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Fiscal Stimulus and Skill Accumulation over the Life Cycle

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Abstract

Using micro data from the U.S. Consumer Expenditure Survey and Current Population Survey, I document that government spending shocks affect individuals differently over the life cycle. Young households increase their consumption after an expansionary shock while prime-age households reduce it, regardless of their level of income or debt. Productivity and wages increase significantly for young workers. To rationalize these findings, I develop a parsimonious New Keynesian life-cycle model where young agents accumulate skills on the job through a learning-by-doing process. An increase in government spending raises hours worked, which enhances skill accumulation, particularly among young workers who face a steep learning curve. The ensuing increase in the relative labor demand for young workers boosts their wages, thus stimulating their consumption.

Topics: Business fluctuations and cycles; Fiscal policy; Productivity
JEL codes: D12, D15, E21, E62, J11, J24

Résumé

À l'aide de microdonnées issues des enquêtes américaines *Consumer Expenditure Survey* et *Current Population Survey*, je montre que les effets des chocs de dépenses publiques sur les individus varient au cours du cycle de vie. Quel que soit leur niveau de revenu ou d'endettement, les jeunes ménages accroissent leur consommation après un choc expansionniste, tandis que les ménages dans la force de l'âge la réduisent. En outre, la productivité et les salaires augmentent de manière significative chez les jeunes travailleurs. Pour expliquer ces résultats, j'élabore un modèle de cycle de vie parcimonieux de type néo-keynésien dans lequel les jeunes agents accumulent des compétences en milieu de travail grâce à l'apprentissage par l'expérience. Une hausse des dépenses gouvernementales accroît les heures travaillées et favorise ainsi l'accumulation de compétences, en particulier chez les jeunes travailleurs pour lesquels la courbe d'apprentissage est pentue. L'augmentation de la demande relative de main-d'œuvre qui s'ensuit pour les jeunes travailleurs fait monter leurs salaires et stimule leur consommation.

Sujets : Cycles et fluctuations économiques; Politique budgétaire; Productivité
Codes JEL : D12, D15, E21, E62, J11, J24

1 Introduction

How do government spending shocks affect individuals? Most empirical studies report heterogeneity in consumption responses, which a large strand of literature interprets as evidence of differences in marginal propensities to consume due to liquidity constraints.[1] Some studies also stress the importance of the distribution of taxes and of different labor elasticities across income groups.[2] However, other demographic and life-cycle factors may play a role in shaping these heterogeneous outcomes, but they have received little attention in this literature. One such dimension is the evolution of human capital accumulation over the life cycle.

In this paper, I provide new evidence that government spending shocks affect individuals differently over the life cycle, and I explore the role of human capital accumulation in explaining this heterogeneity. Using household level data from the U.S. Consumer Expenditure Survey (CEX), I document that young individuals raise their consumption after an increase in government purchases while the prime-age reduce it. My analysis suggests that this heterogeneity does not only reflect differences in liquidity constraints. I further bring evidence, using micro data from the Current Population Survey (CPS), that productivity significantly increases among young workers, with larger responses in wages and hours worked relative to prime-age workers.

Next, I build a parsimonious life-cycle model to rationalize this evidence. The key feature in this model is a learning-by-doing (LBD) process for young workers. LBD refers to the positive effect of time spent at work on individuals' productivity.[3] In the model, young workers accumulate skills on the job at a fast rate, while the productivity of their prime-age counterparts remains roughly stable. This is motivated by the well documented fact that the age-productivity profile is steep for younger workers and becomes flat for prime-age workers.[4] It implies that the return to learning is higher for young individuals, which may induce age-related heterogeneity in adjustment to shocks. According to my proposed mechanism, a fiscal expansion induces a surge in labor demand that increases hours worked. In turn, young workers raise their skill level through LBD and benefit from higher wage increases, which stimulates their consumption.

I start my empirical analysis by examining consumption responses to an unexpected increase in government purchases, aggregating households into pseudo-cohorts according to their

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

[2] See, e.g., Zidar (2019), Ferriere and Navarro (2020).

[3] See Arrow (1962) and Lucas (1988) for seminal contributions.

[4] The concave shape of the age-productivity profile, as predicted by the Ben-Porath (1967) model, is notably documented 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, 2007), Hellerstein et al. (1999), Fukao et al. (2006).

characteristics. I estimate impulse responses using a vector autoregressive (VAR) approach and identify fiscal shocks with a forecast-based measure using the Survey of Professional Forecasters (SPF). I find that younger households strongly increase their consumption after a positive shock, while prime-age households reduce it. This result holds across subgroups with different levels of income or debt.

Next, I explore the dynamics of human capital accumulation of young and prime-age workers after a fiscal expansion. To do so, I build a measure of age-specific productivity using data from the CPS. 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. Then, I estimate the impact of government spending shocks on these productivity series. I find that an increase in government purchases 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 wages and hours worked increase relatively more for young individuals. I confirm the evidence on the effects of fiscal policy on the productivity of young workers at the macro level using a structural VAR 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 higher share of young people.

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

Due to pricing frictions, a fiscal expansion generates an increase in aggregate demand, which in turn leads to higher labor demand. Through the LBD mechanism, young workers raise their skill level. Due to wage rigidities, this translates into a greater demand of firms for young workers, thus boosting their wages. In addition, the increase in productivity, if sufficiently powerful, pushes down marginal costs, and thus expected inflation falls.[5] 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 expansion operates through several channels. On

[5]The negative effect of government spending shocks on inflation was already documented in several papers, e.g., d'Alessandro et al. (2019) and Jørgensen and Ravn (2022).

the one hand, lower real interest rates stimulate consumption expenditures for all individuals via intertemporal substitution. On the other hand, the increase in government spending also generates asymmetric effects across age groups through redistribution, which cannot be captured in a representative agent model. In particular, young borrowers gain from lower real interest rates, at the expense of prime-age savers. In addition, young workers, who primarily finance their consumption through labor income, benefit from higher wage increases. As a result, the young workers win, while the prime-age workers partly lose, from the fiscal expansion.

The observed heterogeneity in labor market outcomes across age groups is hard to reconcile with the predictions of a model with a share of liquidity-constrained agents. To illustrate this, I compare the predictions of the life-cycle model with LBD to a model with young "hand-to-mouth" workers, who fully consume their current disposable income. Both models are able to explain the increase in young individuals' consumption and the decrease in prime-age individuals' consumption 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, and thus is more pronounced for young than for prime-age individuals, in line with the data. In contrast, the model with young hand-to-mouth workers predicts that wage growth remains subdued for both young and prime-age workers.

This study provides new insights into the transmission channels and distributional effects of government spending, as well as important policy implications. Given the accelerating demographic transition towards an older population in advanced economies, results in this paper indicate that fiscal policy measures could become increasingly less effective in boosting the economy. On the other hand, policies that promote human capital formation may increase the effectiveness of fiscal policy, particularly if they are targeted at young individuals.

Contribution to the literature. This paper relates to the literature exploring how the effect of fiscal policy shocks varies across households.[6] Most of these studies focus on consumption responses, highlighting the presence of liquidity constraints as an important determinant of household adjustment to these shocks.[7] In this paper, I further document age-related heterogeneity in the responses of productivity and other labor market variables, which have received limited attention in this literature. My findings show the importance of other life-cycle factors beyond liquidity constraints in shaping the differential consumption responses across age groups.

[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. (2021), Ferriere and Navarro (2020), Zidar (2019), Alpanda et al. (2021).

[7]See, e.g., Heathcote (2005), Galí et al. (2007), Kaplan and Violante (2014), Brinca et al. (2016), Hagedorn et al. (2019) for theoretical contributions.

This paper also adds to the literature that studies the role of demographics in the transmission of fiscal policy.[8] In particular, Basso and Rachedi (2021) find that local fiscal multipliers are larger in U.S. states with a higher population share of young people. My results, based on both 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 propose a novel mechanism that is based on the different dynamics of human capital accumulation over the life cycle. I show that it can create age-specific differences in labor demand, which in turn contribute to heterogeneous outcomes in response to government spending shocks.

Lastly, this paper relates to a strand of literature that explores the supply-side effects of fiscal policy.[9] Most of these papers document a positive response of total factor productivity (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 government spending shock induces an increase in hours worked, which leads to future human capital improvement. In this paper, I show that the increase in productivity in response to fiscal shocks is driven by young workers. As in d'Alessandro et al. (2019), the model I develop features an LBD 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 leads to important redistributive effects of government spending that cannot be captured in an economy without heterogeneity.

Outline. The remainder of the paper is structured as follows. Section 2 documents the heterogeneous effects of government spending shocks on household consumption, productivity and other labor market variables across age groups. Section 3 introduces the life-cycle model with LBD and its parametrization, followed by a description of the transmission mechanism. Section 4 concludes.

2 Empirical Analysis

This section describes the data and the econometric specification, and presents the key empirical findings. I document heterogeneity in the dynamic effects of government spending shocks on consumption and labor market variables across age groups. First, I provide evidence that young households increase their consumption after a positive spending shock, while prime-age households reduce it, even after conditioning on the level of income or debt. Second,

[8] See, e.g., Janiak and Monteiro (2016), Fiori and Ferraro (2020), Basso and Rachedi (2021).

[9] See, e.g., Evans (1992), Ramey (2011), Bachmann and Sims (2012), Aghion et al. (2014), Ben Zeev and Pappa (2015), d'Alessandro et al. (2019), Jørgensen and Ravn (2022).

I explore the role of human capital accumulation in shaping this heterogeneity. I build an age-specific measure of productivity using a wage-based approach. Results show that the impact of government spending shocks on productivity and other labor market variables is age-dependent, with greater responsiveness among young workers.

2.1 Data Description

The analysis combines data from three main sources. I identify government spending shocks using SPF data; household consumption data is from the CEX, and labor market data is from the CPS Merged Outgoing Rotation Groups. Appendix A contains more details on these datasets. The empirical analysis covers the period from 1981Q4 to 2007Q4 with quarterly data.[10]

Government spending shocks. Government spending refers to government purchases, and does not include transfer payments. Following Ramey (2011), government spending shocks are measured as the difference between actual government spending growth and the forecast of government spending growth made one quarter earlier, using SPF data.[11] Ramey (2011) shows these shocks have good explanatory power for government spending for the recent period considered in my analysis.[12] Professional forecasts implicitly contain a very rich information set that includes anticipated changes in fiscal policy and other economic and policy variables. Therefore, this forecast error measure helps to control for all available information and anticipated future policy actions. Thus it effectively deals with the issue of fiscal foresight, namely that most government spending is anticipated by economic agents prior to implementation. Furthermore, the shock is directly identified using information outside the VAR, and thus is unaffected by potential misspecifications of the model or by identification assumptions. This makes it particularly appealing for estimation techniques like distributed lag models, which require a series of previously identified structural shocks.

Consumption data. Household-level data on consumption is from the interview portion of the CEX. The survey records information on detailed categories of consumption expenditures, on demographic characteristics, as well as on labor and financial income of interviewed households. I focus on non-durable consumption expenditure, which is measured in log of real per-capita

[10]The starting date of the sample is determined by the availability of SPF data. The sample is restricted to 2007 to avoid nonlinearities caused by the onset of the Great Recession and the federal funds rate being constrained by the zero lower bound.

[11]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.

[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 *Business Week* magazine. However, the author finds that this defense news shock variable has very low predictive power if both WWII and the Korean War are excluded from the sample.

terms.[13] To conduct my analysis, I aggregate individual observations into pseudo-cohorts by age, defined by the age of the head of household; by income level, measured by household income after taxes for the past 12 months; and by housing tenure, used as proxy for household debt position, as in Cloyne and Surico (2016).[14] I define young and prime-age individuals as those aged 15-29 years and 30-64 years, respectively. The pseudo-cohorts defined by income and housing tenure are further split by age to disentangle the role of liquidity constraints from other life-cycle factors in explaining consumption responses across households.

Labor market data. Individual-level data on wages and hours worked is from the CPS, which is the source of official U.S. government labor market statistics. The survey also contains detailed information on demographic characteristics. To construct age-specific productivity series, I follow the wage-based approach of Bowlus and Robinson (2012).[15] I also build synthetic cohorts of hourly wages and hours worked based on age groups. Individuals pursuing studies, self-employed individuals, and individuals with zero or missing wages are excluded from the sample. To construct the productivity series, I further restrict the sample to full-time male workers, who usually work at least 35 hours per week.[16]

2.2 Empirical Specification

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

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

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, $B_i(L)$ is a (R+1)-order lag polynomial, and i represents the group each household belongs to. The vector $X_{i,t}$ includes the

[13] Household consumption expenditure data is divided by the number of family members and deflated by the Consumer Price Index (CPI).

[14] As explained in Cloyne and Surico (2016), housing tenure status is an effective proxy for household debt position. It can be used 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-constrained.

[15] Bowlus and Robinson (2012) use the annual March supplement of the CPS, 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.

[16] As explained in Bowlus and Robinson (2012), women have experienced considerable changes in their labor force participation, as well as fluctuating discrimination, which raises selection issues, in particular for the identification of their flat spot regions. They are thus excluded from the sample.

log of real government spending per capita and the variable of interest for household group i, 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. The variable of interest alternates between the log of real nondurable consumption per capita, the log of the productivity measure, the log of real hourly wage, and the log of hours worked. 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.

2.3 Heterogeneous Consumption Responses Across Age Groups

I start the analysis by examining the consumption responses to government spending shocks when households are grouped according to a single characteristic. In Appendix B, Figures 8 to 10 display the consumption responses across age groups, income groups, and housing tenure groups.[18] Consumption of the young group, the low-income group, and the mortgagors group increases significantly. In contrast, the response of the prime-age group, the high-income group, and the non-mortgagors group is negative or not statistically different from zero. This heterogeneity in consumption responses is consistent with evidence reported in Anderson et al. (2016), De Giorgi and Gambetti (2012) and Alpanda et al. (2021), and is broadly in line with the predictions of theoretical macroeconomic models in which a fraction of consumers faces liquidity constraints. Specifically, households who are liquidity-constrained or who lack access to financial markets have a high marginal propensity to consume out of transitory income changes. Therefore they 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 lifetime resources decreases due to the associated higher taxes.

Next, I examine consumption responses after splitting each income group (or housing tenure group) by age.[19] Figure 1 displays the responses of consumption to a government spending shock for young (first column) and prime-age households (second column), grouped by their income level (Panel (a)) and by their housing tenure (Panel (b)), respectively. Panel (a) shows that young households increase their consumption, whether they have a low or high income, with a peak six quarters after the shock. In contrast, prime-age households reduce or do not adjust their consumption. Panel (b) shows that the same conclusion applies when analyzing the responses of

[17]The results are robust to assuming different lag structures (see Section 2.5).

[18]Households are split in two income groups, depending on whether their after-tax income is below or above the 35th percentile.

[19]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. The results are robust to considering outright owners and renters separately, with less precise estimates for young outright owners.

age groups by their housing tenure. In the rightmost column, the impulse responses of the ratio of consumption between young and prime-age households confirm that the young tend to adjust their consumption relatively more than the prime age across the different income and housing tenure groups. Note that the responses of young households in the low-income group or in the mortgagors group are more pronounced on impact, which likely reflects the presence of liquidity constraints.

Figure 2 reports the impulse responses of total household gross income and after-tax income for young and prime-age groups. Gross income increases significantly for young households and reaches a peak after six quarters. However, gross income responds less for prime-age households. These estimates indicate that the heterogeneous responses of consumption across age groups could be driven by differential movements in income. There is no significant difference between the responses of gross and net income for both age groups. Therefore it seems unlikely that different movements in taxes are driving the heterogeneity in consumption responses.

In summary, these estimates suggest that age is a key determinant of consumption adjustment to government spending shocks, with larger responses for young households. Although liquidity constraints play a role in shaping individual consumption responses, this heterogeneity appears to reflect differences in income responses across age groups. In the next subsection, I provide new evidence that differential productivity responses to government spending shocks may account for this age-specific heterogeneity.

2.4 Heterogeneous Productivity Responses Across Age Groups

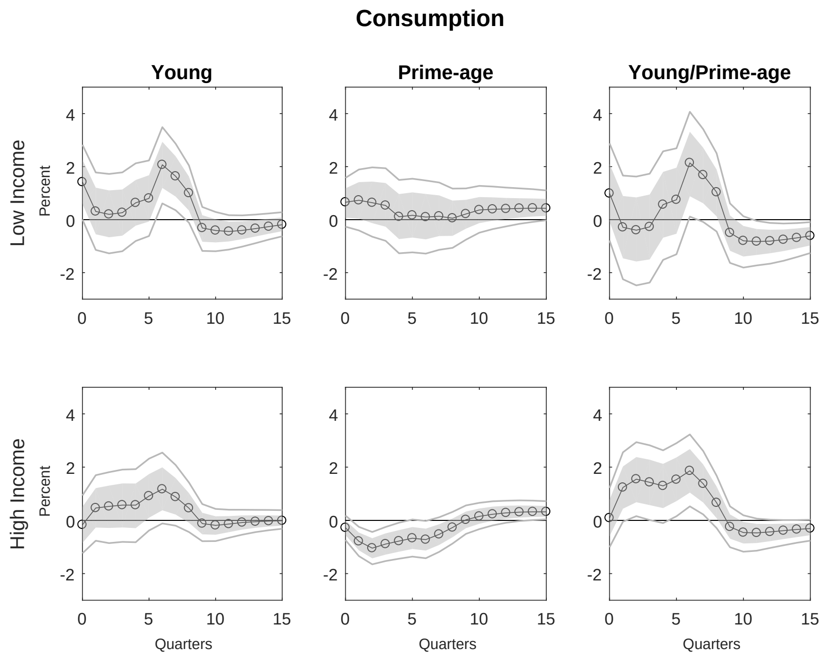
In this subsection, I examine the impact of government spending shocks on productivity across age groups. To do so, I identify the number of supplied efficiency units from the real hourly wage for each age group. I use these efficiency time series as proxy for the productivity of workers. Then, I estimate the impulse response of this measure of productivity to government spending shocks for young and prime-age workers separately.

To identify the number of efficiency units from the wage, I follow the wage-based approach of Bowlus and Robinson (2012), inspired by the Ben-Porath (1967) model of optimal life-cycle production of human capital and its extensions.[20] 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, which are both unobservable. It is assumed that there are different "types" of human capital, associated with different education levels, implying different

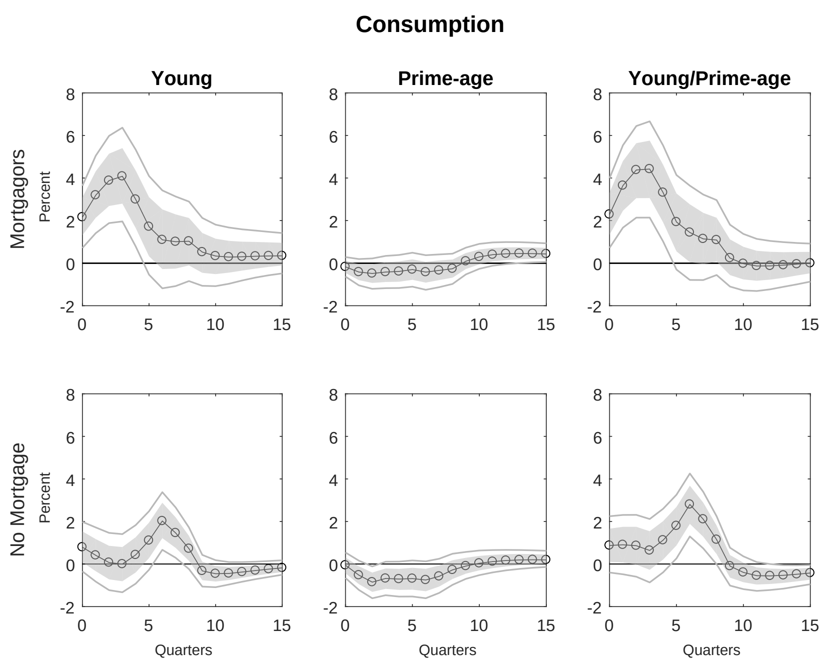
[20]Bowlus and Robinson (2012) extend the Ben-Porath framework by incorporating two sources of cohort effects, namely selection on ability in education choices as well as technological change.

Figure 1: Impulse response functions (IRFs) to government spending shocks

(a) By age and income level

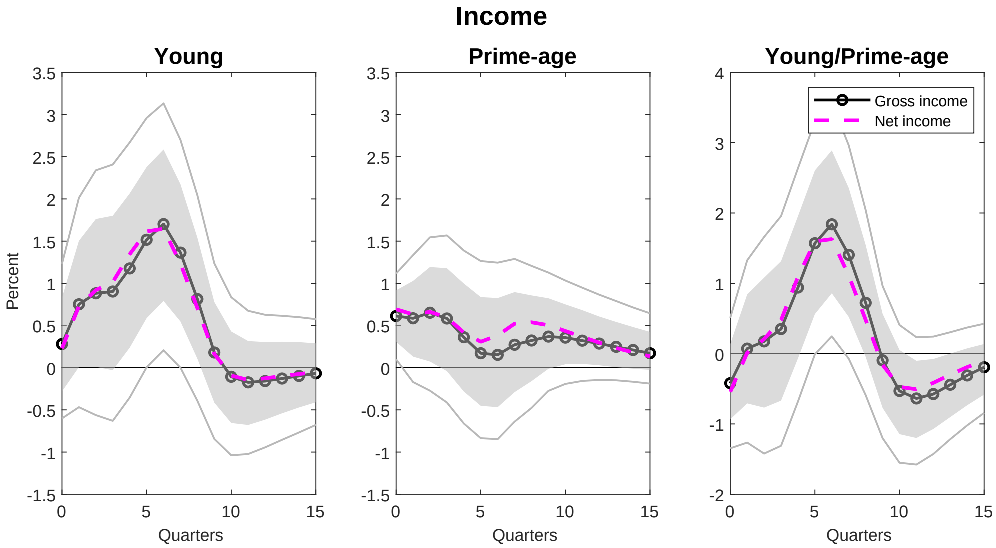


(b) By age and housing tenure



Notes: These graphs show the IRFs 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 expenditure. The IRFs for young households (under 30 years of age) are depicted on the first column, for prime-age households (30-64 years of age) on the second column, and for the ratio between young and prime-age households on the last column. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 2: IRFs of gross and net income to government spending shocks



Notes: These graphs show the IRFs of gross and net income for young and prime-age households to a 1% shock to government expenditure. The impulse responses of the ratio between young and prime-age households are displayed in the rightmost graph. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown.

prices. At each period, the prices are assumed to be identical for all workers in a given education group.

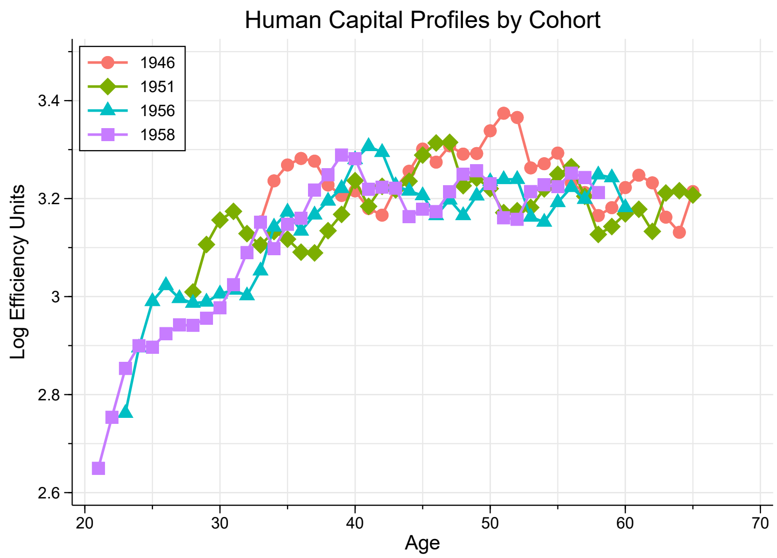
According to human capital theory, individuals have fewer incentives to invest in human capital toward the ends of their working lives. This implies that wage changes for older workers are more likely to reflect changes in prices than changes in efficiency. Based on this insight, the key strategy for identifying prices from observed wages is to assume that supplied efficiency units are constant over a flat spot age range. Thus, the change in the wage between two periods for workers in their flat spot corresponds to the change in the price. This assumption offers a way to construct price series for each education group. Then, productivity of a given group of workers can be calculated by dividing the real hourly wage by the price.

To construct the price series, I consider two education levels: low-educated workers are defined as having at most a high school diploma, and high-educated workers as having some college and more. I assume that the flat spot age regions are 48-57 for the high-educated, and 44-53 for the low-educated, in line with Bowlus and Robinson (2012).[21] 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.

[21] 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.

Figure 3 depicts the life-cycle profile of productivity for different cohorts of workers.[22] As predicted by the Ben-Porath model, the profile is steep for young workers and gradually becomes flat for prime-age workers. The life-cycle profile is very similar across the different cohorts.

Figure 3: Estimated productivity life-cycle profiles by cohort

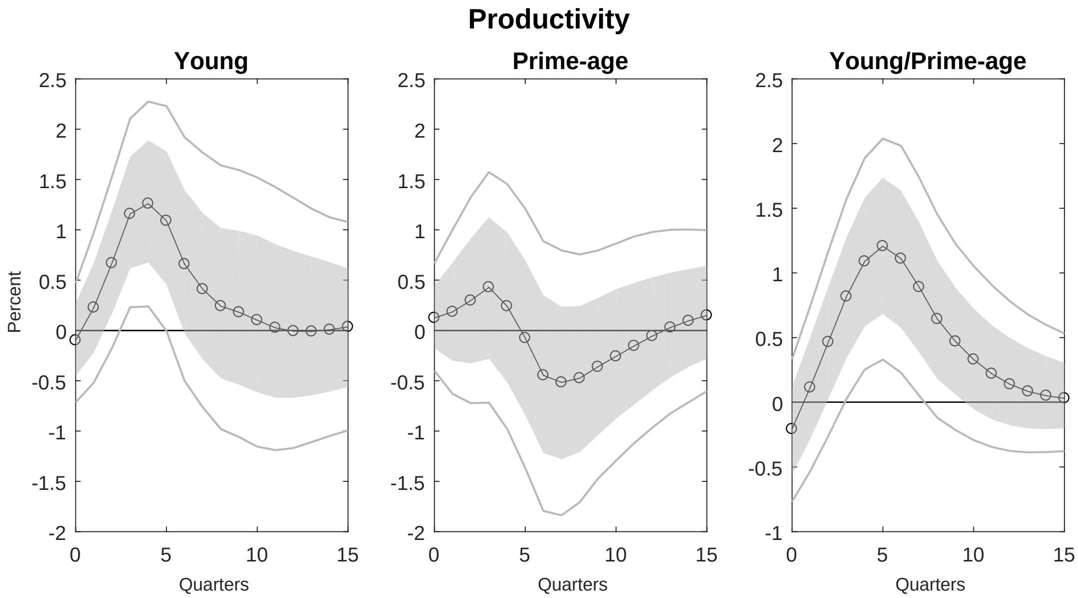


Next, I estimate the dynamic impact of government spending shocks on productivity for young and prime-age groups using the VAR specification discussed in Section 2.2. The estimated impulse response functions of productivity for both age groups are reported in Figure 4. Productivity of the young increases significantly, 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. I further examine the effects of government spending shocks on wages and hours worked for young and prime-age agents. Figure 5 shows that wages of young workers increase significantly at the 32% level after a few quarters and reach a peak six quarters after the shock, while the response of the prime-age group is not statistically significant. These estimates are consistent with the evidence for total income reported in Section 2.3. In addition, hours worked strongly increase in the short run for young people and, to a lesser extent, for prime-age people. The impulse response functions of the ratios, displayed in the rightmost column, confirm the greater responsiveness of productivity, wages and hours worked to positive government spending shocks for young workers.

Overall, these results suggest that the positive impact of government spending shocks on hours is accompanied by an increase in productivity and wages among young workers, in contrast to

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

Figure 4: IRFs of productivity to government spending shocks



Notes: These graphs show the IRFs of measured productivity to a 1% shock to government expenditure for young and prime-age workers, as well as for the ratio between 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.

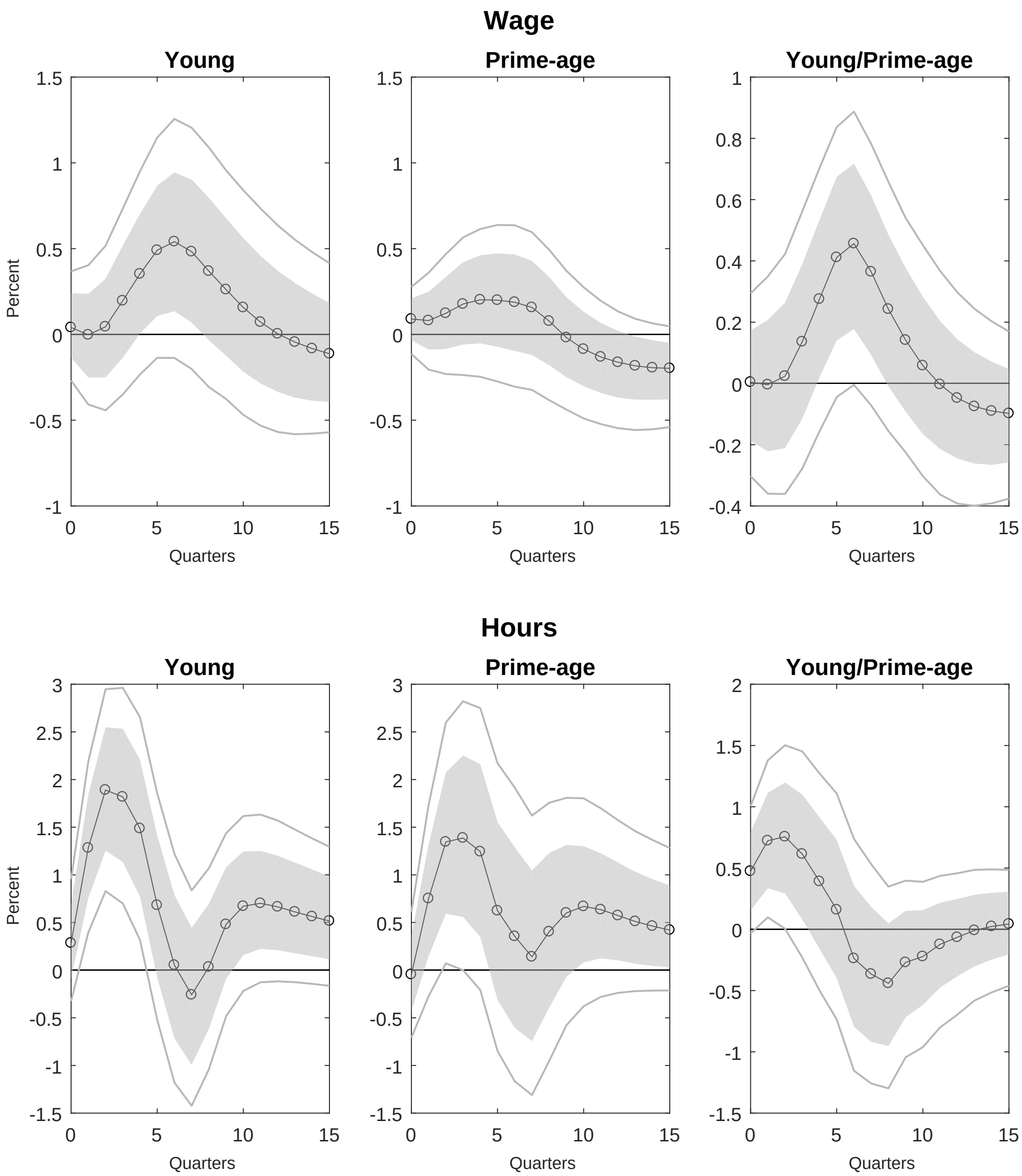
prime-age workers who experience insignificant change. This age-specific impact on productivity seems to be a good candidate for explaining the different consumption responses across age groups to shifts in government expenditure. In Section 3, I show that these findings can be rationalized with a New Keynesian life-cycle model featuring a skill accumulation mechanism for young workers.

2.5 Robustness and Extensions

Heterogeneous effects on consumption. Results documented in Section 2.3 hold when considering other proxies for liquidity constraints, such as educational attainment and financial market participation. As a 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.[23] 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

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

Figure 5: IRFs of wages and hours worked to government spending shocks



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

households, for which added hours worked of head and spouse are strictly positive. The results are similar.

A concern when splitting households according to their housing tenure or income level is the possibility of endogenous changes in group composition over time. To tackle this issue, I consider another grouping estimator using the propensity score approach proposed in Attanasio et al. (2002), which holds the composition of the group constant. Specifically, for each age group, the predicted probability of being a mortgagor (or having a low income) is estimated based on variables that are fully predictable from one period to the next, namely age and education. Results are not overturned. I also estimated the impulse responses of the group shares to an unexpected government spending shock. The estimates suggest that government spending shocks do not lead to significant compositional change. All related figures can be found in Appendix D.1.

Further robustness. I perform additional robustness checks of the main findings regarding the age-dependent effects of government spending shocks on consumption, productivity, wages and hours worked. I check the sensitivity of the results to another measure of government spending shocks that explicitly controls for information provided by several macroeconomic variables and for other forecasts. Specifically, I regress real government spending growth on the one-quarter ahead forecast of government spending growth and lags of government spending, tax revenues, output and unemployment. I also include in the regressors the one-year ahead forecast of annual output growth, since government spending forecasts can be driven by expected changes in output. The shocks are defined as the estimated residuals from this regression. Estimated impulse responses are qualitatively similar to benchmark results. Similar results are also obtained with alternative dynamic specifications. Finally, I check that the results based on the age-specific productivity measures are robust to alternative specifications of the flat spot ranges. All related figures are reported in Appendix D.2.

Cross-country evidence. In Appendix E, I provide further evidence of the age-dependent effects of government spending shocks on consumption and productivity using a structural VAR for a panel of countries. Following Ilzetzki et al. (2013), government spending shocks are identified using the Blanchard and Perotti (2002) identification strategy. Results show that there is a strong and significant increase in both productivity and consumption after a positive spending shock in the group of countries with higher shares of young people in the total population. In contrast, in the group with low shares of young people, productivity remains virtually unchanged while consumption significantly drops after the shock.

3 A Life-Cycle Model with Learning By Doing (LBD)

In this section, I build a New Keynesian DSGE model with a parsimonious life-cycle structure that rationalizes the empirical findings documented in Sections 2.3 and 2.4. The key feature is an LBD mechanism, which I introduce for young workers. The model illustrates how different dynamics of human capital accumulation over the life cycle lead to redistribution effects of government spending that differentially affect young and prime-age workers' incentives to consume.

3.1 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, nor 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 they attain prime age. I further incorporate life-cycle human capital accumulation. During the earlier phase of their working life, workers are young and accumulate skills on the job. In the second phase of their career, when they attain prime age, workers are assumed to have reached their highest level of productivity, which remains stable. To model skill accumulation, I specify an LBD 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 expenditure 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 agent models, notably because the wealth distribution responds endogenously to aggregate shocks. Gertler (1999) proposes a tractable overlapping generations setup which allows deriving 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, following Sterk and Tenreyro (2018). In particular, this strategy allows the introduction of wage rigidity and of standard preferences. Although there is no within-group heterogeneity in this model, between-group heterogeneity, i.e., across the age dimension, is preserved. The model can be solved with standard linearization methods, using the certainty equivalence property of the first order approximation.[24]

3.1.1 Households and Life-cycle Structure

The economy is populated by a continuum of households who belong to three different age groups: young (y), prime age (p) and retiree (r). At each period, young agents face a constant probability of becoming prime age 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 the total population can be computed using the fact that the number of new prime-age agents is equal to the number of prime-age workers retiring, i.e., $\omega_p N_y = \omega_r N_p$, and the number of prime-age workers 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 workers, prime-age workers, and retirees, respectively. Therefore, denoting ν_y, ν_p and ν_r the shares of each age group, we get:

$$\begin{aligned} \nu_y &= \frac{1}{1 + \frac{\omega_p}{\omega_r} + \frac{\omega_p}{\omega_x}} \\ \nu_p &= \frac{1}{1 + \frac{\omega_r}{\omega_p} + \frac{\omega_r}{\omega_x}} \\ \nu_r &= 1 - \nu_y - \nu_p \end{aligned} \tag{2}$$

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 $A^i_{j,t+1}$

[24]Details of the derivations are provided in Appendix H.

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.

$$\begin{cases} P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} + W^i_{j,t} L^i_{j,t} - P_t \tau^i_t + \mathrm{bq}^i_{j,t} + P_t {\tau^G_{NY,t}}^i & \text{if } j = \{y\} \\ P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} + W^i_{j,t} L^i_{j,t} - P_t \tau^i_t + (1-\tau_d)\mathrm{div}^i_t + P_t {\tau^G_{NP,t}}^i & \text{if } j = \{p\} \\ P_t C^i_{j,t} + B^i_{j,t} = A^i_{j,t} & \text{if } j = \{r\} \end{cases} \tag{3}$$

$$A^i_{j,t+1} = (R_{n,t} + \zeta \mathbb{I}_{\{j=y\}}) B^i_{j,t}$$

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 $\mathrm{bq}^i_{j,t}$ among young individuals. Prime-age agents earn nominal dividends $\mathrm{div}_{j,t}$, taxed at proportional rate τ_d, from imperfectly competitive intermediate firms. Young and prime-age individuals pay the same amount of lump-sum taxes. Finally, the newborns and new prime-age individuals receive government transfers ${\tau^G_{NY,t}}^i$ and ${\tau^G_{NP,t}}^i$, respectively.[25]

3.1.2 Firms

The supply side of the economy is composed of a continuum of firms under monopolistic competition that 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.

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

$$Y_t = \left(\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}} dz \right)^{\frac{\epsilon}{\epsilon-1}} \tag{4}$$

where Y_t corresponds to the quantity of the final good and $Y_t(z)$ to the quantity of intermediate

[25] As explained in Section 3.1.4, this assumption aims at making the model tractable.

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

$$Y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon} Y_t \tag{5a}$$

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

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

$$Y_t(z) = L_t(z). \tag{6}$$

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

$$L_t(z) = \left(\nu_y (X_{y,t} L_{y,t}(z))^{\frac{\eta-1}{\eta}} + \nu_p (X_{p,t} L_{p,t}(z))^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{7a}$$

$$L_{y,t}(z) = \left(\frac{1}{\nu_y}\int_0^{\nu_y} L_{y,t}(z,k)^{\frac{\varepsilon_w-1}{\varepsilon_w}} dk\right)^{\frac{\varepsilon_w}{\varepsilon_w-1}} \tag{7b}$$

$$L_{p,t}(z) = \left(\frac{1}{\nu_p}\int_{\nu_y}^{\nu_y+\nu_p} L_{p,t}(z,k)^{\frac{\varepsilon_w-1}{\varepsilon_w}} dk\right)^{\frac{\varepsilon_w}{\varepsilon_w-1}} \tag{7c}$$

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.[26] $X_{y,t}$ 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 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 LBD 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.

[26] 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.

(2019), firms take productivity levels as given.

$$X_{y,t} = X_{y,t-1}^{\phi} L_{y,t-1}^{\mu} \tag{8a}$$

$$X_{p,t} = X_{p,t-1}. \tag{8b}$$

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

$$L_{j,t}(z,k) = \left(\frac{W_{j,t}(k)}{W_{j,t}}\right)^{-\varepsilon_w} L_{j,t}(z) \qquad \text{for} \;\; j \in \{y,p\} \tag{9}$$

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

$$W_{y,t} = \left(\frac{1}{\nu_y}\int_0^{\nu_y} W_{y,t}(k)^{1-\varepsilon_w} dk\right)^{\frac{1}{1-\varepsilon_w}} \tag{10a}$$

$$W_{p,t} = \left(\frac{1}{\nu_p}\int_{\nu_y}^{\nu_y+\nu_p} W_{p,t}(k)^{1-\varepsilon_w} dk\right)^{\frac{1}{1-\varepsilon_w}}. \tag{10b}$$

Finally, taking the wage indexes $W_{y,t}$ and $W_{p,t}$ as given, each firm minimizes labor costs subject to Equation (7a). The optimality conditions with respect to $L_{y,t}(z)$ and $L_{p,t}(z)$ yield

$$MC_t = \left(\nu_y \left(\frac{W_{y,t}}{X_{y,t}}\right)^{1-\eta} + \nu_p \left(\frac{W_{p,t}}{X_{p,t}}\right)^{1-\eta}\right)^{\frac{1}{1-\eta}} \tag{11a}$$

$$\frac{L_{y,t}}{L_{p,t}} = \left(\frac{W_{y,t}}{W_{p,t}}\right)^{-\eta} \left(\frac{X_{y,t}}{X_{p,t}}\right)^{\eta-1} \tag{11b}$$

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

$$\max_{P_t^*(z)} \;\; \mathbb{E}_t \left(\sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} \left[P_t^*(z) - MC_{t+s}\right] Y_{t+s}(z)\right) \tag{12}$$

subject to the final goods firm's demand constraint Equation (5a) 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

$$P_t^*(z) = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} P_{t+s}^{\epsilon-1} Y_{t+s}(z) MC_{t+s}}{\mathbb{E}_t \sum_{s=0}^{\infty} \theta_p^s Q_{t,t+s} P_{t+s}^{\epsilon-1} Y_{t+s}(z)} \tag{13a}$$

$$P_t = \left((1-\theta_p) P_t^*(z)^{1-\epsilon} + \theta_p P_{t-1}^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}} . \tag{13b}$$

3.1.3 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 3.1.2. 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.[27] The adjustment cost parameter θ_w is the same for 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

[27]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.

rate.[28]

$$(1-\varepsilon_w)\frac{W_{j,t}}{P_t} = -\varepsilon_w MRS_{j,t} + \theta_w(\Pi^w_{j,t}-1)\Pi^w_{j,t}\frac{W_{j,t}}{P_t} - \beta\mathbb{E}_t\theta_w(\Pi^w_{j,t+1}-1)\Pi^w_{j,t+1}\frac{L_{j,t+1}}{L_{j,t}}\frac{W_{j,t+1}}{P_{t+1}} \quad j\in\{y,p\}\,. \tag{15}$$

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.[29]

3.1.4 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.

$$B_{G,t} = R_{n,t-1}B_{G,t-1} + P_tG_t - P_tT_t + P_t(\nu_y\omega_x\tau^G_{NY,t} + \nu_p\omega_p\tau^G_{NP,t}) - \tau_d\nu_p\text{div}_t. \tag{16}$$

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

$$P_tT_t = \Phi_B B_{G,t} + \Phi_G P_t G_t. \tag{17}$$

Government spending evolves exogenously and follow a first-order autoregressive process.

$$G_t = \rho_G G_{t-1} + \varepsilon_{G,t}. \tag{18}$$

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-age and pre-existing prime-age. This ensures that all young

[28]See details in Appendix H.

[29]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.

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

$$\begin{aligned} P_t \tau^G_{NY,t} &= A_{y,t} \\ A_{y,t} + P_t \tau^G_{NP,t} &= A_{p,t} \end{aligned} \tag{19}$$

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.

3.1.5 Monetary Policy

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

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\gamma} \left[\left(\frac{\Pi_t}{\Pi_{ss}}\right)^{\phi_\pi}\right]^{1-\gamma} \tag{20}$$

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

3.1.6 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 agents who do not become prime age. The laws of motion of assets held by prime-age and retired agents can be defined similarly.

$$A_{y,t} = (1-\omega_p)\left((R_{n,t-1}+\zeta)B_{y,t-1}\right) + \omega_x\left(R_{n,t-1}B_{r,t-1}\right) \tag{21a}$$

$$A_{p,t} = (1-\omega_r)\left(R_{n,t-1}B_{p,t-1}\right) + \omega_p\left((R_{n,t-1}+\zeta)B_{y,t-1}\right) \tag{21b}$$

$$A_{r,t} = (1-\omega_x)\left(R_{n,t-1}B_{r,t-1}\right) + \omega_r\left(R_{n,t-1}B_{p,t-1}\right). \tag{21c}$$

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

$$X_{y,t} = (1 - \omega_p) \left(X_{y,t-1}^{\phi} L_{y,t-1}^{\mu} \right) + \omega_x X_{y,0} \tag{22a}$$

$$X_{p,t} = (1 - \omega_r) X_{p,t-1} + \omega_p \xi_p X_{y,t-1} \tag{22b}$$

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 the total population, and similarly for total taxes. Markets for bonds and goods clear.[30]

$$C_t = \nu_y C_{y,t} + \nu_p C_{p,t} + \nu_r C_{r,t} \tag{23a}$$

$$T_t = (\nu_y + \nu_p) \tau_t \tag{23b}$$

$$B_{G,t} = \nu_y B_{y,t} + \nu_p B_{p,t} + \nu_r B_{r,t} \tag{23c}$$

$$Y_t = C_t + G_t. \tag{23d}$$

3.2 Calibration

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

Demographic structure. As in the empirical analysis, young individuals are defined as between 15 and 29 years old, and prime-age individuals 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 the 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-state hours of prime-age workers by the relative employment rates of young and prime-age workers in the data.[31] The Frisch elasticities are set to $\varphi_y = 0.5$ and $\varphi_p = 0.5$, in line with conventional micro estimates.[32] The subjective discount factor is fixed to match an annualized interest rate at steady state of 2%,

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

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

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

which leads to $\beta = 0.97$. The risk premium faced by young agents is calibrated to match the consumption ratio of prime-age individuals relative to young individuals 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).[33] The profits are fully taxed.

Learning by doing. The LBD parameters 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-age relative to young workers in the data, which is approximately equal to 1.5. 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).

3.3 Results

Figure 6 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

[33] Welch (1979) finds values 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.

steady state.

Let us first consider the responses of aggregate variables (Panel (a)). A positive government expenditure shock leads to a negative wealth effect because 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. Because prices are sticky, firms increase their production to meet higher demand; hence, there is 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. In turn, inflation increases, since it depends on current and expected future marginal costs.[34] 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 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 consistent with my estimates based on aggregate data, displayed in Appendix C, and with evidence reported notably in Jørgensen and Ravn (2022) and d'Alessandro et al. (2019).[35]

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, while lower inflation increases the value of holdings of nominal bonds, the decline in interest rates favors borrowers and penalizes savers. Young agents increase borrowing, while prime-age agents are hurt by lower interest income. 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

[34]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.

[35]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), and Hall and Thapar (2021).

mechanism, as they supply more hours. However, their productivity growth is 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 into 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 their consumption. However, for prime-age individuals, the negative redistribution effects generated by the fiscal expansion and the negative wealth effect associated with increased taxation tend to dominate, leading to a small reduction of their consumption.

3.4 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 G.

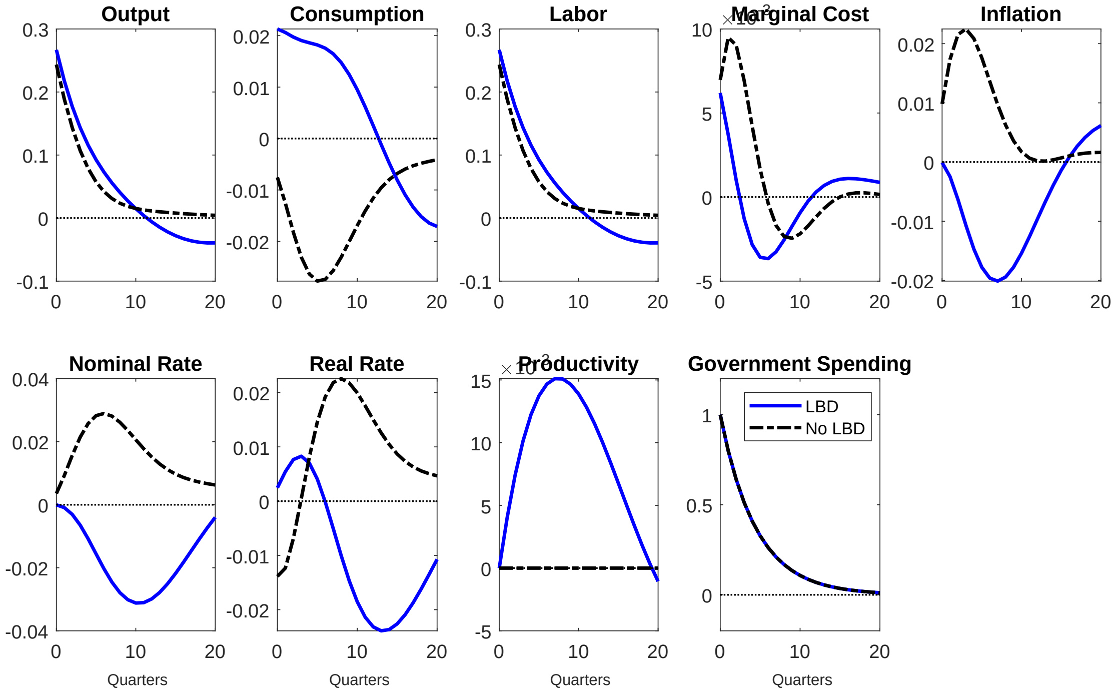
First, it is worth noting that price and wage rigidities are critical in generating an increase in consumption for young agents. Figure 24 shows the impulse responses to a government spending shock in the baseline case with nominal frictions, compared to the case with flexible price and wages. Without 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 young workers.[36] 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. However, as showed in Figure 25 and Figure 26, 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 27 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 young agents, and becomes less negative for prime-age agents.

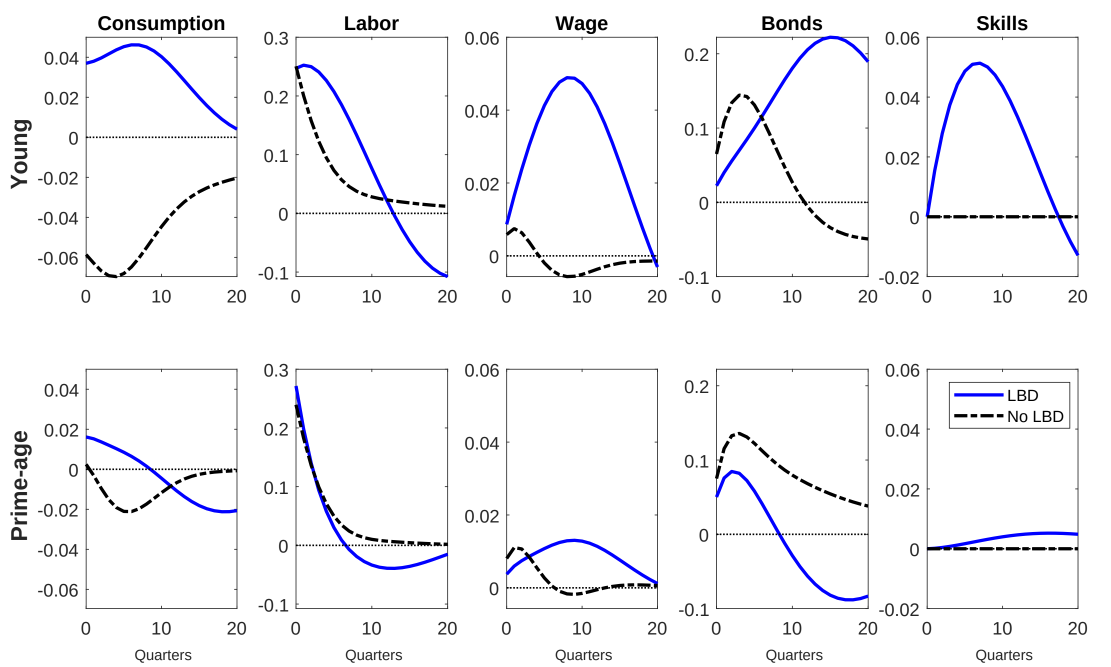
[36] Marginal costs and inflation are unchanged in the case of flexible prices.

Figure 6: IRFs 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 IRFs 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).

Figure 28 displays the responses of consumption for young and prime-age agents 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 redistribution effect from higher wages and lower real interest rates. As a result, young agents also reduce their consumption for high values of the persistence.

Figure 29 reports the sensitivity of consumption responses for young and prime-age agents to the fiscal rule parameters at different horizons. The consumption responses among young agents are always positive and display little sensitivity to the fiscal rule parameters. Therefore, everything else being equal, the negative wealth effect from higher taxes is always lower than the positive redistribution effect from higher wages and lower real interest rates. Young people anticipate that they will have to pay higher taxes, either while they are still young or when they will be prime-age workers, so their consumption decision is little affected by the timing of taxes or the extent of deficit financing of government spending. The consumption response of prime-age agents is broadly negative, except for lower values of Φ_B and Φ_G, corresponding to a higher degree of deficit financing and a lower response to debt. In this case, debt is allowed to accumulate for a long time and taxes are raised very gradually. Therefore the negative wealth effect is reduced for prime-age agents since they expect the burden of taxes to fall on the next generations of workers.

Figure 30 reports the sensitivity of consumption responses for young and prime-age agents to the LBD parameters at different horizons. The figure shows that the consumption response of young agents is positive for a reasonably large range of values, while it is broadly negative for prime-age agents.

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 literature, in particular to partially account for the greater volatility of hours of young relative to prime-age workers, as observed in the data.[37] Figure 31 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 that young individuals have higher labor supply elasticity than prime-age individuals.

[37] 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.

3.5 Discussion: Model with Hand-to-Mouth Agents

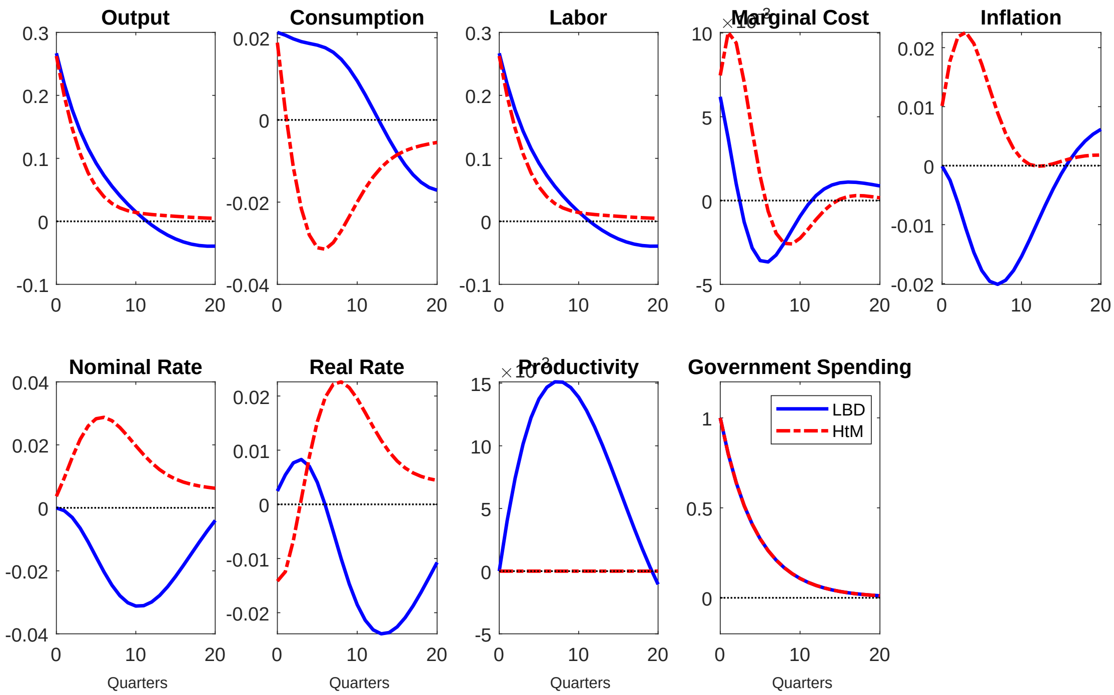
Introducing hand-to-mouth agents is a key mechanism for generating asymmetric consumption responses to government spending shocks across individuals. "Hand-to-mouth" agents fully consume their current disposable income because they can neither borrow nor save due to liquidity constraints or a lack of access to financial markets. Galí et al. (2007) show that these households increase their consumption after a government spending shock in the 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 preserved and reinforced when assuming that wages are sticky. This theory could also justify why young agents, more likely to be liquidity 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 3.1 to a life-cycle model where a share of young agents behave in a "hand-to-mouth" fashion. Figure 7 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 agents is set equal to 0.5 in the model with liquidity constraints. At the aggregate level, both models predict an increase in labor, output and consumption. However, the model with liquidity constraints predicts an increase in marginal costs due to the surge in real wages, which is not counteracted by a rise in productivity. This increase in marginal costs 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 discussed in Section 3.3.

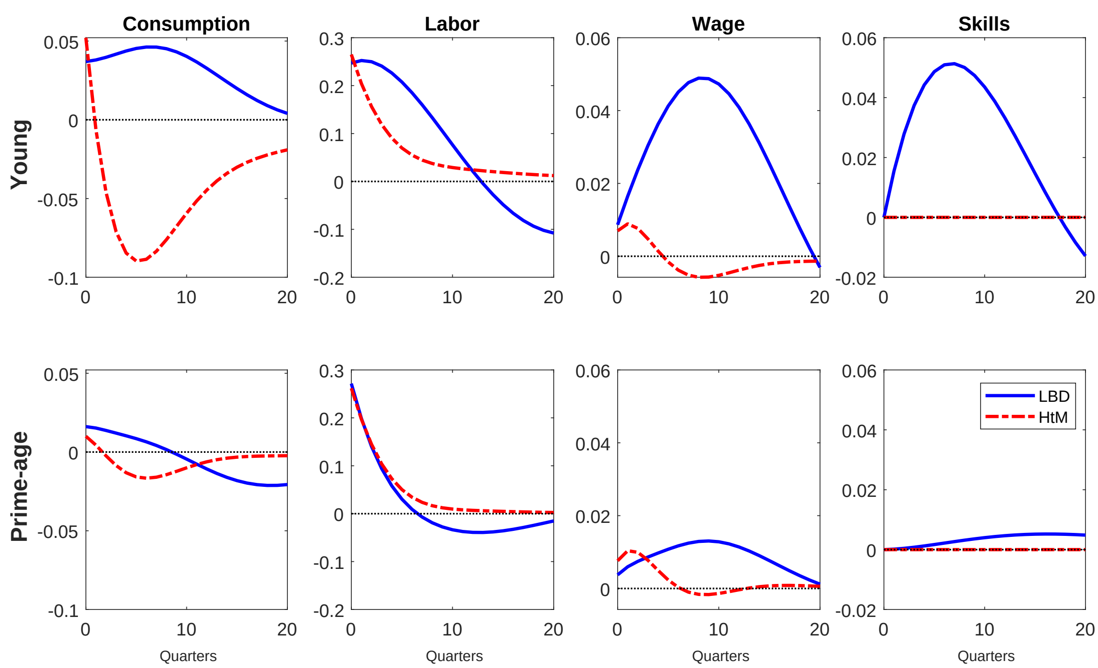
Turning to disaggregate variables, consumption strongly increases for young individuals in both models, while it remains flat or decreases for prime-age individuals. The increase in consumption for young individuals is more pronounced on impact in the model with liquidity constraints, but is less persistent 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 prime-age agents, reflecting their increase in skills, while the response of wages is nearly flat for both young and prime-age individuals in the

Figure 7: IRFs of selected variables to an expansionary government spending shock in the life-cycle model with LBD vs. with hand-to-mouth agents

(a) IRFs of aggregate variables



(b) IRFs of disaggregate variables



Notes: This figure shows the impulse response functions 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 young hand-to-mouth agents (red dashed lines).

model with liquidity constraints. As shown in Section 2.4, evidence suggests that the growth in real wages is more pronounced for young workers, as predicted by the model with LBD.

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 young hand-to-mouth workers does not capture. However, liquidity constraints and human capital accumulation likely interact.[38] Quantifying the relative contribution of each of these channels in shaping these differential outcomes across age groups would certainly yield interesting insights.

4 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 at business-cycle frequency. First, I provide new evidence, using U.S. micro-level data, that young people are more responsive to government spending shocks. They raise their consumption after a fiscal expansion, while prime-age households hardly change theirs, regardless of their level of income or debt. I further document that productivity and wages increase significantly for young workers in response to such shocks.

The second contribution of the paper is to develop a parsimonious New Keynesian DSGE life-cycle model that is able to rationalize these empirical findings. The introduction of a learning-by-doing process for young individuals is key to generating these heterogeneous responses across age groups. Government spending enhances human capital accumulation, and thus affects more young workers who have a steep age-productivity profile. As an increase in government spending raises hours, young workers accumulate skills faster than their prime-age counterparts. Relative labor demand for the young increases, boosting their wages.

The age-specific heterogeneity in productivity and consumption responses to government spending shocks suggests that the effectiveness of fiscal policy may decline as the population ages. However, policies that promote human capital formation may increase the effectiveness of fiscal policy, in particular if they are targeted at young people.

[38] See, e.g., Hai and Heckman (2017) and Caucutt and Lochner (2020) for recent studies estimating structural life-cycle models with human capital accumulation in the presence of liquidity constraints.

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Appendix

A Data

A.1 CPS

To inspect the effects of government spending shocks on age-specific labor-market outcomes, 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 labor market statistics. It provides information on individuals' employment status, hourly wages and weekly hours worked, as well as on their education and demographic characteristics. Interviewed households are selected to be representative of the U.S. population. 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 individuals, and individuals with zero or missing wages are excluded from the sample. Hours worked are computed as the product of usual weekly hours and the number of persons employed. The extremely large sample size of the CPS dataset allows accurate analyses at a high degree of disaggregation. Notably, I use this dataset to build measures of productivity for different age groups using a wage-based approach. The series are seasonally adjusted by X-12 ARIMA. My final sample contains about 5 million observations over 1981Q3-2007Q4.

A.2 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 their labor and financial income, 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.[39] 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 regarding CEX data, such as the presence of measurement error and underreporting by high-income households.[40] An advantage of this approach is that it attenuates the attrition problem and reduces measurement error since it aggregates across agents.

A.3 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 expenditure and gross investment, which is the variable of interest to build the shock, individual forecasts are available from 1981Q3 onwards. Because 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 because the base year changed multiple times during the sample period.

A.4 Aggregate US Data

The time series for gross domestic product, non-durable consumption, wages, GDP price deflator, and the three-month Treasury Bill rate are available from the website of the Federal Reserve Board of St. Louis (FRED). Federal government expenditure includes direct consumption and investment purchases, which exclude the imputed rent on government capital

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

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

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. The total hours worked series is constructed as the product of average weekly hours in the non-farm 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 expenditure 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.5 Cross-Country Panel Data

The data series for real GDP, real government consumption expenditure, real private consumption, the current account and the real effective exchange rate used in Appendix E are taken from Ilzetzki et al. (2013). These quarterly series cover the period from 1960Q1 to 2009Q4 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 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, and 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 into two groups according to their share of young people in the 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 1 lists the countries included in each group. The first group—countries with high share of young in the total population—are characterized by an average share of people aged 15-29 over 1970-2010 above the sample mean of 23.6%. The second group consists of countries with a share of young people strictly below the sample mean. The distribution of countries in the two groups remains unchanged if the share of people aged 15-34, rather than 15-29, is considered.

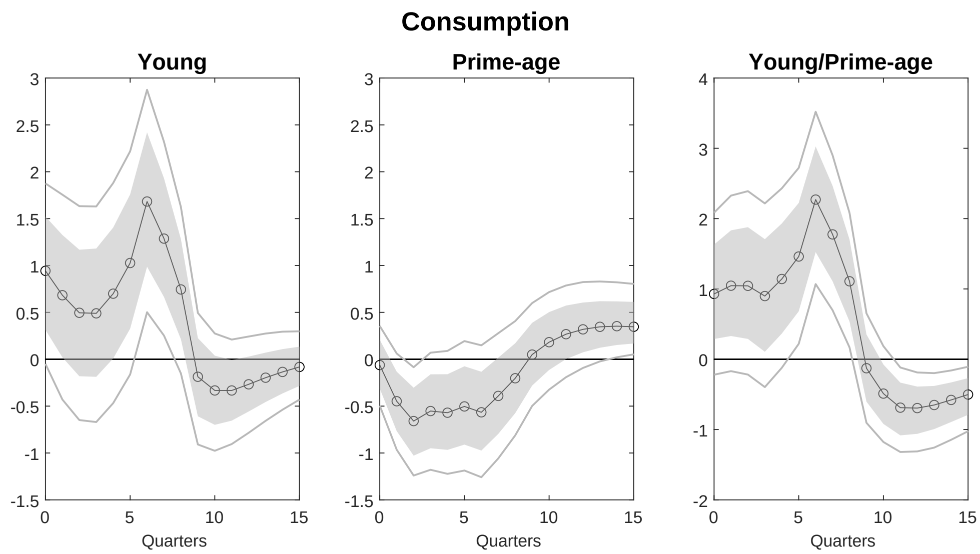
Table 1: Share of young people in total population across panel of 39 countries

High Share of Young People		**Low Share of Young People**	
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 (under 30 years of age) among the total population over 1970-2010 across a panel of 39 countries. The overall sample mean is 23.6%.

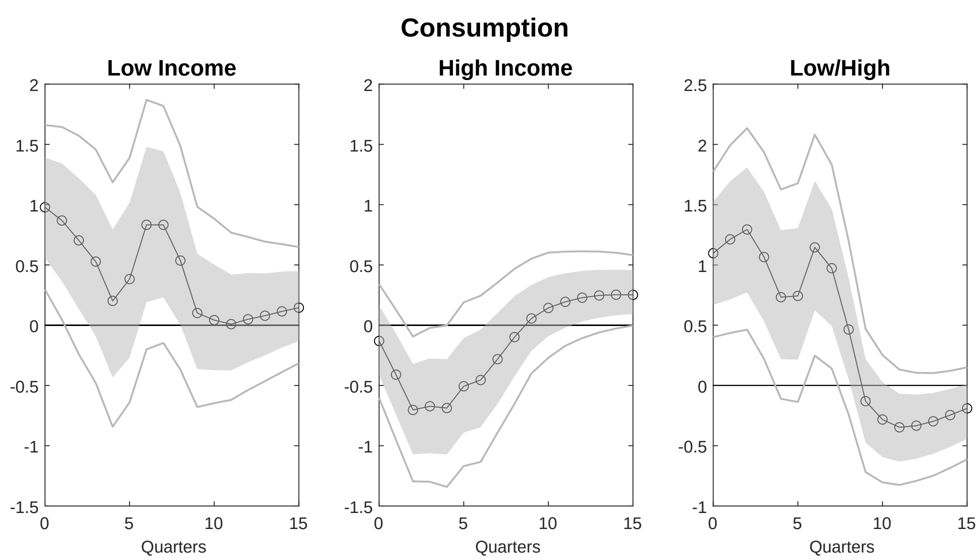
B IRFs of Consumption by Age, Income and Housing Tenure Groups

Figure 8: Impulse responses to government spending shocks by age group



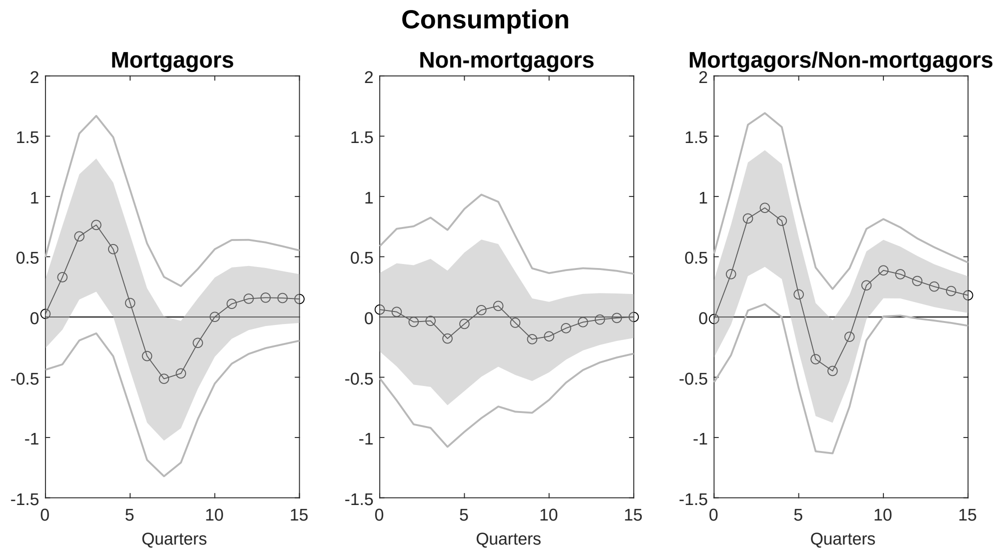
Notes: These graphs show the IRFs of nondurable consumption for young and prime-age households to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence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

Figure 9: IRFs to government spending shocks by income group



Notes: These graphs show the IRFs of nondurable consumption for low- and high-income households to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 10: IRFs to government spending shocks by housing tenure



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

C 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 VAR, 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 Treasury 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.

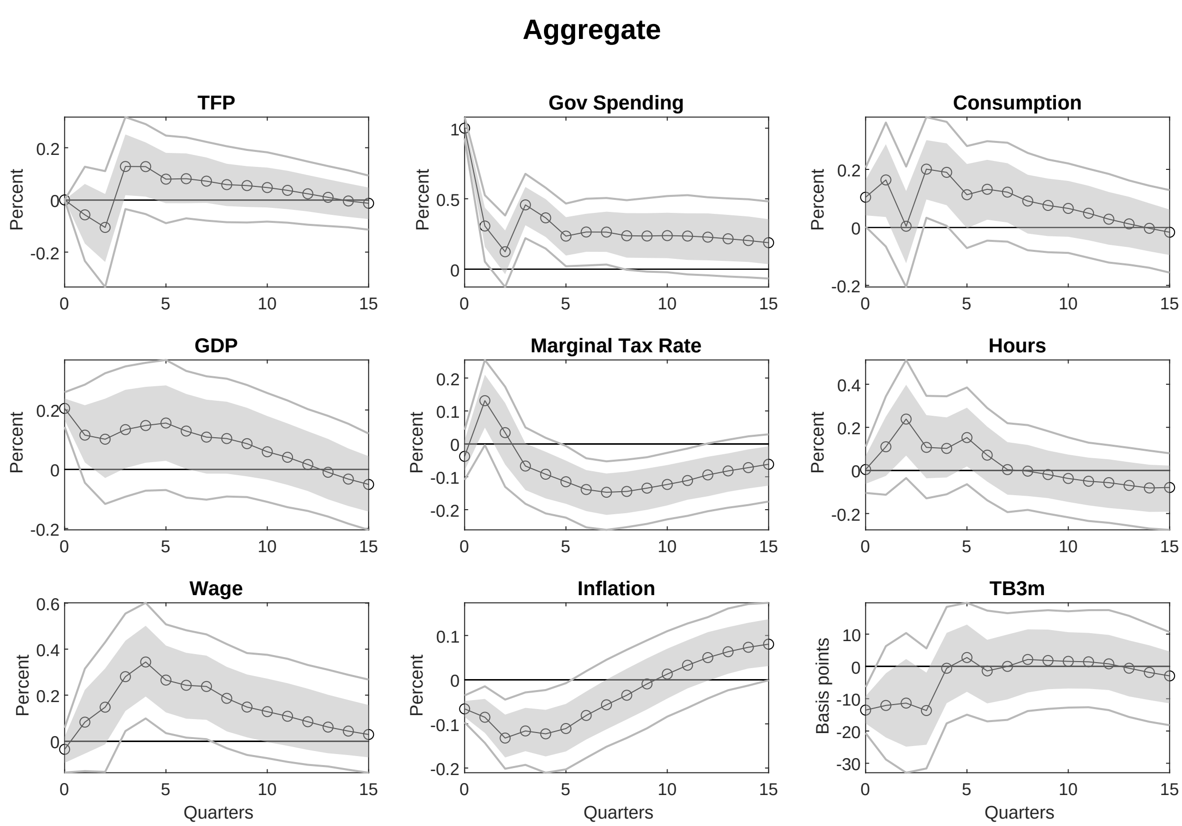
Using a standard Choleski decomposition, shocks to government spending are identified as innovations to the SPF forecast-based measure which are orthogonal to TFP movements on impact and pre-determined with respect to remaining variables. This specification controls for the measurement error component that may induce a bias in the IRFs of output and TFP, following Ben Zeev and Pappa (2015).[41] Furthermore, following Blanchard and Perotti

[41] 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 helps to properly identify the true effects of the shocks on macroeconomic variables.

(2002), this specification implies that government spending cannot react to changes in remaining variables within the same quarter due to implementation lag.

Figure 11 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 literature, notably in d'Alessandro et al. (2019) and Jørgensen and Ravn (2022).

Figure 11: IRFs of aggregate variables to government spending shocks



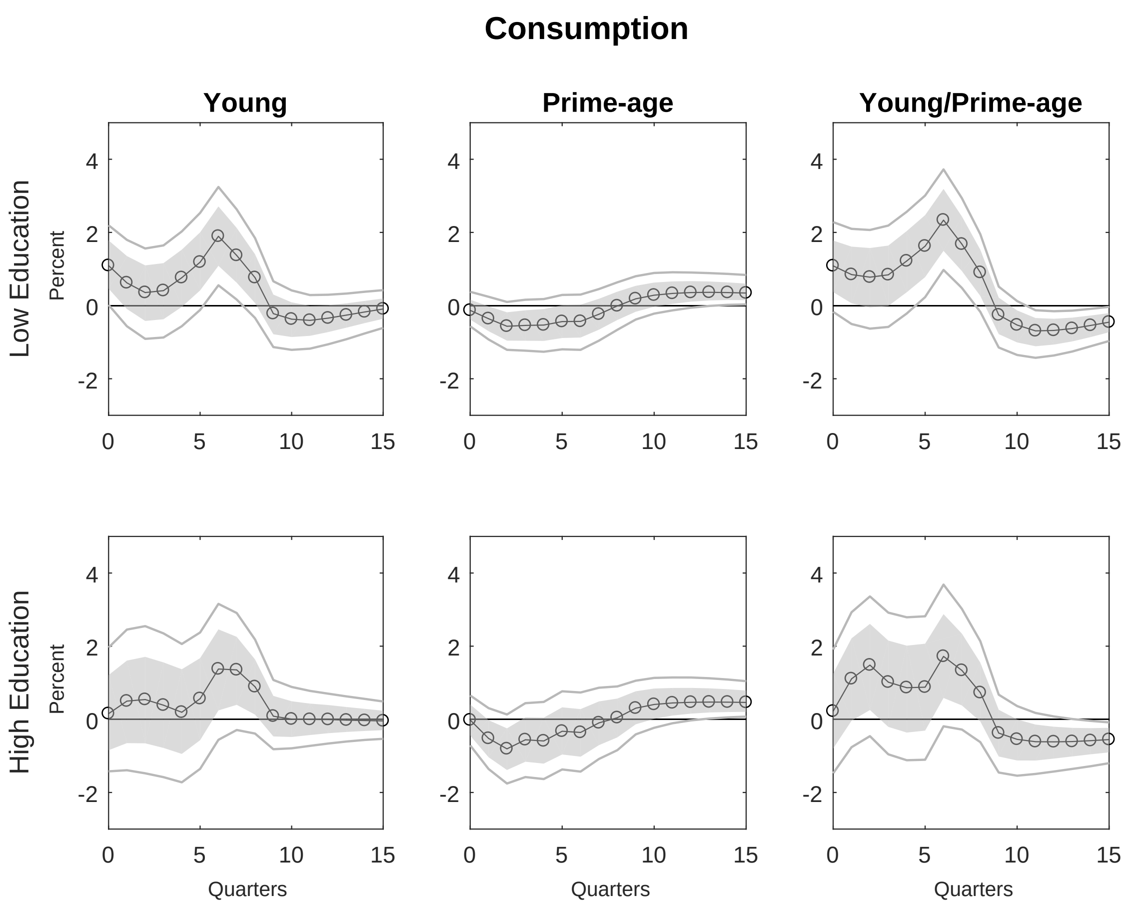
Notes: These graphs show the IRFs of aggregate variables to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

D Robustness

D.1 Heterogeneous Effects on Consumption: Robustness

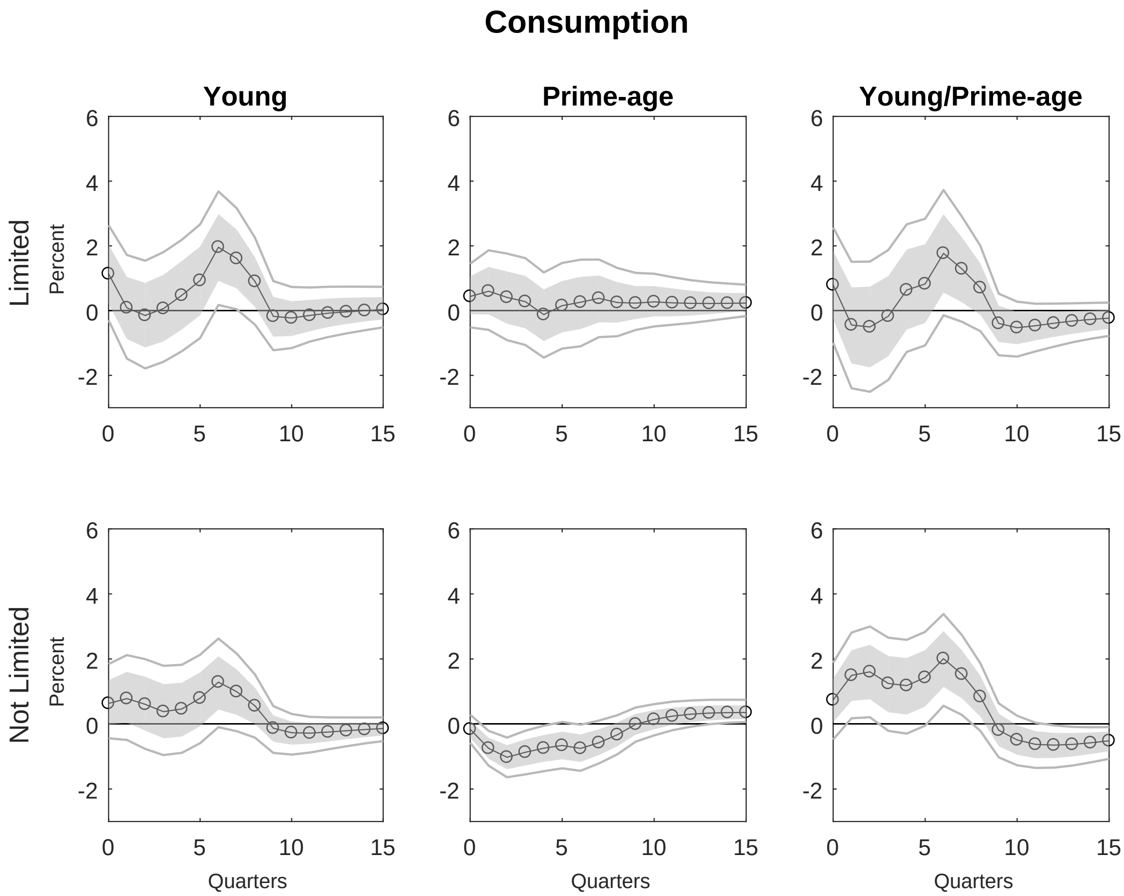
Using other proxies for liquidity constraints

Figure 12: IRFs to government spending shocks by age and education level



Notes: These graphs show the IRFs 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 expenditure. The IRFs for the young (under 30 years of age) are depicted on the first column, for the prime age (30-64 years of age) on the second column, and for the ratios between young and prime age on the last column. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 13: IRFs to government spending shocks by age and financial market participation

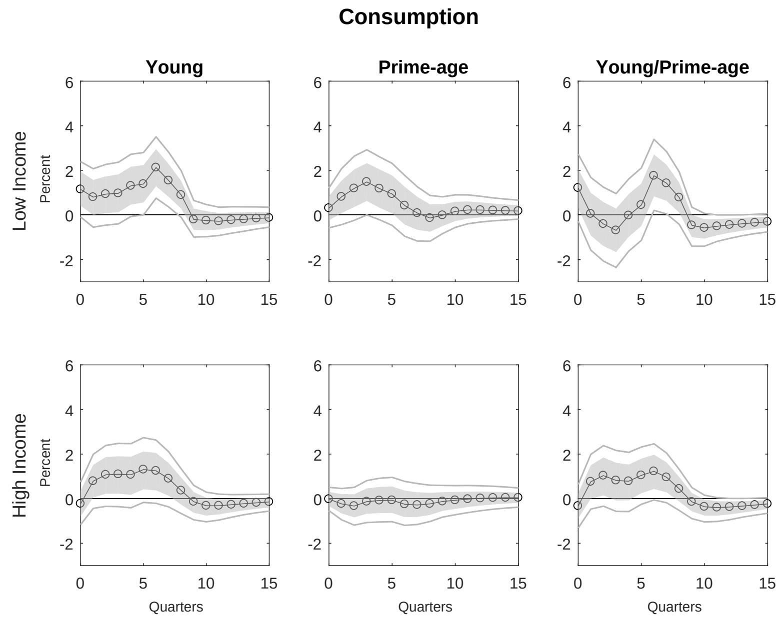


Notes: These graphs show the IRFs of nondurable consumption for young and prime-age households, grouped by their financial market participation (limited: no income from financial assets; not limited: non-zero income from financial assets) to an exogenous government spending shock leading to an initial 1% increase in government expenditure. The IRFs for the young (under 30 years of age) are depicted on the first column, for the prime age (30-64 years of age) on the second column, and for the ratios between young and prime age on the last column. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

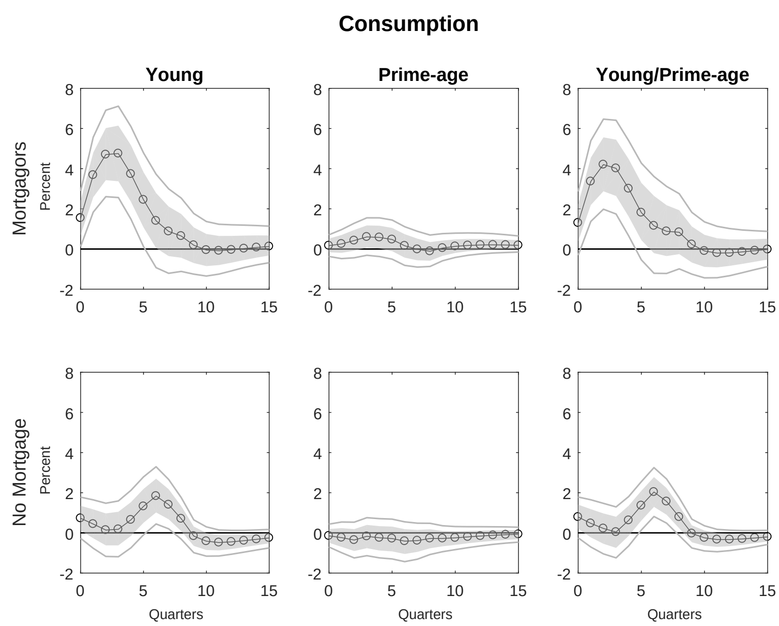
Using a broader definition of consumption

Figure 14: IRFs of consumption for young and prime-age groups

(a) By income level



(b) By housing tenure

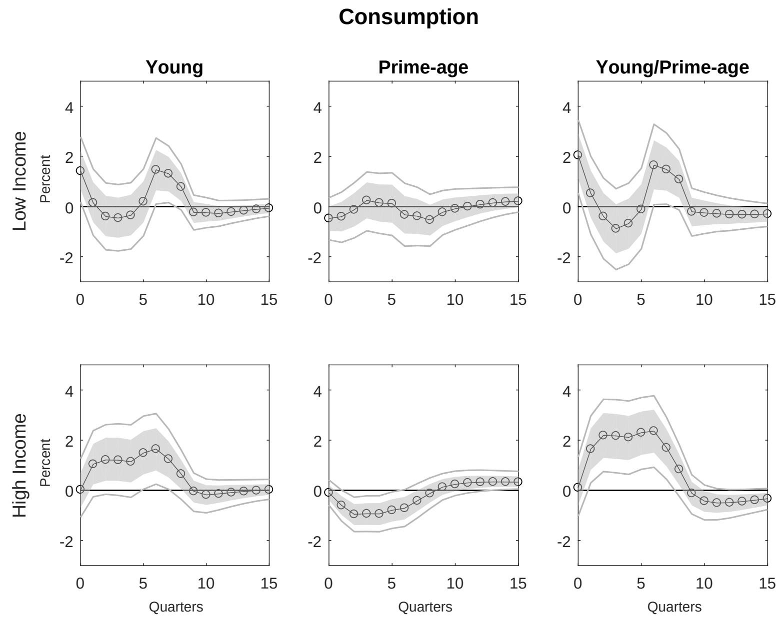


Notes: These graphs show the IRFs of nondurable consumption for young and prime-age households, by their income level in Panel (a) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditure. The IRFs of the ratios between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

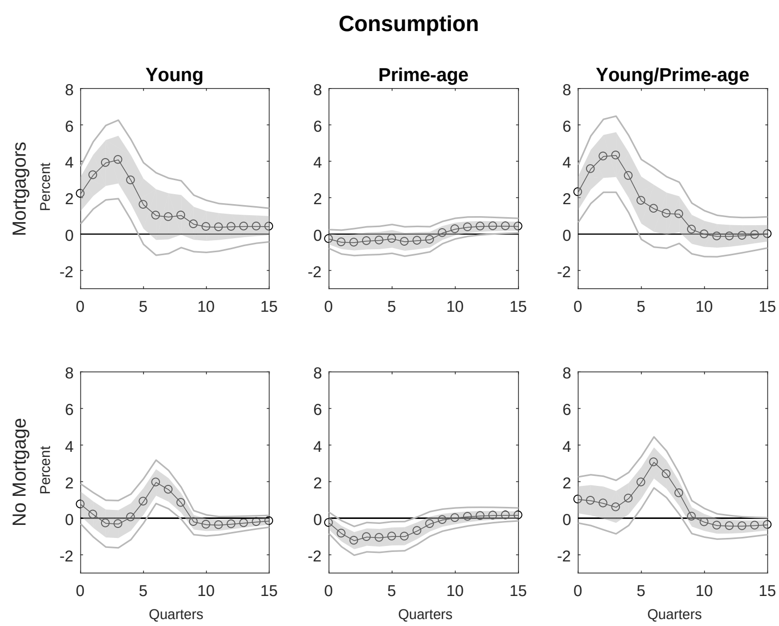
Restricting the sample to employed households

Figure 15: IRFs of consumption for young and prime-age groups

(a) By income level



(b) By housing tenure

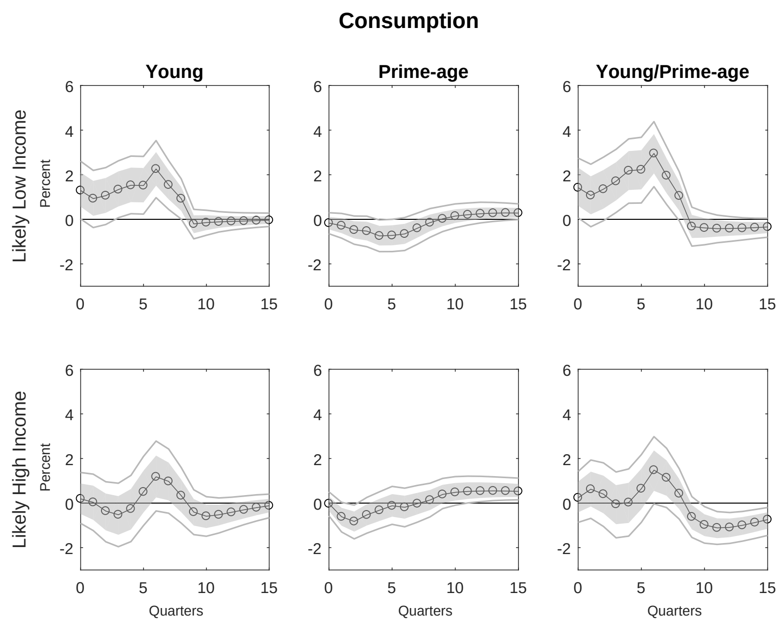


Notes: These graphs show the IRFs of nondurable consumption for young and prime-age households, by their income level in Panel (a) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints,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

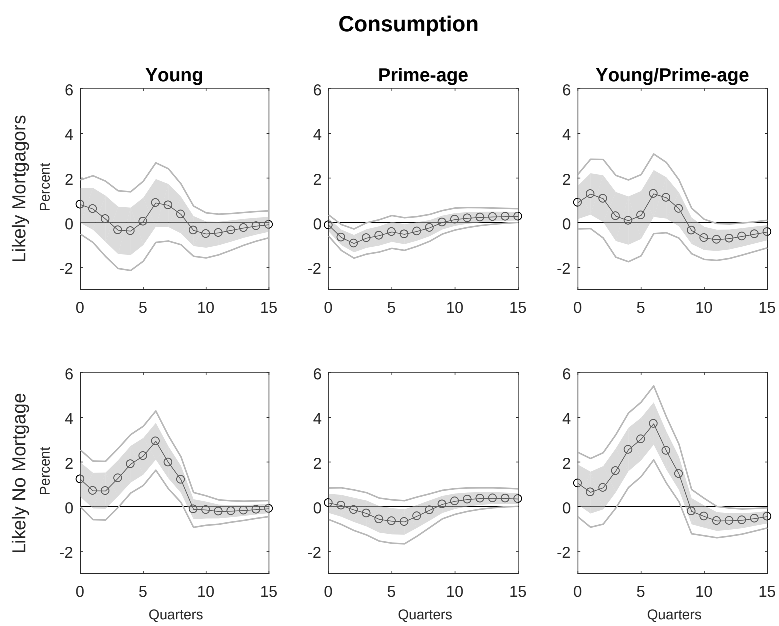
Compositional change

Figure 16: IRFs of consumption for young and prime-age groups, using propensity score approach

(a) By income level



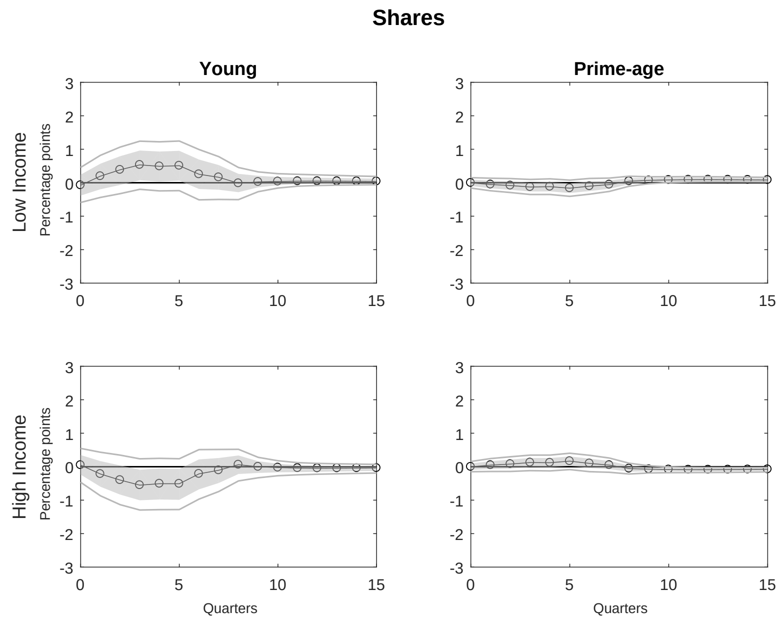
(b) By housing tenure



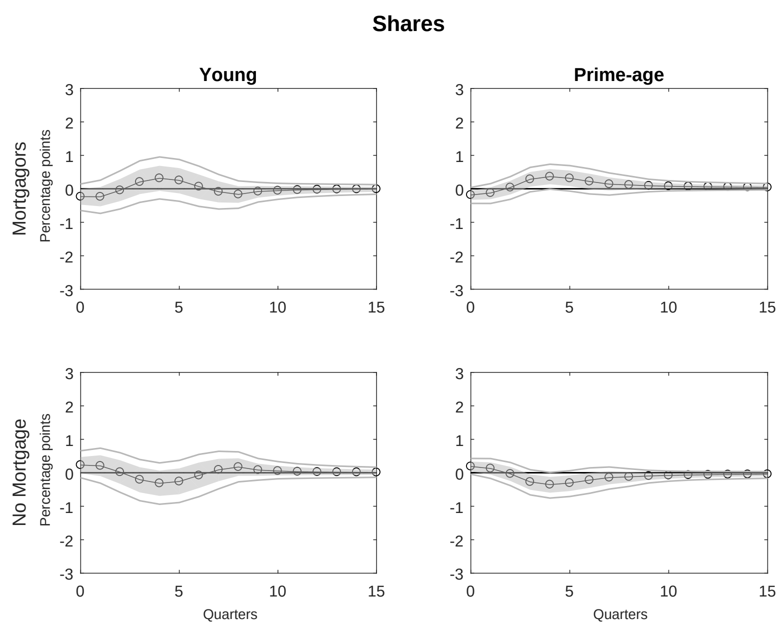
Notes: These graphs show the IRFs of nondurable consumption for young and prime-age households, by their income level in Panel (a) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints,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

Figure 17: IRFs of shares

(a) By income level



(b) By housing tenure

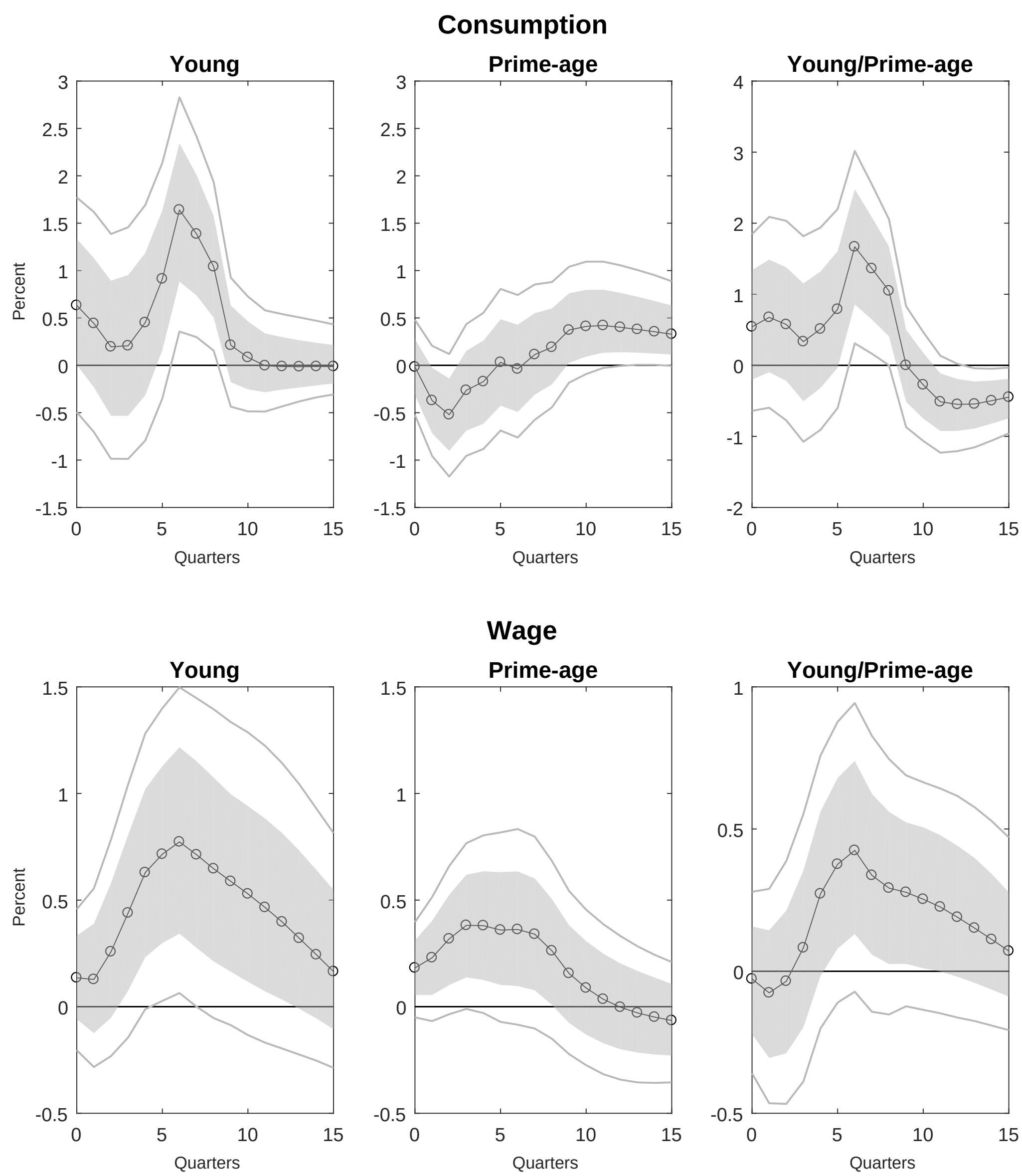


Notes: These graphs show the IRFs of the shares of young and prime-age households, by their income level in Panel (a) and by their housing tenure in Panel (b), to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Except for the endpoints, the coefficients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

D.2 Further Robustness

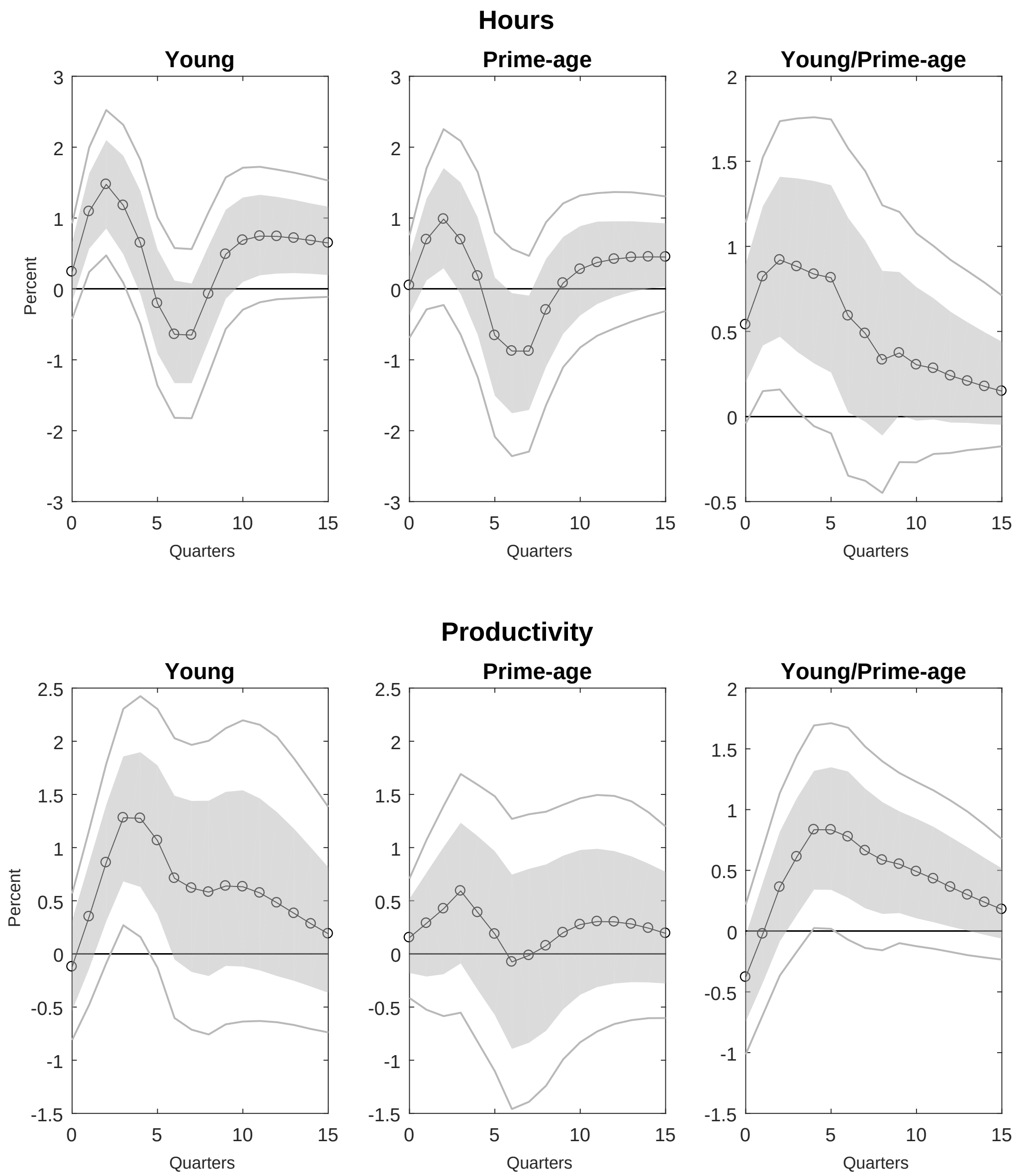
Other measure of government spending shocks

Figure 18: IRFs of nondurable consumption and hourly wages



Notes: These graphs show the IRFs of nondurable consumption and hourly wages for young and prime-age workers, and of the ratios between young and prime age to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Several controls are added in the estimation of the shocks. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

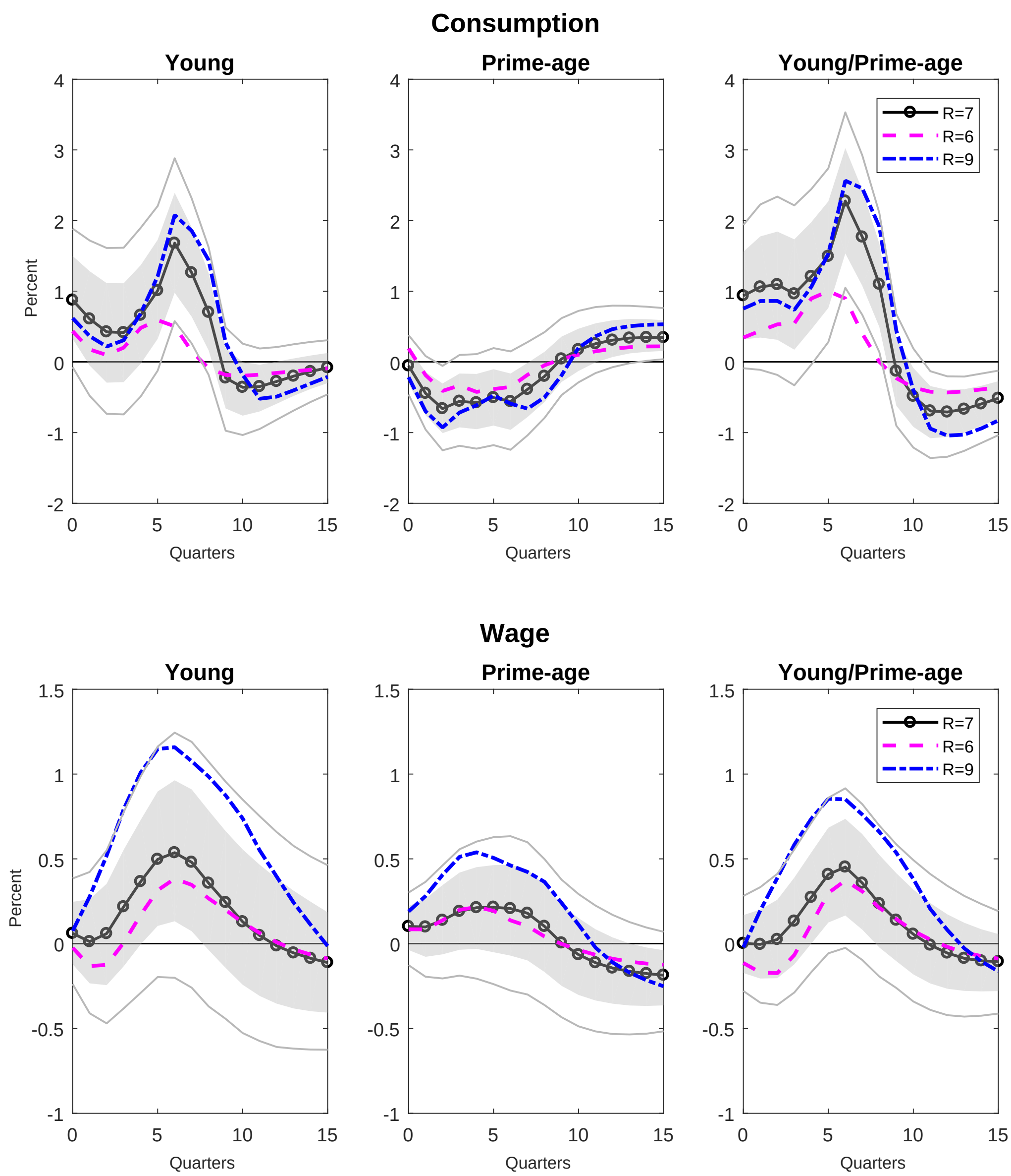
Figure 19: IRFs of hours worked and productivity



Notes: These graphs show the IRFs of hours worked and productivity for young and prime-age workers, and of the ratios between young and prime age to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Several controls are added in the estimation of the shocks. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

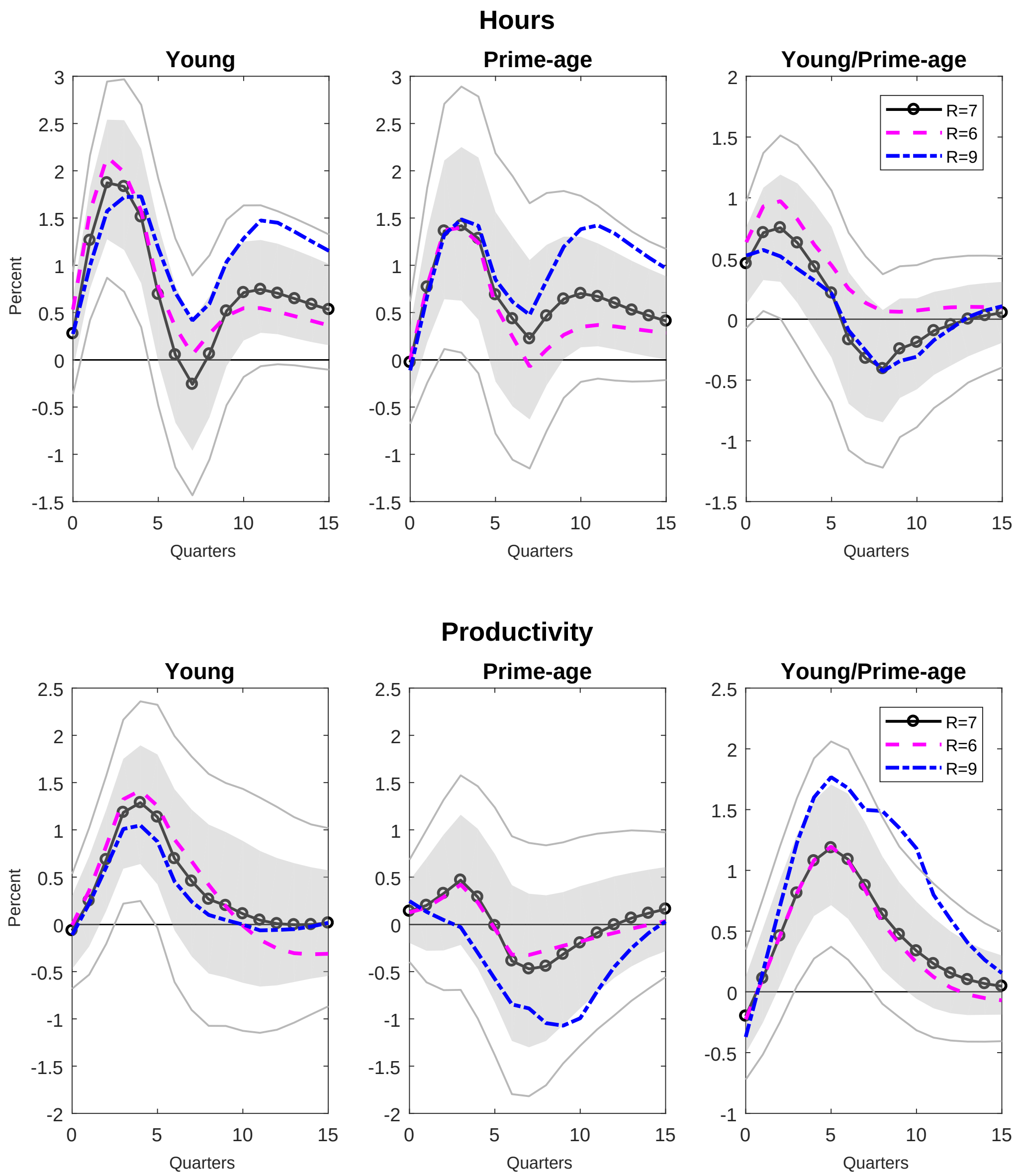
Dynamic specification

Figure 20: IRFs of nondurable consumption and hourly wages



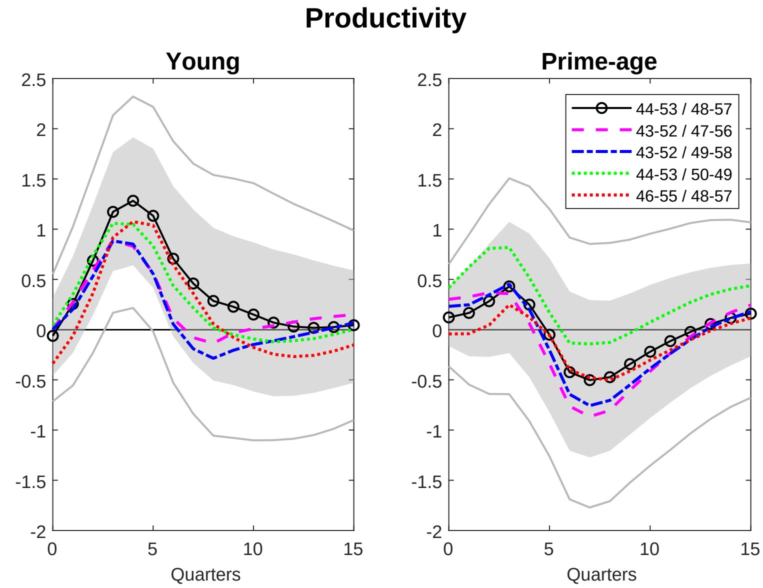
Notes: These graphs show the IRFs of nondurable consumption and hourly wages for young and prime-age workers, and of the ratios between young and prime-age to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Median IRFs are reported for different numbers of lags of the shocks in the VAR model. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 21: IRFs of hours worked and productivity



Notes: These graphs show the IRFs of hours worked and productivity for young and prime-age workers, and of the ratios between young and prime-age to an exogenous government spending shock leading to an initial 1% increase in government expenditure. Median IRFs are reported for different numbers of lags of the shocks in the VAR model. Except for the endpoints, the coefficients are smoothed over three consecutive periods. 90% and 68% confidence intervals are shown in all cases.

Figure 22: IRFs of productivity to government spending shocks—Sensitivity to the flat spot range



Notes: These graphs show the IRFs 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 IRF (flat spot: 44-53 / 48-57).

E Further Evidence Using Macro Panel Data

I provide further evidence on the age-dependent effects of government spending shocks on consumption and productivity using a structural VAR 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 the total population.[42] I estimate the following model:

$$AX_{j,t} = \sum_{k=1}^{K} C_k X_{j,t-k} + BU_{j,t} \tag{24}$$

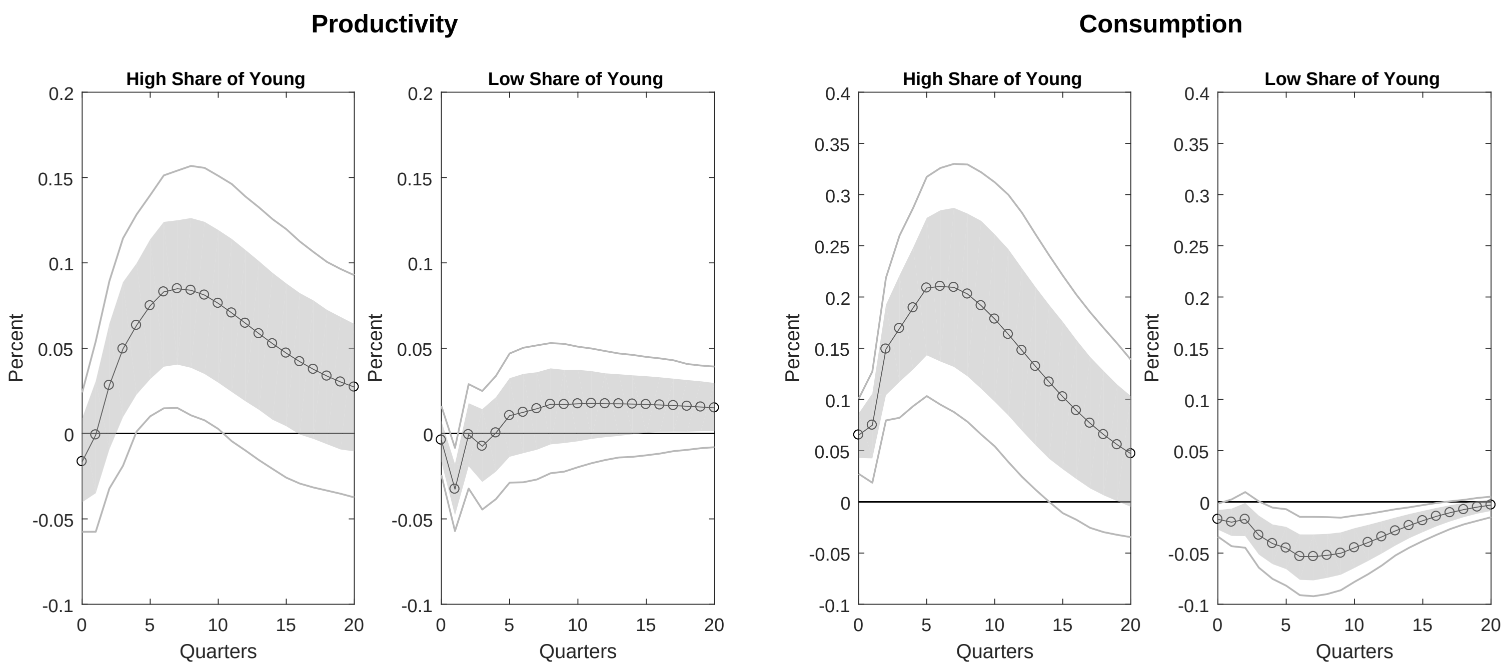
where $X_{j,t}$ is a vector of endogenous variables in country j at quarter t that consists of real government consumption expenditure, real GDP, real private consumption and labor productivity. Following Ilzetzki et al. (2013), government spending shocks are identified using

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

Blanchard and Perotti (2002) identification strategy, and the model is estimated by panel least squares (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 people in the total population above and below the sample mean. The VAR model is then estimated for the two groups separately in order to compare the IRFs of productivity and private consumption to government spending shocks in the two groups of countries.

Figure 23: IRFs of productivity and consumption to government spending shocks in countries with high vs. low shares of young people in total population



Notes: These graphs show the IRFs 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 people (aged 15-29) vs. high share of young people in the total population. 90% and 68% confidence intervals are shown in all cases.

As can be observed in Figure 23, countries with a high share of young people display very different responses of productivity and consumption to government spending shocks compared to countries with a low share of young people. Specifically, in the group of countries with a high share of young people, there is a strong and significant increase in both productivity and consumption after a positive shock in government spending. In contrast, in the group with a low share of young people, productivity remains virtually unchanged while consumption significantly drops after the shock. These results confirm the findings from the micro-level analysis reported in Sections 2.3 and 2.4 and show the importance of demographics in the transmission of government spending shocks to productivity and consumption.

F Model: Calibration

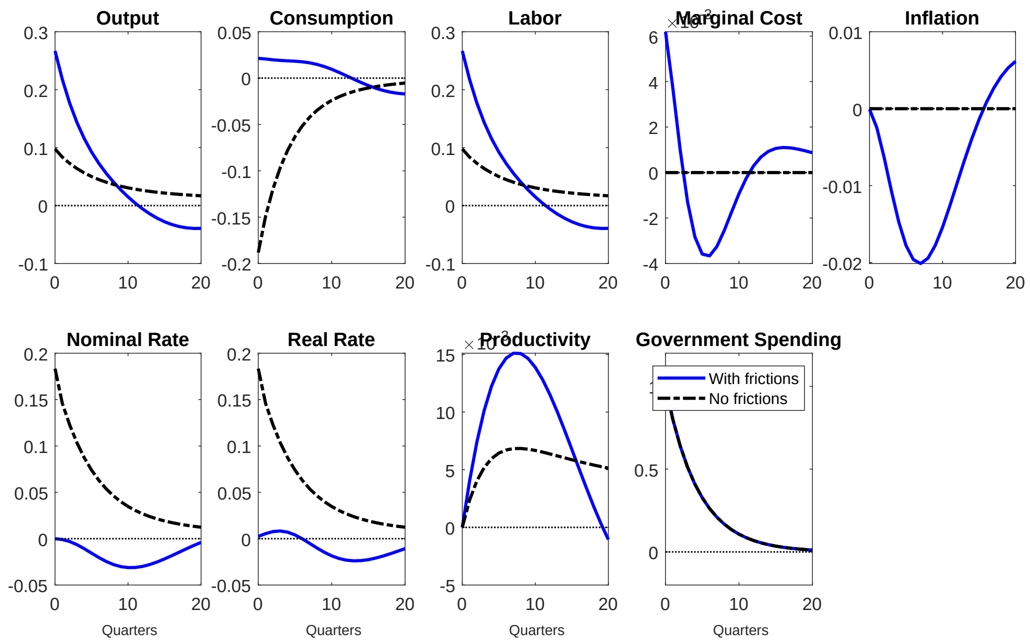
Table 2: Calibration values

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 age	Wage ratio prime age/young
$X_{y,0}$	0.5	Initial level of skills	Normalization
φ_y	0.5	Frisch elasticity of labor supply for young	Chetty et al. (2011)
φ_p	0.5	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)

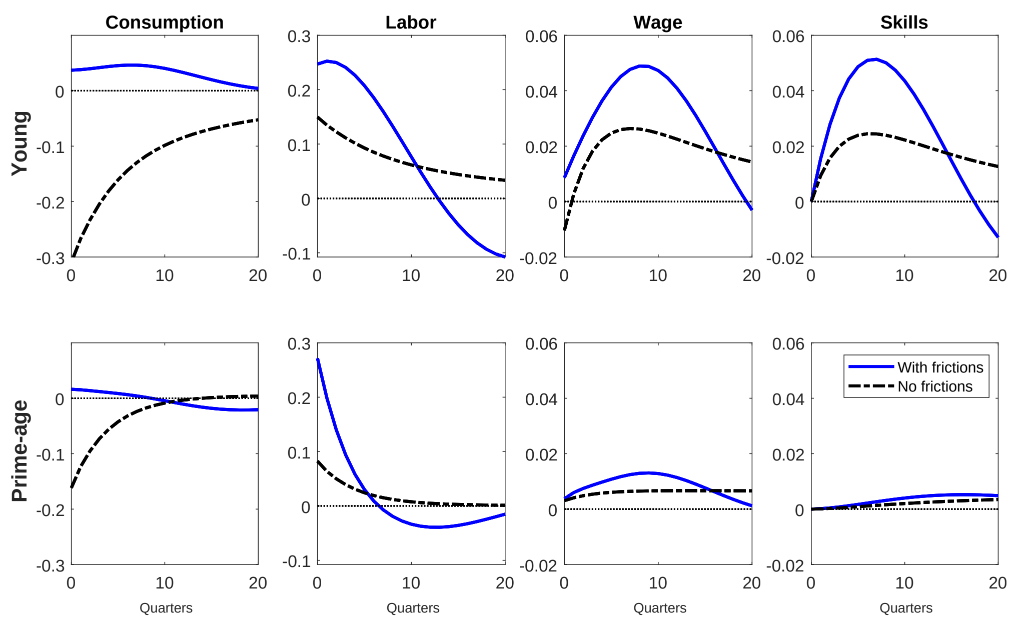
G Model: Sensitivity Analysis

Figure 24: IRFs to a government spending shock—With vs. without nominal rigidities

(a) IRFs of aggregate variables



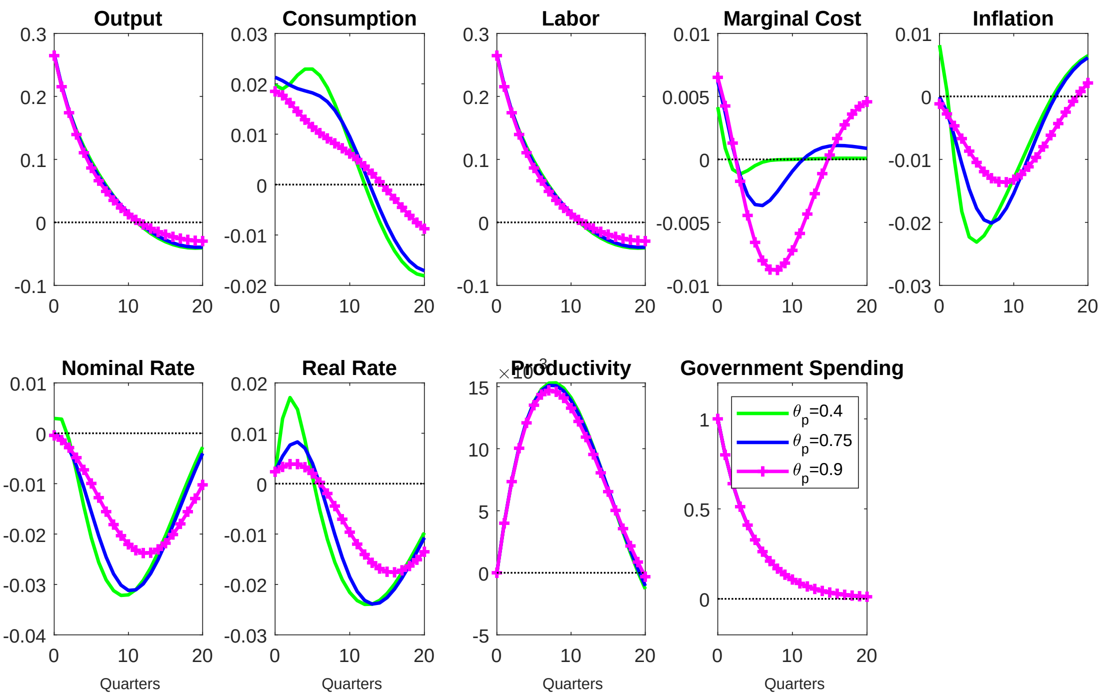
(b) IRFs of disaggregate variables



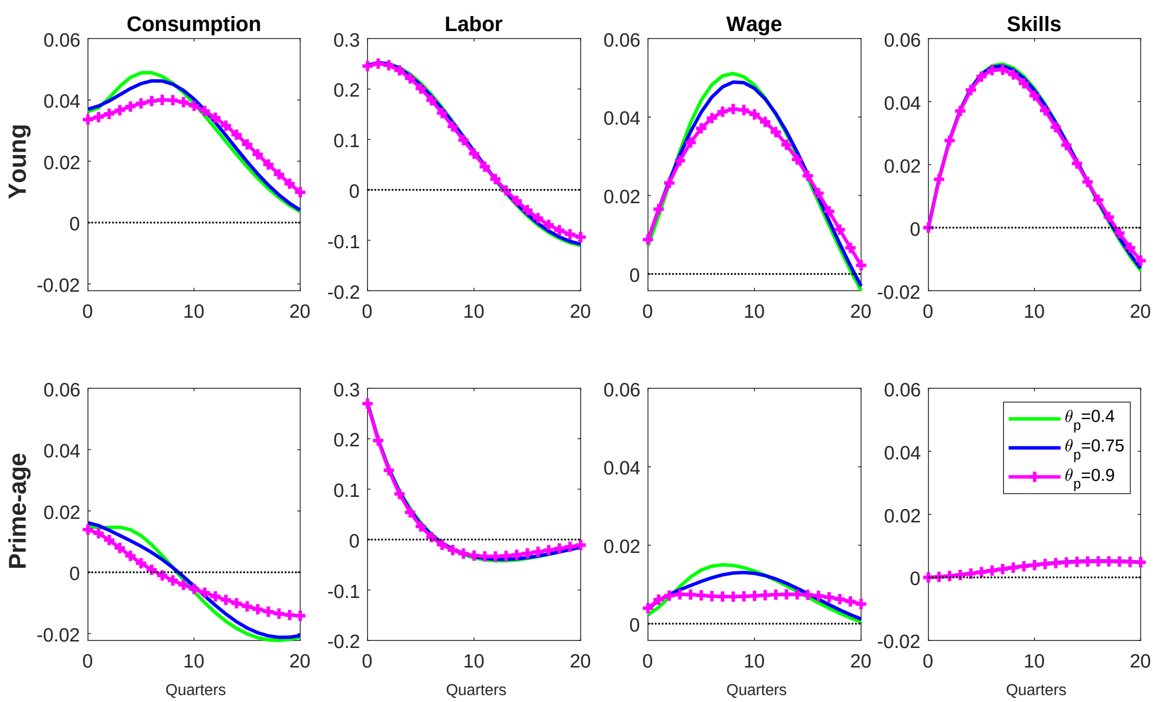
Notes: This figure shows the IRFs of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD, with and without nominal rigidities.

Figure 25: IRFs to a government spending shock—Sensitivity to price stickiness

(a) IRFs of aggregate variables



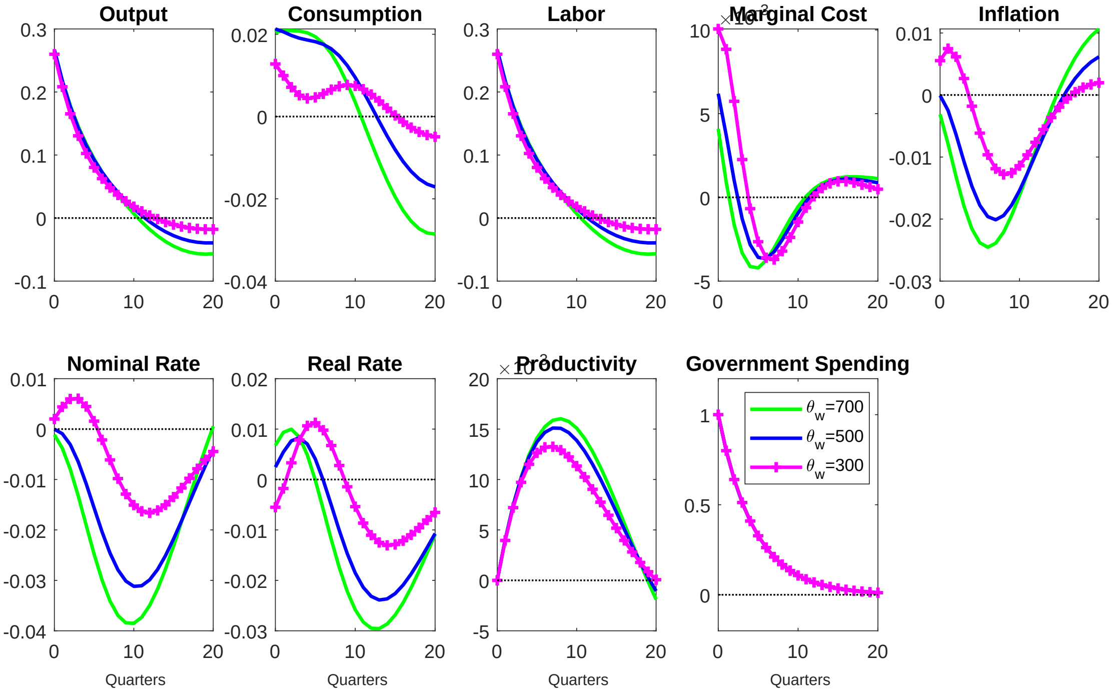
(b) IRFs of disaggregate variables



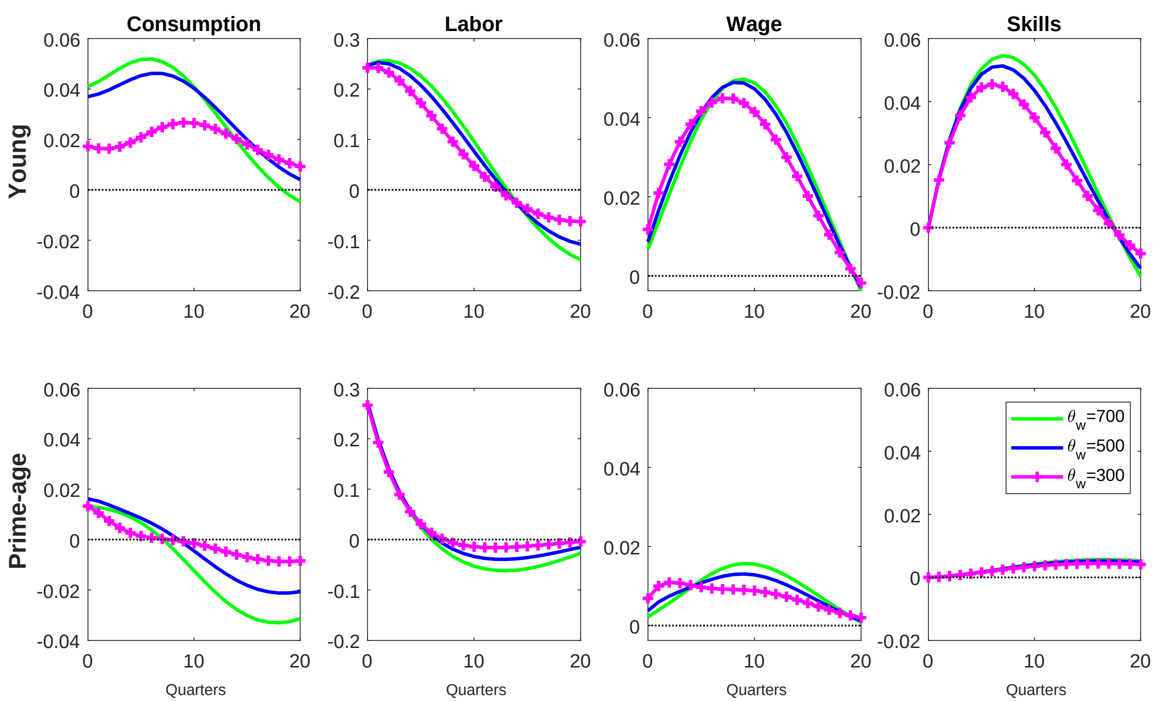
Notes: This figure shows the IRFs of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the price stickiness parameter θ_p.

Figure 26: IRFs to a government spending shock—Sensitivity to wage stickiness

(a) IRFs of aggregate variables

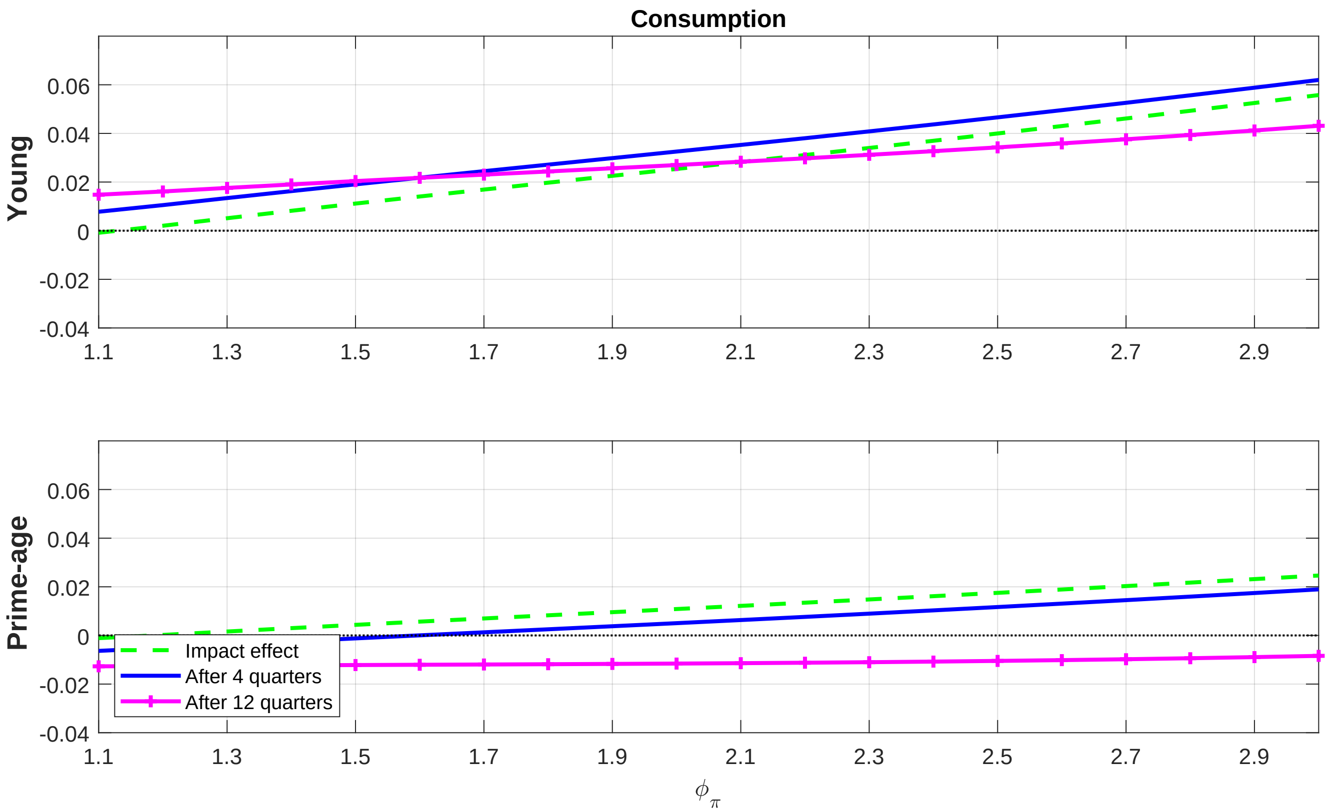


(b) IRFs of disaggregate variables



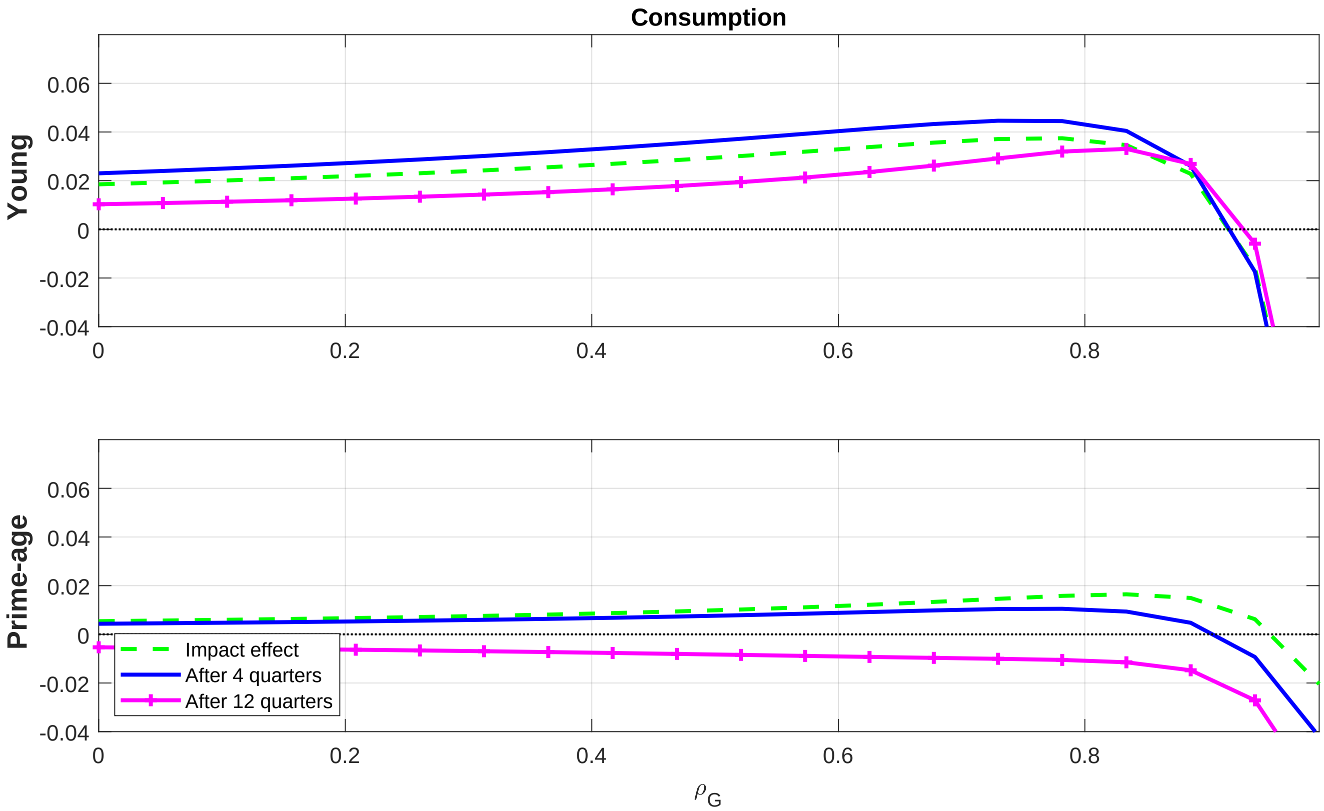
Notes: This figure shows the IRFs of aggregate variables (Panel (a)) and disaggregate variables for young and prime-age workers (Panel (b)) to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the wage adjustment cost parameter θ_w.

Figure 27: IRFs to a government spending shock—Sensitivity to monetary policy parameter ϕ_π



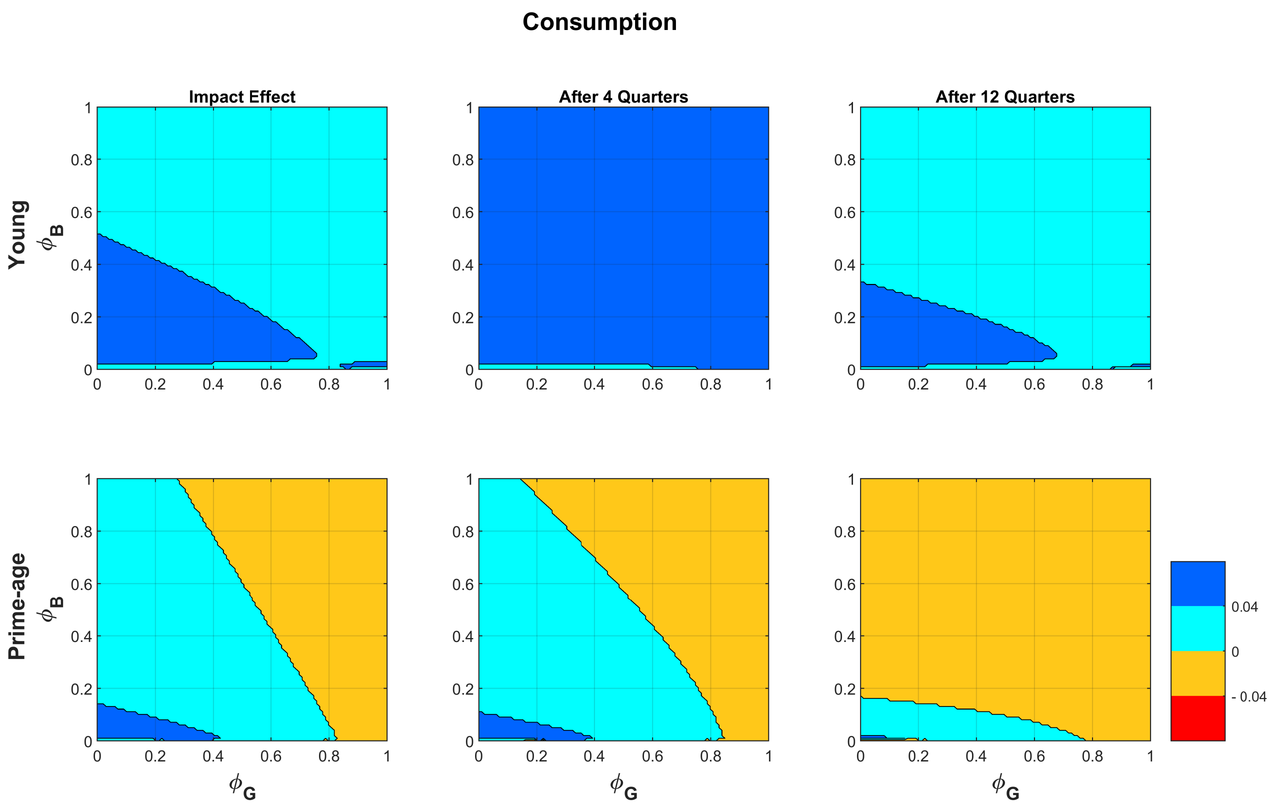
Notes: This figure shows the consumption responses for young and prime-age workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the Taylor rule parameter ϕ_π.

Figure 28: IRFs to a government spending shock—Sensitivity to shock persistence



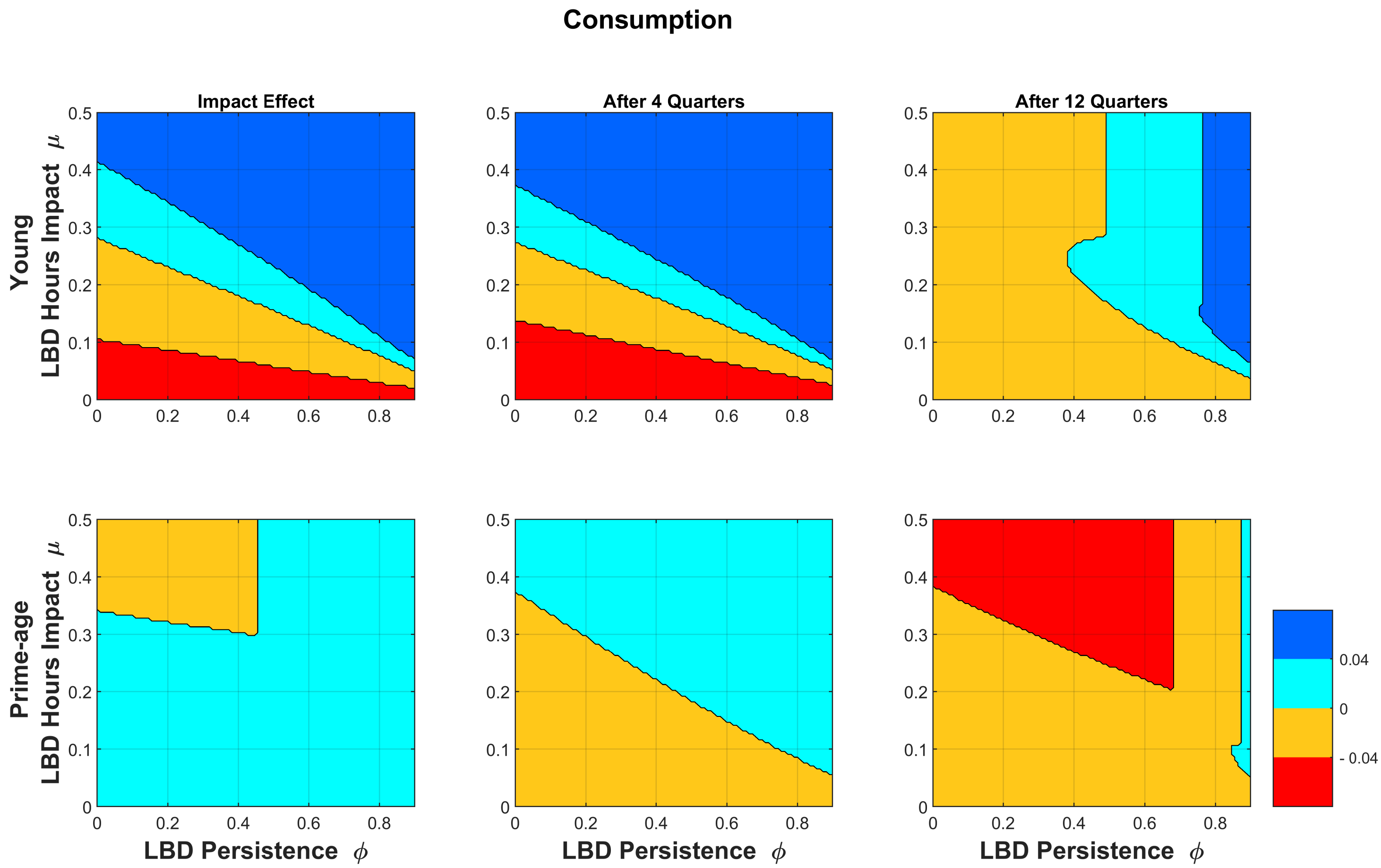
Notes: This figure shows the consumption responses for young and prime-age workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the persistence of the shock ρ_G.

Figure 29: IRFs to a government spending shock—Sensitivity to fiscal rule 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 fiscal rule parameters, Φ_G and Φ_B.

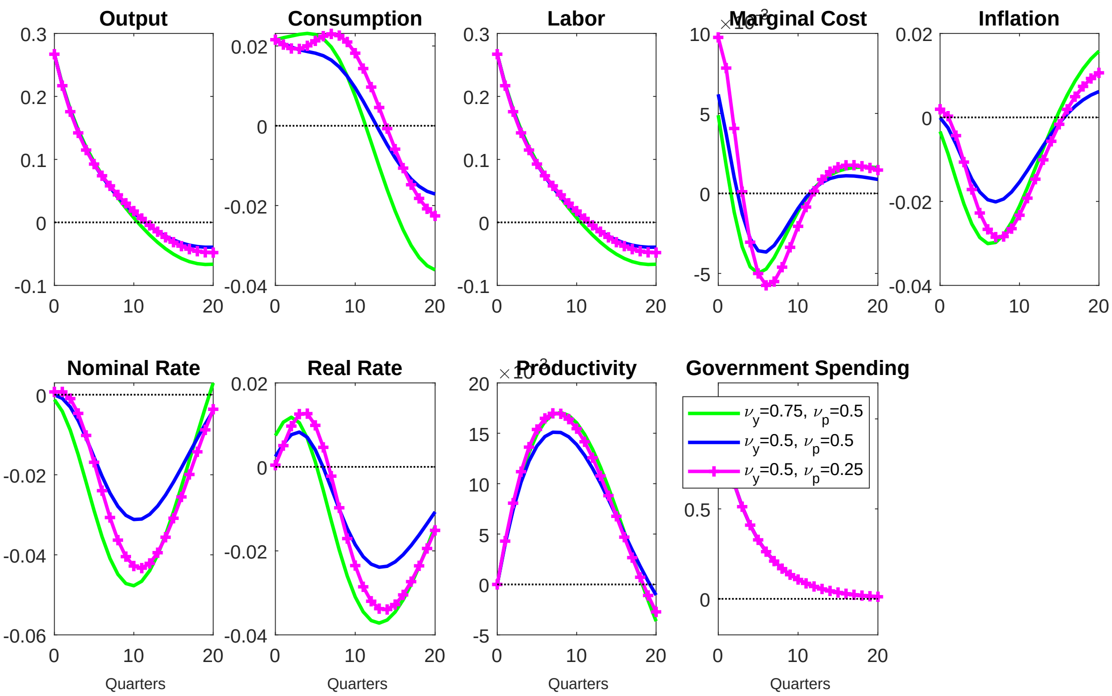
Figure 30: IRFs to a government spending shock—Sensitivity to learning-by-doing parameters



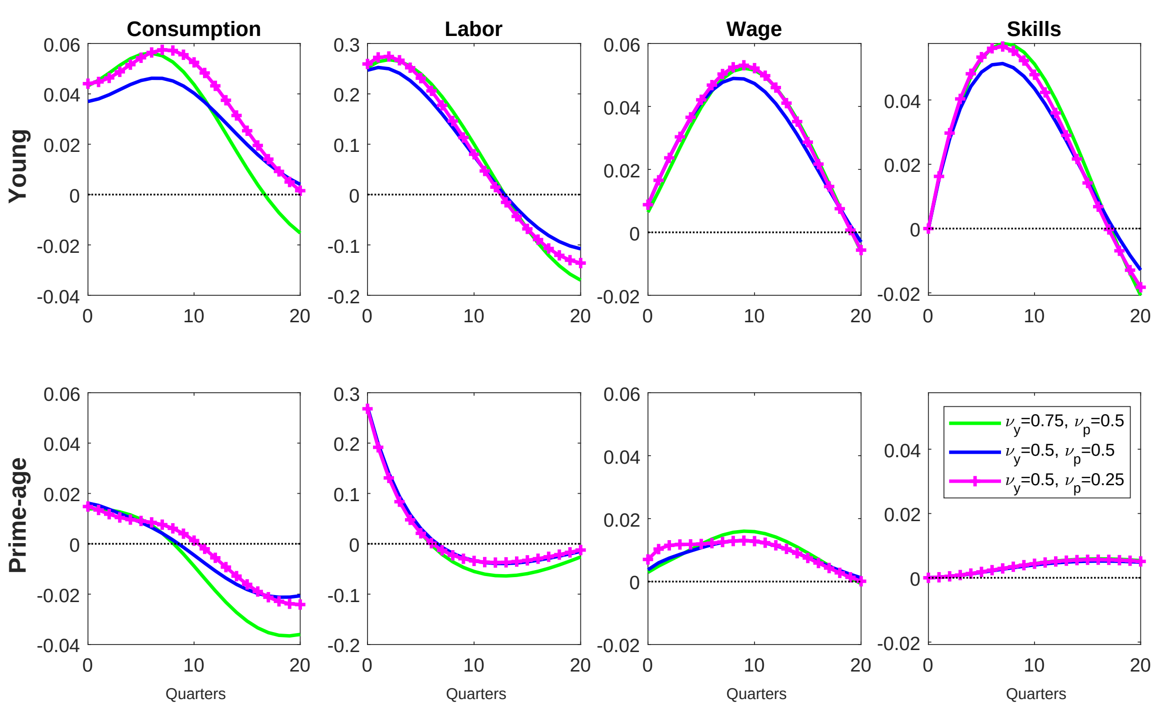
Notes: This figure shows the consumption responses for young (first row) and prime-age (second row) workers at different horizons to a 1% shock to government expenditure in the life-cycle model with LBD for different values of the parameters capturing the impact of past hours μ and the skill persistence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

Figure 31: IRFs 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 IRFs 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.

H Model: Derivations

H.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.[43] 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

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

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

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

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

Combining these conditions yields the Euler equation

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

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

$$ c^i_{r,t} = \gamma^i_{r,t} a^i_{r,t}. \tag{29} $$

Rearranging the budget constraint we have

$$ a^i_{r,t+1} = \frac{R_{n,t}}{\Pi_{t+1}}(1-\gamma^i_{r,t})a^i_{r,t}. \tag{30} $$

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

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

Therefore the marginal propensity to consume is only a function of aggregate variables, and thus is identical for all retired agents $\gamma_{r,t} = \gamma^i_{r,t} \quad \forall i$. 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

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

$$\text{s.t.} \quad c_{p,t} + b_{p,t} = a_{p,t} + w_{p,t}L_{p,t} - \tau_t + (1-\tau_d)\text{div}_{p,t}, \qquad a_{p,t+1} = \frac{R_{n,t}}{\Pi_{t+1}} b_{p,t}. \tag{35}$$

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

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

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

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

Problem of the Representative Young Worker

The optimization problem of the representative young worker is given by

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

s.t.

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

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

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

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

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

H.2 Derivation of the Wage Phillips Curves

Each union solves the following optimization problem

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

subject to

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

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

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

From the envelope theorem

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

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

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

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

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

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

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