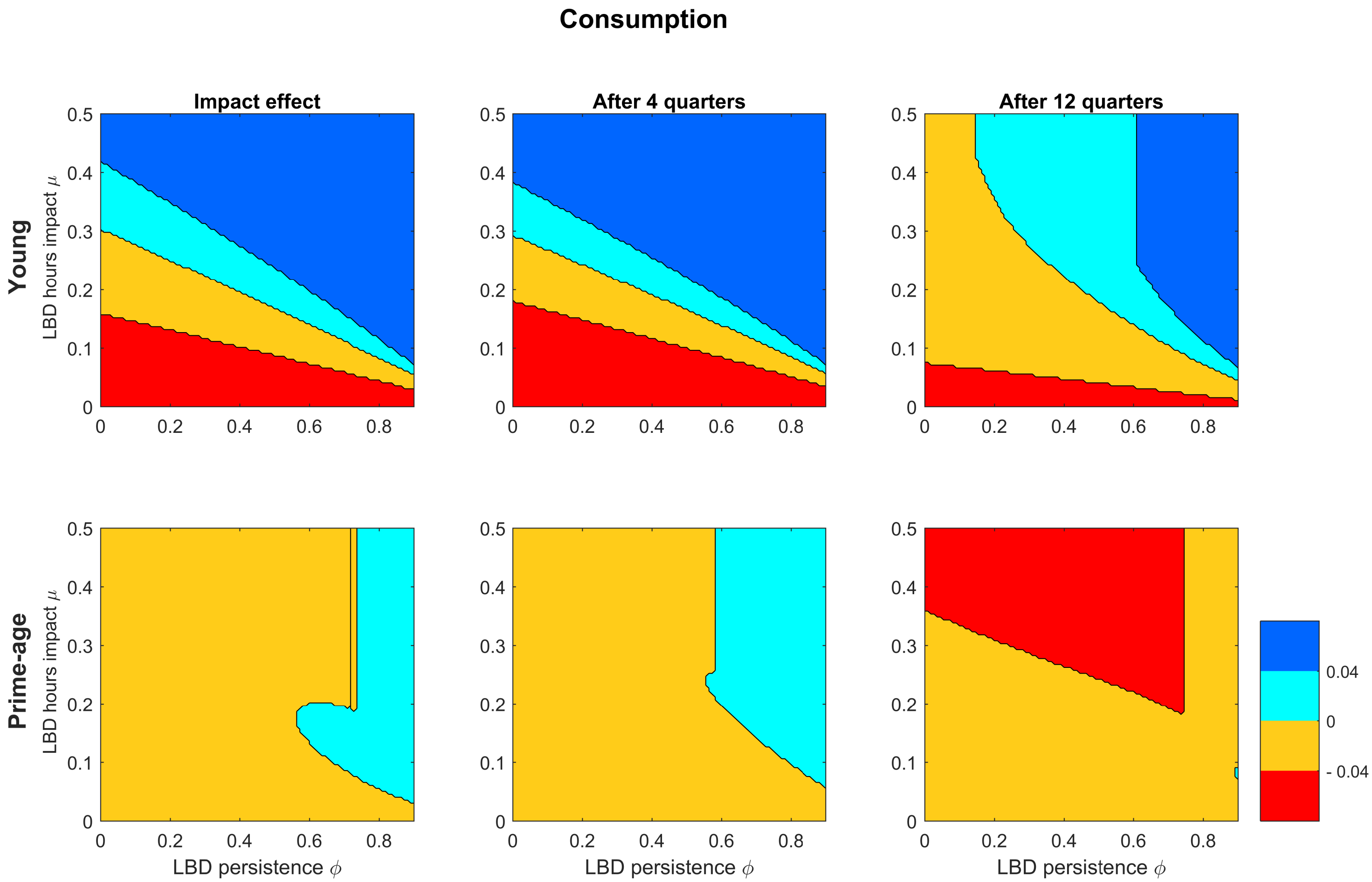
Notes: this figure shows the consumption responses for young and prime-age workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the Taylor rule parameter ϕ_π.

Figure 32: Impulse responses to a government spending shock - Sensitivity to shock persistence



Notes: this figure shows the consumption responses for young and prime-age workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the persistence of the shock ρ_G.

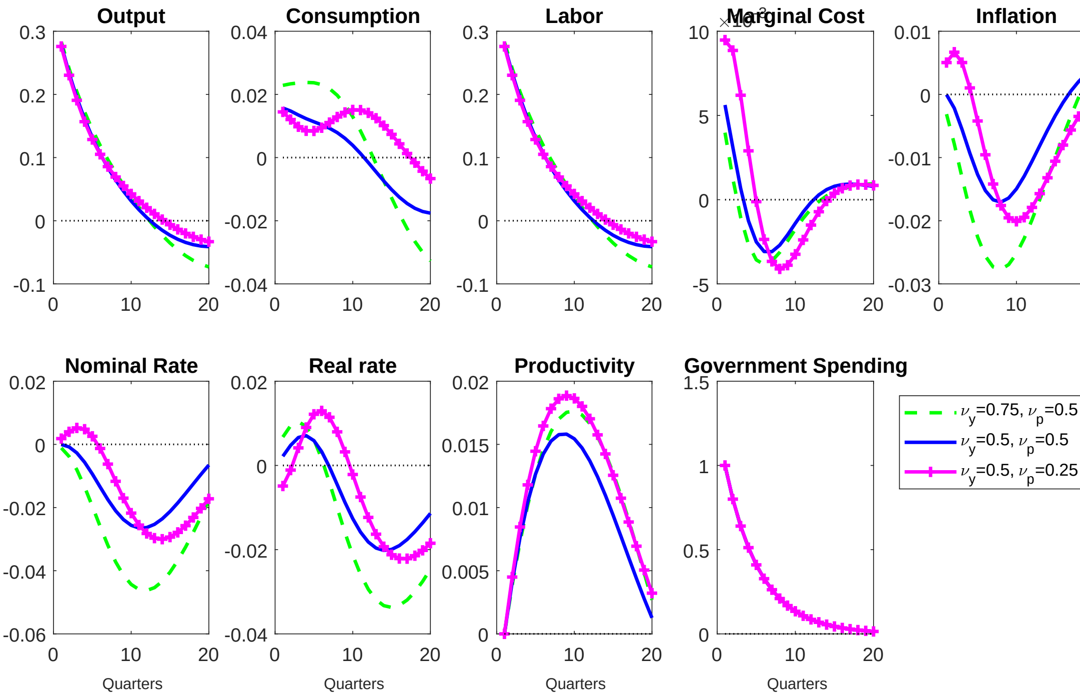
Figure 33: Impulse responses to a government spending shock - Sensitivity to learning-by-doing parameters



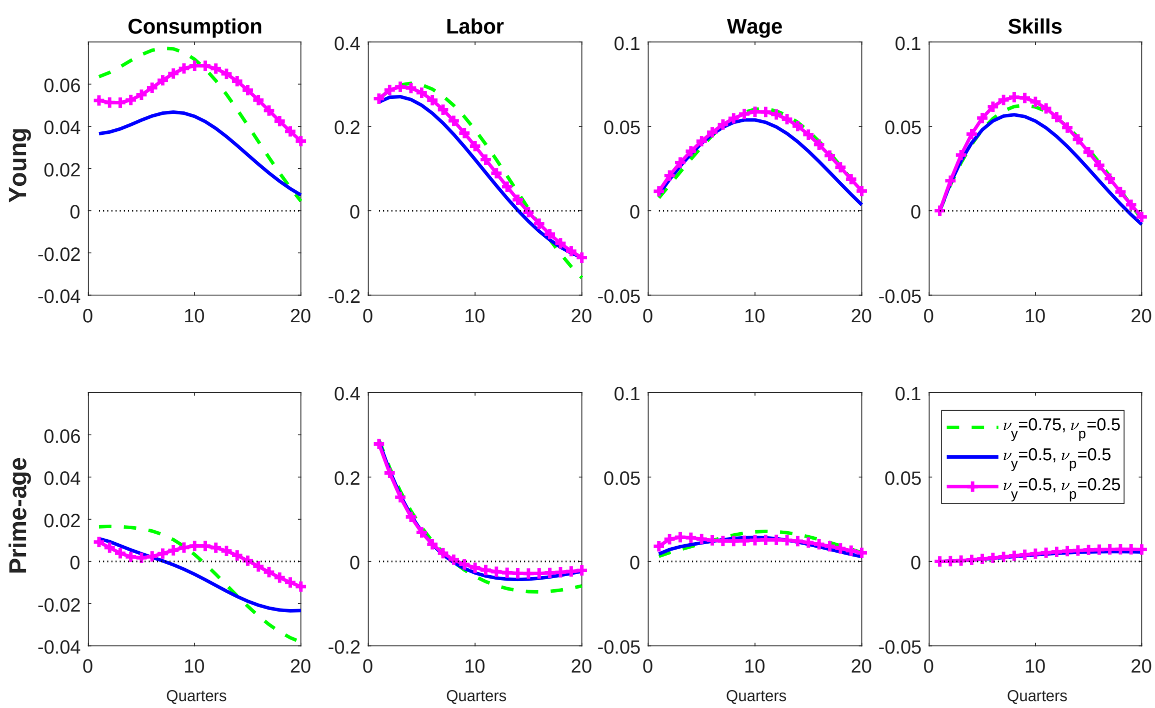
Notes: this figure shows the consumption responses for young (first row) and prime-age (second row) workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the parameters capturing the impact of past hours μ and the skill persistence ϕ.

Figure 34: Impulse responses to a government spending shock - Sensitivity to labor supply elasticity

(a) IRFs of aggregate variables



(b) IRFs of disaggregate variables



Notes: this figure shows the impulse responses of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD for different values of labor supply elasticity for young and prime-age workers: ν_y and ν_p respectively.

G Model Derivations

G.1 Solving the Optimization Problems of Households

In this Appendix, I derive the optimal decisions of each age group. I show that the decision rules of retirees are linear in wealth, so they can be linearly aggregated. In addition, as explained in the main text, the groups of young and prime-age individuals can be reduced to a representative young agent and a representative prime-age agent.

I solve the model using the certainty equivalence property of first-order perturbation.[48] The expectations operators are thus omitted. All the optimization problems and decisions rules are derived in real terms.

Problem of the Retiree

The optimization problem for retired agent i is given by

$$\begin{aligned} \max_{c^i_{r,t},b^i_{r,t}} \quad & V^i_{r,t} = \frac{{c^i_{r,t}}^{1-\sigma}}{1-\sigma} + \beta(1-\omega_x)V^i_{r,t+1} \\ \text{s.t.} \quad & \\ & c^i_{r,t} + b^i_{r,t} = a^i_{r,t} \\ & a^i_{r,t+1} = \frac{R_{n,t}}{\Pi_{t+1}} b^i_{r,t} \end{aligned} \tag{25}$$

The first-order condition with respect to consumption is given by

$$ {c^i_{r,t}}^{-\sigma} = \beta(1-\omega_x)\frac{\partial V^i_{r,t+1}}{\partial b^i_{r,t}} \tag{26}$$

From the envelope theorem condition we have

$$\frac{\partial V^i_{r,t+1}}{\partial b^i_{r,t}} = \frac{R_{n,t}}{\Pi_{t+1}} {c^i_{r,t+1}}^{-\sigma} \tag{27}$$

[48]See Schmitt-Grohé and Uribe (2004).

Combining these conditions yields the Euler equation

$$c_{r,t}^{i}{}^{-\sigma} = \beta(1-\omega_x)\frac{R_{n,t}}{\Pi_{t+1}}c_{r,t+1}^{i}{}^{-\sigma} \tag{28}$$

Next, conjecture a solution as follows, where is introduced the marginal propensity to consume $\gamma_{r,t}^i$

$$c_{r,t}^i = \gamma_{r,t}^i a_{r,t}^i \tag{29}$$

Rearranging the budget constraint we have

$$a_{r,t+1}^i = \frac{R_{n,t}}{\Pi_{t+1}}(1-\gamma_{r,t}^i)a_{r,t}^i \tag{30}$$

Substituting $c_{r,t}^i$ in the Euler equation and collecting terms we get

$$\frac{1}{\gamma_{r,t}^i} = 1 + (\beta(1-\omega_x))^{\frac{1}{\sigma}}\left(\frac{R_{n,t}}{\Pi_{t+1}}\right)^{\frac{1-\sigma}{\sigma}}\frac{1}{\gamma_{r,t+1}^i} \tag{31}$$

Therefore the marginal propensity to consume is only a function of aggregate variables, thus is identical for all retired agents $\gamma_{r,t} = \gamma_{r,t}^i \;\; \forall i$. Given the linearity of the consumption function, this implies that the aggregate consumption of retirees $c_{r,t}$ can be expressed as

$$c_{r,t} = \gamma_{r,t}a_{r,t} \tag{32}$$

where $a_{r,t}$ denotes the total wealth of retirees, which depends on the total savings of the prime-age workers who have just retired and of the retirees who are still alive.

$$a_{r,t} = (1-\omega_x)\left(\frac{R_{n,t-1}}{\Pi_t}b_{r,t-1}\right) + \omega_r\left(\frac{R_{n,t-1}}{\Pi_t}b_{p,t-1}\right) \tag{33}$$

Therefore the decision rules of retirees can be described by the following equations

$$c_{r,t} = \gamma_{r,t}a_{r,t} \tag{34a}$$

$$\frac{1}{\gamma_{r,t}} = 1 + (\beta(1-\omega_x))^{\frac{1}{\sigma}}\left(\frac{R_{n,t}}{\Pi_{t+1}}\right)^{\frac{1-\sigma}{\sigma}}\frac{1}{\gamma_{r,t+1}} \tag{34b}$$

$$a_{r,t} = (1-\omega_x)\left(\frac{R_{n,t}}{\Pi_{t+1}}b_{r,t-1}\right) + \omega_r\left(\frac{R_{n,t}}{\Pi_{t+1}}b_{p,t-1}\right) \tag{34c}$$

Problem of the Representative Prime-age Worker

The optimization problem of the representative prime-age worker is given by

$$\max_{c_{p,t}, b_{p,t}} \quad V_{p,t} = \frac{{c_{p,t}}^{1-\sigma}}{1-\sigma} - \chi_j \frac{{L_{p,t}}^{1+\varphi_p}}{1+\varphi_p} + \beta\left((1-\omega_r)V_{p,t+1} + \omega_r V_{r,t+1}\right)$$

s.t.

$$\begin{aligned} & c_{p,t} + b_{p,t} = a_{p,t} + w_{p,t}L_{p,t} - \tau_{p,t} + (1-\tau_d)\text{div}_{p,t} \\ & a_{p,t+1} = \frac{R_{n,t}}{\Pi_{t+1}} b_{p,t} \end{aligned} \tag{35}$$

The first order condition with respect to consumption is given by

$$c_{p,t}^{-\sigma} = \beta\left((1-\omega_r)\frac{\partial V_{p,t+1}}{\partial b_{p,t}} + \omega_r \frac{\partial V_{r,t+1}}{\partial b_{r,t}}\right) \tag{36}$$

Using the envelope theorem conditions yields the Euler equation

$$c_{p,t}^{-\sigma} = \beta\frac{R_{n,t}}{\Pi_{t+1}}\left((1-\omega_r)c_{p,t+1}^{-\sigma} + \omega_r c_{r,t+1}^{-\sigma}\right) \tag{37}$$

Finally, the wealth of a prime-age agent can be expressed as the total savings of the prime-age workers who do not retire and of the young agents who have just become prime-age.

$$a_{p,t} = (1-\omega_r)\left(\frac{R_{n,t-1}}{\Pi_t} b_{p,t-1}\right) + \omega_p\left(\frac{(R_{n,t-1}+\zeta)}{\Pi_t} b_{y,t-1}\right) \tag{38}$$

Thus the decision rules of the representative prime-age worker can be described by the following equations

$$c_{p,t} + b_{p,t} = a_{p,t} + w_{p,t}L_{p,t} - \tau_{p,t} + (1-\tau_d)\text{div}_{p,t} \tag{39a}$$

$$c_{p,t}^{-\sigma} = \beta\frac{R_{n,t}}{\Pi_{t+1}}\left((1-\omega_r)c_{p,t+1}^{-\sigma} + \omega_r c_{r,t+1}^{-\sigma}\right) \tag{39b}$$

$$a_{p,t} = (1-\omega_r)\left(\frac{R_{n,t-1}}{\Pi_t} b_{p,t-1}\right) + \omega_p\left(\frac{(R_{n,t-1}+\zeta)}{\Pi_t} b_{y,t-1}\right) \tag{39c}$$

Problem of the Representative Young Worker

The optimization problem of the representative young worker is given by

$$\max_{c_{y,t},b_{y,t}} \quad V_{y,t} = \frac{{c_{y,t}}^{1-\sigma}}{1-\sigma} - \chi_y \frac{{L_{y,t}}^{1+\varphi_y}}{1+\varphi_y} + \beta\left((1-\omega_p)V_{y,t+1} + \omega_p V_{p,t+1}\right)$$

$$\begin{aligned} &\text{s.t.} \\ &c_{y,t} + b_{y,t} = a_{y,t} + w_{y,t}L_{y,t} - \tau_{y,t} \\ &a_{y,t+1} = \frac{(R_{n,t}+\zeta)}{\Pi_{t+1}} b_{y,t} \end{aligned} \tag{40}$$

The decision rules of the representative young worker can be derived similarly to those for the prime-age worker.

$$c_{y,t} + b_{y,t} = a_{y,t} + w_{y,t}L_{y,t} - \tau_{y,t} \tag{41a}$$

$$c_{y,t}^{-\sigma} = \beta \frac{(R_{n,t}+\zeta)}{\Pi_{t+1}}(1-\omega_p)c_{y,t+1}^{-\sigma} + \beta \frac{R_{n,t}}{\Pi_{t+1}}\omega_p c_{p,t+1}^{-\sigma} \tag{41b}$$

$$a_{y,t} = (1-\omega_p)\left(\frac{(R_{n,t-1}+\zeta)}{\Pi_t} b_{y,t-1}\right) + \omega_x \left(\frac{R_{n,t-1}}{\Pi_t} b_{r,t-1}\right) \tag{41c}$$

G.2 Derivation of the Wage Phillips Curves

Each union solves the following optimization problem

$$\begin{aligned} V_t^{w_j}(W_{j,t-1}(k)) = &\max_{W_{j,t}(k)} \int \left(\frac{W_{j,t}(k)}{P_t} L_{j,t}(k) - \chi_j \frac{L_{j,t}(k)^{1+\varphi_j}}{1+\varphi_j} \frac{1}{\lambda_{j,t}} \right) dk \\ &- \int \frac{\theta_w}{2} \left(\frac{W_{j,t}(k)}{W_{j,t-1}(k)} - 1 \right)^2 \frac{W_{j,t}}{P_t} L_{j,t} dk + \beta \mathbb{E}_t V_{t+1}^{w_j}(W_{j,t}(k)) \end{aligned}$$

subject to

$$L_{j,t}(k) = \left(\frac{W_{j,t}(k)}{W_{j,t}} \right)^{-\varepsilon_w} L_{j,t} \qquad j \in \{y, p\}$$

The first order condition with respect to $W_{j,t}(k)$ gives

$$0 = (1-\varepsilon_w)\frac{1}{P_t}\left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w} L_{j,t} + \chi_j \varepsilon_w L_{j,t}(k)^{\varphi_j}\frac{1}{\lambda_{j,t}}\left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w-1}\frac{L_{j,t}}{W_{j,t}} - ... \\ ... - \theta_w\left(\frac{W_{j,t}(k)}{W_{j,t-1}(k)}-1\right)\frac{1}{W_{j,t-1}(k)}\frac{W_{j,t}}{P_t}L_{j,t} + \beta\mathbb{E}_t\frac{\partial V^{w_j}_{t+1}}{\partial W_{j,t}(k)} \tag{43}$$

From the envelope theorem

$$\frac{\partial V^{w_j}_{t+1}}{\partial W_{j,t}(k)} = \theta_w\left(\frac{W_{j,t+1}(k)}{W_{j,t}(k)}-1\right)\frac{W_{j,t+1}(k)}{W^2_{j,t}(k)}\frac{W_{j,t+1}}{P_{t+1}}L_{j,t+1} \tag{44}$$

Combining Equation (43) and Equation (44), we obtain

$$0 = (1-\varepsilon_w)\frac{1}{P_t}\left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w} L_{j,t} + \chi_j \varepsilon_w L_{j,t}(k)^{\varphi_j}\frac{1}{\lambda_{j,t}}\left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w-1}\frac{L_{j,t}}{W_{j,t}} - ... \\ ... - \theta_w\left(\frac{W_{j,t}(k)}{W_{j,t-1}(k)}-1\right)\frac{1}{W_{j,t-1}(k)}\frac{W_{j,t}}{P_t}L_{j,t} + \beta\mathbb{E}_t\theta_w\left(\frac{W_{j,t+1}(k)}{W_{j,t}(k)}-1\right)\frac{W_{j,t+1}(k)}{W^2_{j,t}(k)}\frac{W_{j,t+1}}{P_{t+1}}L_{j,t+1} \tag{45}$$

Using that $W_{j,t}(k) = W_{j,t}$ and $L_{j,t}(k) = L_{j,t}$, and defining the wage inflation rate $\Pi^w_{j,t} \equiv \frac{W_{j,t}}{W_{j,t-1}}$, we get

$$0 = (1-\varepsilon_w)\frac{1}{P_t}L_{j,t} + \chi_j\varepsilon_w L_{j,t}{}^{\varphi_j}\frac{1}{\lambda_{j,t}}\frac{L_{j,t}}{W_{j,t}} - \theta_w\left(\Pi^w_{j,t}-1\right)\Pi^w_{j,t}\frac{1}{P_t}L_{j,t} + ... \\ ... + \beta\mathbb{E}_t\theta_w\left(\Pi^w_{j,t+1}-1\right)\Pi^w_{j,t+1}\frac{1}{W_{j,t}}\frac{W_{j,t+1}}{P_{t+1}}L_{j,t+1} \tag{46}$$

Finally, after dividing by $L_{j,t}$ and multiplying by $W_{j,t}$, we get

$$(1-\varepsilon_w)\frac{W_{j,t}}{P_t} = -\varepsilon_w MRS_{j,t} + \theta_w(\Pi^w_{j,t}-1)\Pi^w_{j,t}\frac{W_{j,t}}{P_t} - \beta\mathbb{E}_t\theta_w(\Pi^w_{j,t+1}-1)\Pi^w_{j,t+1}\frac{L_{j,t+1}}{L_{j,t}}\frac{W_{j,t+1}}{P_{t+1}} \\ j \in \{y,p\} \tag{47}$$