Demographic Trends and the Transmission of Monetary Policy

Giacomo Mangiante

University of Lausanne

European Economic Association
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Motivation

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- What about **short-term** implications?

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- There might be long-term effects for monetary policy as well (e.g., steady state levels of inflation and interest rates)
- What about **short-term** implications? This paper studies the impact of population aging on the effectiveness of monetary policy.

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  - ⇒ Older people purchase more from product categories with higher levels of price rigidity (prices are adjusted less often)
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  - ⇒ Output responds more to MP shocks

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- Provide empirical evidence that output in U.S. states with higher old-age dependency ratio responds more to MP shocks (not shown today) Macro evidence
- Develop a **two-sector OLG-NK** model to:
  - Estimate the impact of demographic trends on MP propagation
  - Quantify the size of the new channel

Literature

- **Time-varying effects of monetary policy**: Boivin et al. (2010), Imam (2014), Galesi and Rachedi (2018), Kronick and Ambler (2019)
- **Monetary policy and demographic trends**: Carvalho et al. (2016), Aksoy et al. (2019), Eggertsson et al. (2019), Papetti (2019), Lis et al. (2020), Bielecki et al. (2020), Lisack et al. (2021), Fujiwara and Teranishi (2008), Kantur (2013), Yoshino and Miyamoto (2017), Leahy and Thapar (2020), Kimberly et al. (2021), ...
- **Flattening of the Phillips curve**: Bernanke (2010), McLeay and Tenreyro (2019), Jorda et al. (2019), Rubbo (2020)

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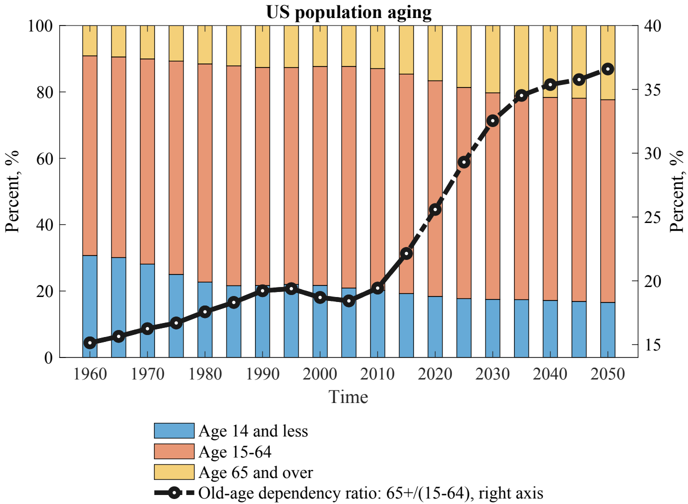
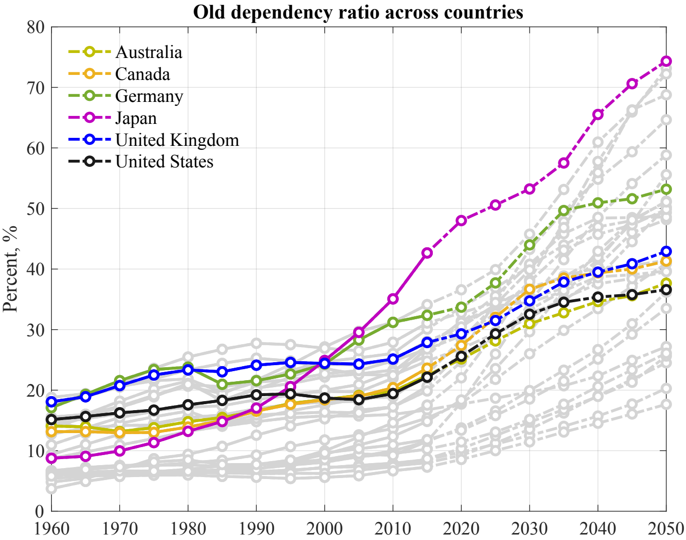
Demographic trends



Source: UN (2017) World Population Prospects

Demographic trends



Source: World Bank Population Estimate and Projection

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Age-group level price stickiness

We combine data from:

- The **Consumer Expenditure Survey** (CEX) reports households' expenditures for around 600 Universal Classification Code (UCC) categories (e.g. *white bread*)
- The **frequency of price adjustment** estimated by Nakamura and Steinsson (2008) for 272 Entry Level Items (ELI) categories (e.g. *bread*)

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We define **age-group price stickiness** level as:

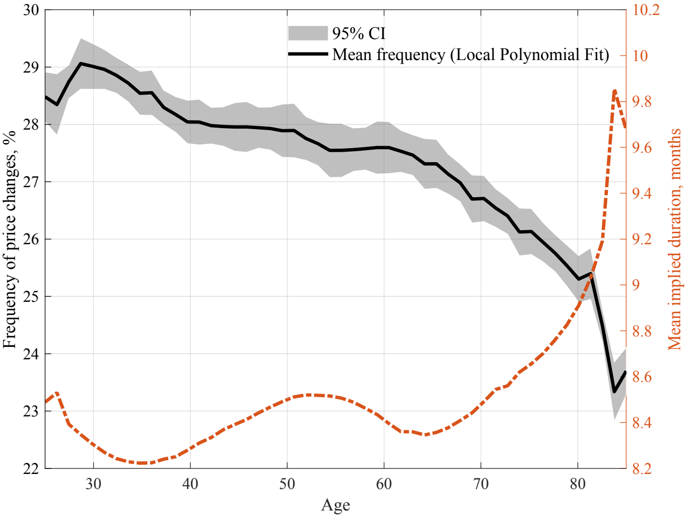
$$\theta_t^a = \sum_{j \in J} \omega_{t,j}^a \theta_j$$

with $\omega_{t,j}^a = \frac{C_{t,j}^a}{\sum_j C_{t,j}^a}$ the **expenditure weight** on category j for age group a and θ_j the **frequency of price adjustment**.

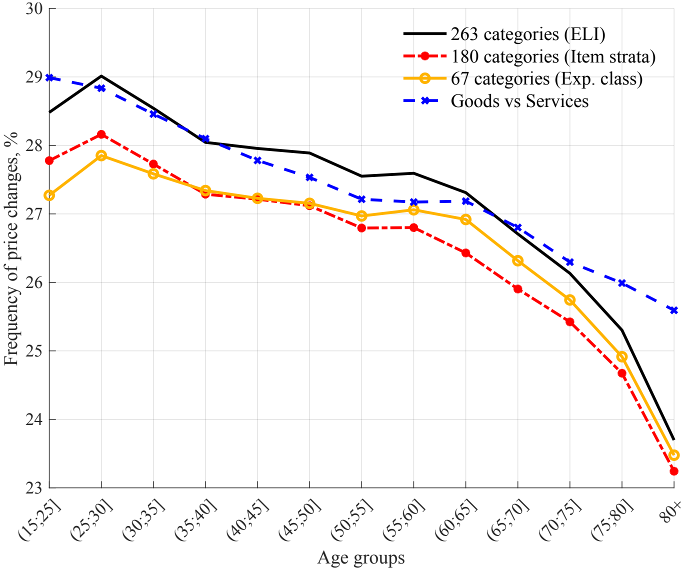
▸ Expenditure weights

Frequency of price adjustment across age groups

▸ Over time ▸ Expenditure differences ▸ Expenditure weights ▸ Excluding sales ▸ Consumption quantiles ▸ Education



Alternative aggregation



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OLG-NK model

Two-sector OLG-NK model (Heer et al., 2017, Bielecki et al., 2020 and Papetti, 2021)

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Households of different age

- Choose consumption
- **Workers** supply labor, **retirees** receive pension
- Capital, bonds and firms' shares are transferred to a perfectly competitive and risk-neutral investment funds ▸ Equations

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Firms of two sectors ▸ Equations

- Final-goods firms: Services and goods
- Monopolistically competitive intermediate-good producers
- **Calvo** price adjustment mechanism: $\theta^S > \theta^G$

Government

- Taxes labor income of workers ▸ Equations
- Provides pension benefit for retirees

Monetary authority

- Sets interest rate based on a **Taylor rule**

Demographic structure

- Households is born at age $j = 1$ (real life age of 15) and live for a maximum of $J = 85$ years (real life age of 99)
- Survive with an **age-specific probability** s_j from age j to age $j + 1$
- Work until $jw = 50$ (real life age of 64) and then retire
- N_j donetes the **size of cohort** j relative to the overall population, $\sum_{j=1}^{J} N_j = 1$.

Households

The maximization problem of the representative household of age j at time t is:

$$\max_{c_{t+i,j+1},l_{t+i,j+1},a_{t+i+1,j+i+1}} \mathbb{E}_t \sum_{i=0}^{J-j} \beta^i s_{j+i} \left(\frac{c_{t+i,j+i}^{1-\sigma}}{1-\sigma} - \phi \frac{l_{t+i,j+i}^{1+\eta}}{1+\eta} \right)$$

with

$$c_{t,j} = \left[\alpha_j^{\frac{1}{\eta}} (c_{t,j}^S)^{\frac{\eta-1}{\eta}} + (1-\alpha_j)^{\frac{1}{\eta}} (c_{t,j}^G)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

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subject to:

$$P_{t,j} c_{t,j} + a_{t+1,j+1} = a_{t,j} R_t^a + y_{t,j}$$

$$y_{t,j} = (1-\tau_t) w_t n_{t,j} h_j \mathbf{I}_{j \leq jw} + pen_t \mathbf{I}_{j > jw} + beq_t$$

$$a_{t,1} = 0 \qquad a_{t+J+1,J+1} = 0$$

Quantitative analysis

- We use the model to compare the transmission of monetary policy shocks around **three steady-states**:
  - 1980 (baseline), when CEX data becomes available
  - 2010
  - 2050, using population projection from World Bank
- The three steady states differ only in terms of:
  - population distribution N_j ▸ Population distribution
  - mortality rate $(1 - s_j)$ ▸ Mortality rate
  - service preferences α_j ▸ Service share ▸ Labor efficiency

all the other parameters are kept fixed

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We answer the following questions:

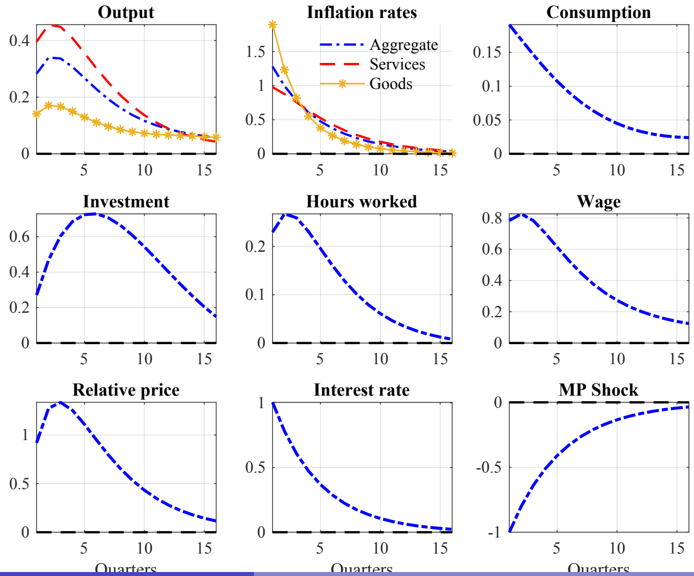
- Do demographic trends change the way MP propogates in the U.S.?
- To what extent consumption heterogeneity across age groups contributes?

Calibration

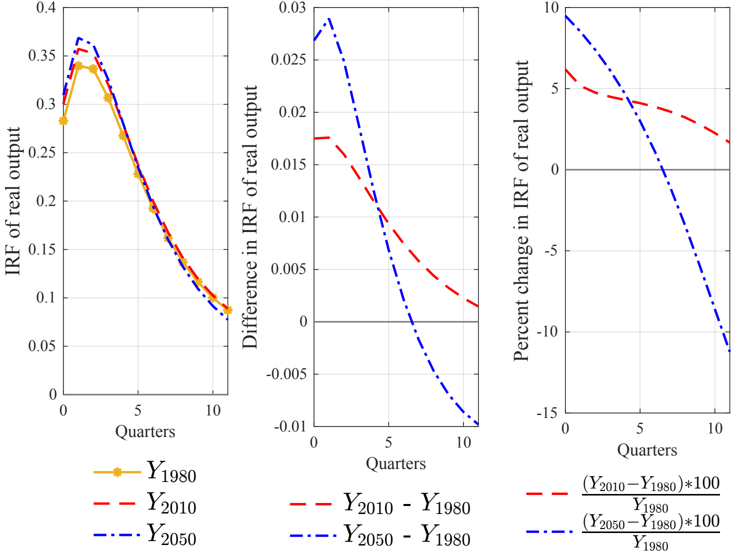
Parameter	Value	Description	Target
β	0.999	Discount factor	Annual interest rate between 4 and 5 %
δ	0.02	Depreciation rate	Capital-output ratio between 2 and 2.7
σ	1	Intertemporal elasticity of substitution	Standard value
ϕ	2	Frish elasticity of labor supply	Standard value
N_j	Population distribution	Population shares. Source: World Bank	
s_j	Mortality rate	Survival probability. Source: Social Security Administration	
α_j	Service share	Share of consumption devoted to services. Source: CEX	
h_j	Labor efficiency	Individual life-cycle labor supply in efficiency units from Fullerton (1999)	Wage profile
ϵ	6	Elasticity of demand for each intermediate good	Steady-state markup of 20 %
θ^S	0.75	Calvo Frequency Services. Source: Nakamura and Steinsson (2008)	Price adjustment every 13 months
θ^G	0.25	Calvo Frequency Goods. Source: Nakamura and Steinsson (2008)	Price adjustment every 3 months
α	0.33	Capital share	Standard value

Model impulse response function to MP shock

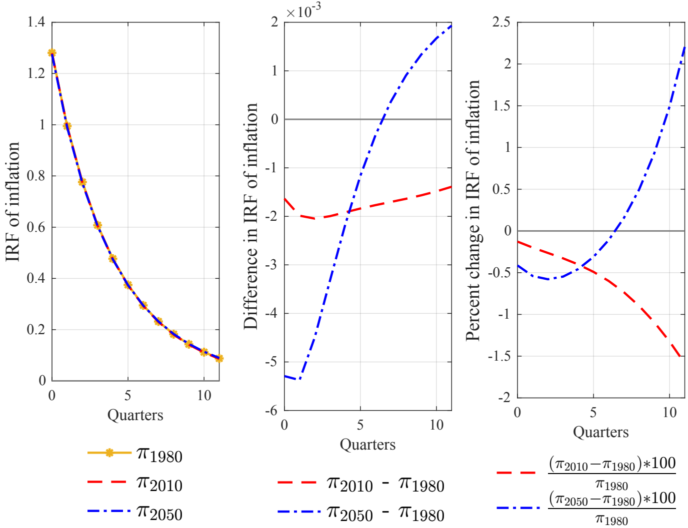
Age responses



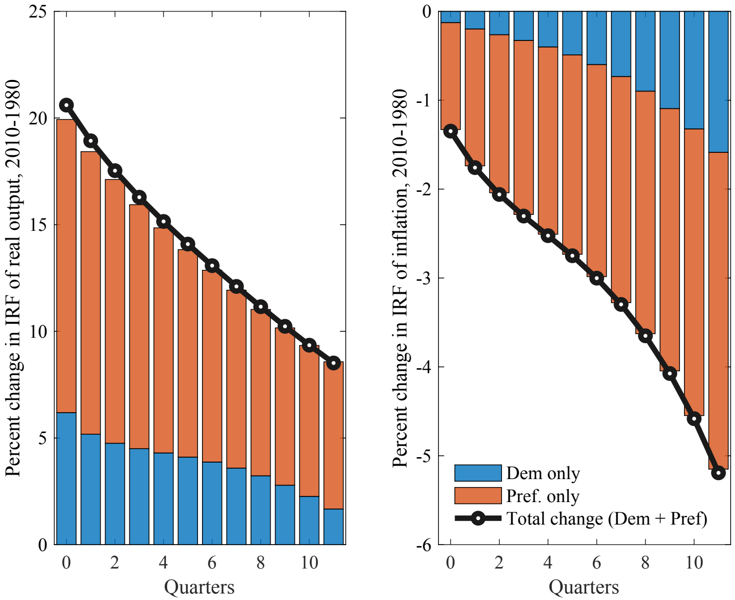
IRFs difference wrt baseline (changing only dem.), output



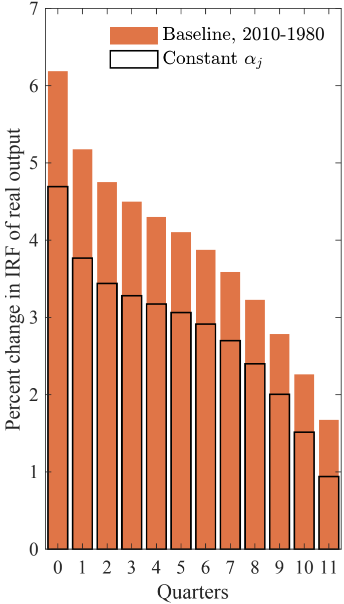
IRFs difference wrt baseline (changing only dem.), inflation

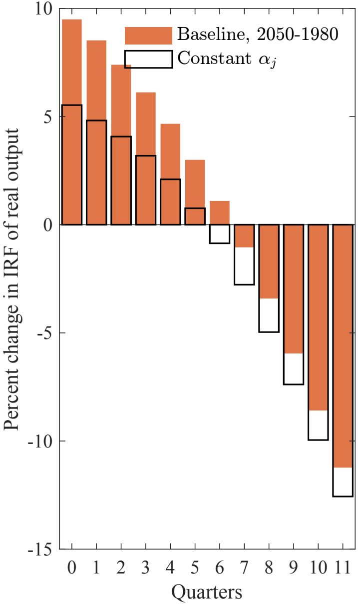


Contribution from demographics change

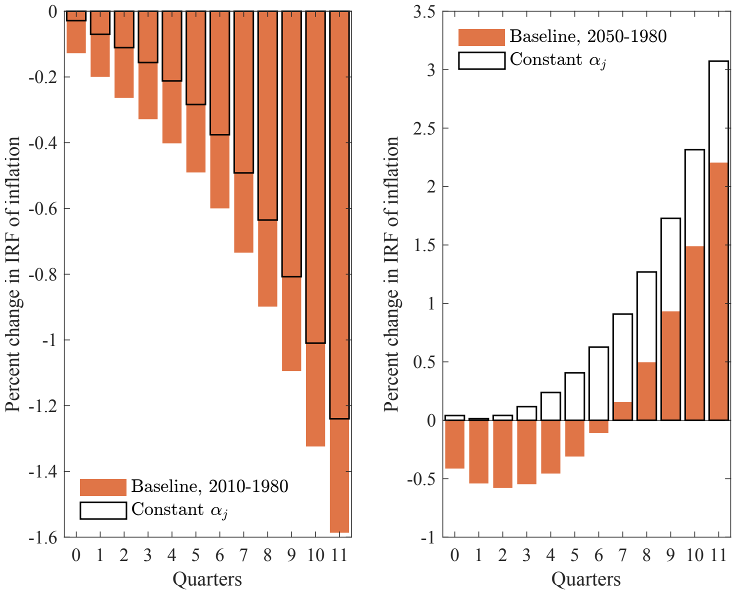


Size of the new channel, Output





Size of the new channel, Inflation



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Conclusion

Main results:

- Using micro data, document significant price stickiness heterogeneity across consumption bundles of different age groups

Conclusion

Main results:

- Using micro data, document significant price stickiness heterogeneity across consumption bundles of different age groups
- Develop a two-sector OLG-NK model to evaluate the effects of population aging on MP shocks propagation in the U.S.:
  - Output has become more responsive over time
  - Consumption differences across age groups significantly contribute to this effect

Thank you for your attention!

References I

Aksoy, Y., Basso, H. S., Smith, R. P., , and Grasl, T. (2019). "Demographic Structure and Macroeconomic Trends". *American Economic Journal: Macroeconomics 2019, 11(1): 193–222.*

Bernanke, B. (2010). "The Economic Outlook and Monetary Policy". *Speech, Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming.*

Bielecki, M., Brzoza-Brzezin, M., and Kolasab, M. (2020). "Demographics and the natural interest rate in the euro area". *European Economic Review, Volume 129.*

Boivin, J., Kiley, M. T., and Mishkin, F. S. (2010). "How Has the Monetary Transmission Mechanism Evolved Over Time?". *Handbook of Monetary Economics, Volume 3, 2010, Pages 369-422 Chapter 8.*

Carvalho, C., Ferrero, A., and Nechio, F. (2016). "Demographics and real interest rates: Inspecting the mechanism". *European Economic Review 88 (2016) 208–226.*

Cloyne, J., Clodomiro, F., Maren, F., and Surico, P. (2018). "Monetary Policy, Corporate Finance and Investment". *NBER Working Papers 25366, National Bureau of Economic Research, Inc December 2018.*

Eggertsson, G. B., Mehrotra, N. R., and Robbins, J. A. (2019). "Population Aging and the Macroeconomy". *A Model of Secular Stagnation: Theory and Quantitative Evaluation.*

Fujiwara, I. and Teranishi, Y. (2008). "A dynamic new Keynesian life-cycle model: Societal aging, demographics, and monetary policy". *Journal of Economic Dynamics and Control 32 (2008) 2398–2427.*

Fullerton, H. N. (1999). "Labor force participation: 75 years of change, 1950-98 and 1998-2025". *Monthly Labor Review, 122:3–12.*

Galesi, A. and Rachedi, O. (2018). "Services Deepening and the Transmission of Monetary Policy". *Journal of the European Economic Association, Volume 17, Issue 4, August 2019, Pages 1261–1293.*

References III

Hauptmeier, S., Holm-Hadulla, F., and Nikalexi, K. (2020). "Monetary Policy and Regional Inequality". *ECB Working Paper No. 2385.*

Hazell, J., Herreno, J., Nakamura, E., and Steinsson, J. (2021). "The Slope of the Phillips Curve: Evidence from U.S. States". *Working paper.*

Heer, B., Rohnbacher, S., and Scharrer, C. (2017). "Aging, the great moderation, and the business-cycle volatility in a life-cycle model". *Macroeconomic Dynamics, 21, 362–383.*

Ilzetzki, E., Mendoza, E., and Vegh., C. (2013). "How Big (Small?) Are Fiscal Multipliers?". *Journal of Monetary Economics, 60, 239-54*.

Imam, P. (2014). "Shock from Greying: Is the Demographic Shift Weakening Monetary Policy Effectiveness". *International Journal of Finance & Economics.*

Jarociński, M. and Karadi, P. (2020). "Deconstructing monetary policy surprises: the role of information shocks". *American Economic Journal: Macroeconomics, 12(2): 1-43.*

References IV

Jordà, O. (2005). "Estimation and Inference of Impulse Responses by Local Projections". *American Economic Review, 95 (1), 161–182.*

Jorda, O., Chitra, M., Fernanda, N., and Eric, T. (2019). "Why Is Inflation Low Globally?". *FRBSF Economic Letter 2019-19.*

Kantur, Z. (2013). "Aging and Monetary Policy". *Working paper.*

Kimberly, B., Curtis, C., Lugauer, S., and Mark, N. C. (2021). "Demographics and Monetary Policy Shocks". *Journal of Money, Credit, and Banking.*

Kronick, J. and Ambler, S. (2019). "Do Demographics Affect Monetary Policy Transmission in Canada?". *International Journal of Finance and Economics. Vol. 24(2), pg. 787–811. April.*

Leahy, J. and Thapar, A. (2020). "Age Structure and the Impact of Monetary Policy". *American Economic Journal: Macroeconomics (forthcoming).*

References V

Lis, E., Nickel, C., and Papetti, A. (2020). "Demographics and inflation in the euro area: a two-sector new Keynesian perspective". *Working Paper Series 2382, European Central Bank*.

Lisack, N., Sajedi, R., and Thwaites, G. (2021). "Population Aging and the Macroeconomy". *International Journal of Central Banking.*

McLeay, M. and Tenreyro, S. (2019). "Optimal inflation and the identification of the Phillips curve". *NBER Macroeconomics Annual 2019.*

Nakamura, E. and Steinsson, J. (2008). "Five facts about prices: a reevaluation of menu cost models". *The Quarterly Journal of Economics, Volume 123, Issue 4, November 2008, Pages 1415–1464*.

Papetti, A. (2019). "Demographics and the natural real interest rate: historical and projected paths for the euro area". *Working Paper Series 2258, European Central Bank*.

References VI

Papetti, A. (2021). "Population Aging, Relative Prices and Capital Flows across the Globe". *Bank of Italy Working Papers, No 1333.*

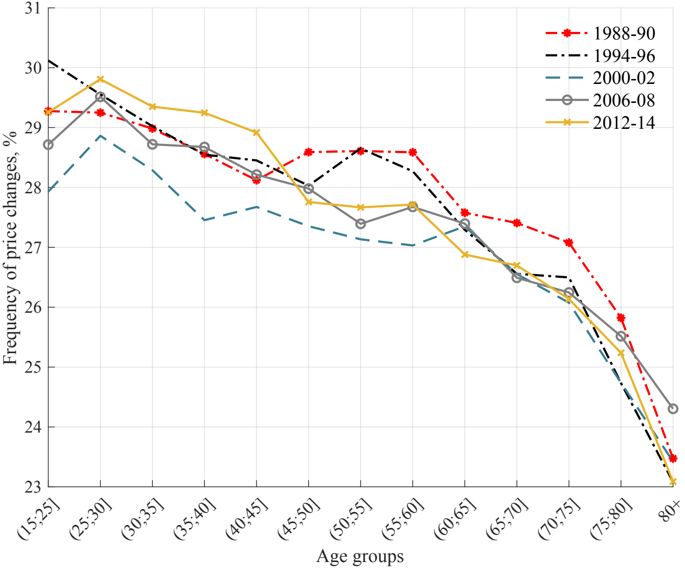
Ramey, V. (2016). "Macroeconomic shocks and their propagation". *In Handbook of Macroeconomics. Vol. 2, 71.*

Romer, C. D. and Romer, D. H. (2004). "A new measure of monetary shocks: Derivation and implications". *American Economic Review 94(4), 1055-84*.

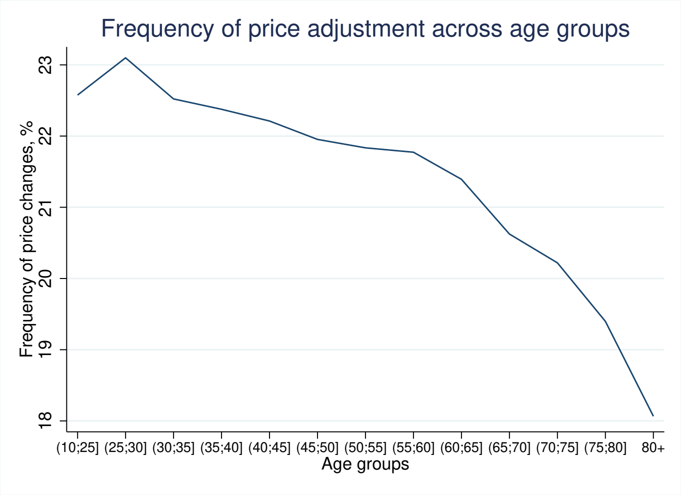
Rubbo, E. (2020). "Networks, Phillips Curves, and Monetary Policy". *Revise and Resubmit at Econometrica.*

Yoshino, N. and Miyamoto, H. (2017). "Declined effectiveness of fiscal and monetary policies faced with aging population in Japan". *Japan and the World Economy 42 (2017) 32–44.*

Across age groups and time



Frequency of price adjustment excluding sales



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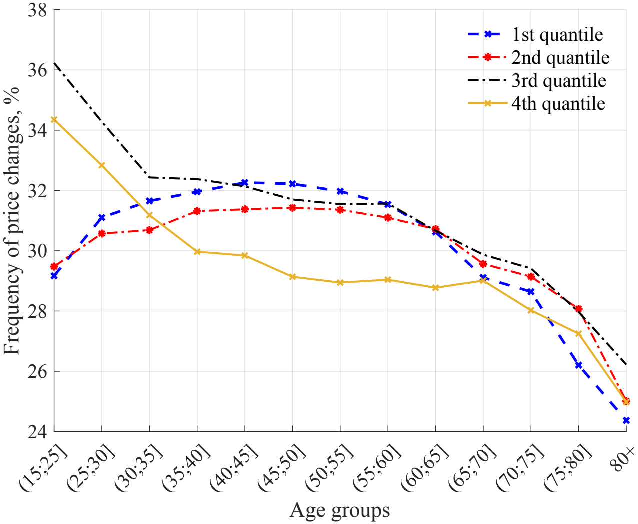
Across age groups and consumption quantiles



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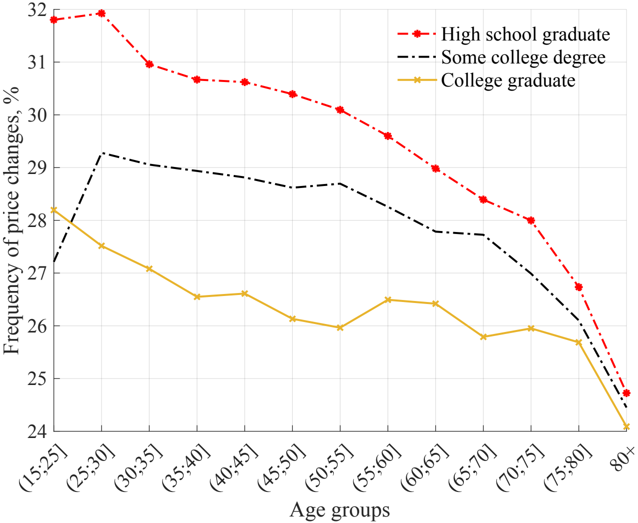
Across age groups and education levels



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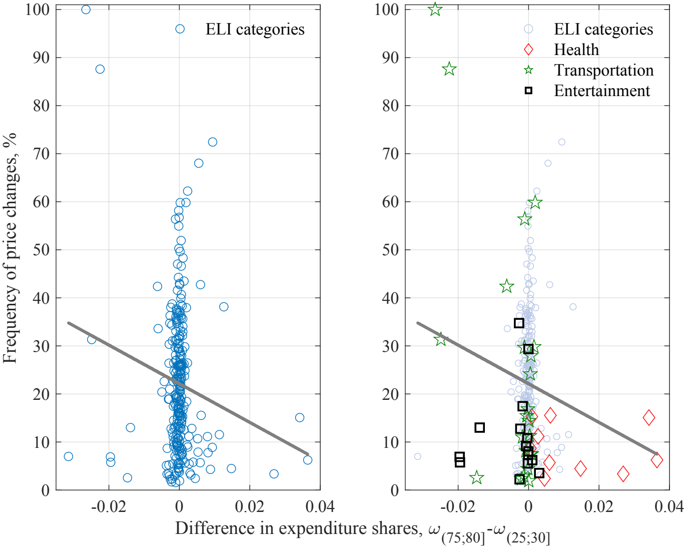
Expenditure differences across age group



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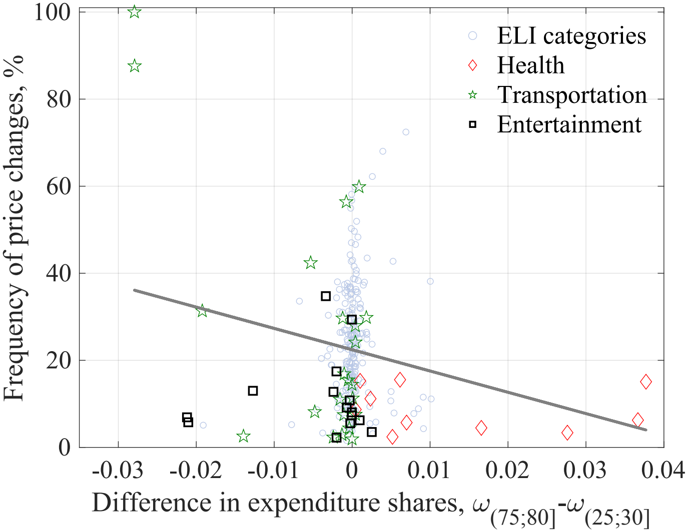

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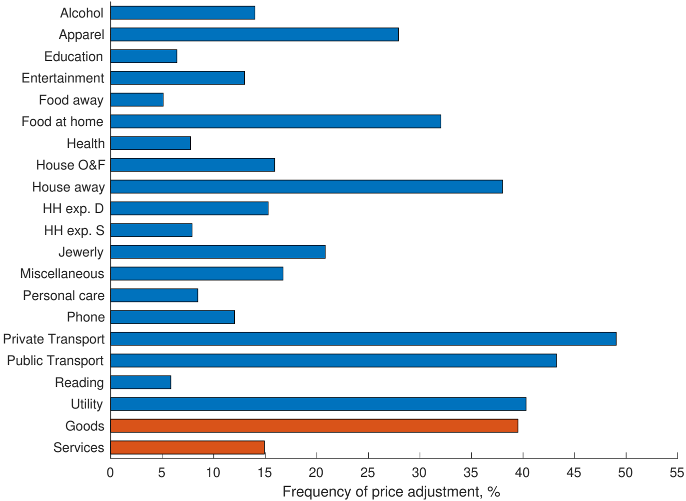
Price stickiness across categories



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Within-between decomposition

What percentage of the increase in the share of services in total consumption is explained by changes in the age distribution?

The **share of services** in aggregate consumption can be written as:

$$\alpha_t^s = \frac{\sum_a C_t^{s,a}}{\sum_a \sum_j C_t^{j,a}} = \sum_a \alpha_t^{s,a} s_t^a$$

with $\alpha_t^{s,a} = \frac{C_t^{s,a}}{\sum_j C_t^{j,a}}$ and $s_t^a = \frac{\sum_j C_t^{j,a}}{\sum_a \sum_j C_t^{j,a}}$

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The change in services between t_1 and t_2 can then be decomposed in:

$$\Delta\alpha_t^s = \underbrace{\sum_a \Delta\alpha^{s,a}\bar{s}^a}_{\text{Within}} + \underbrace{\sum_a \bar{\alpha}^{s,a}\Delta s^{s,a}}_{\text{Between}}$$

with $\Delta x = x_{t_2} - x_{t_1}$ and $\bar{x} = \frac{x_{t_2} - x_{t_1}}{2}$ for any variable x.

Within-between decomposition

$$\Delta\alpha_t^s = \underbrace{\sum_a \Delta\alpha^{s,a}\bar{s}^a}_{\text{Within}} + \underbrace{\sum_a \bar{\alpha}^{s,a}\Delta s^{s,a}}_{\text{Between}}$$

Within-between decomposition, 1982-1990 to 2010-2018

	Service share	Contribution	Implied duration, months
Within	0.044	72.3 %	0.42 (+5.4 %)
Between	0.017	27.7 %	0.16 (+2.1 %)
Total	0.061	100 %	0.58 (+7.5 %)
	(46.69 % to 52.75 %)		(7.83 to 8.42)

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U.S. states, data and empirical specification

Prediction: Economic activity in U.S. states with higher old-age dependency ratio should react more to MP shocks ▸ State variation ▸ Services ▸ Health ▸ Back

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The **average state level response** to a MP shock is estimated using Local Projection à la Jordà (2005):

$$y_{i,t+h} = \alpha_{i,h} + \beta_h MP_t + \theta_{i,h} X_{i,t-1} + \gamma_h X_{t-1} + \epsilon_{i,t+h}$$

for $h = 1, ..., 16$

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- Dependent variable $y_{i,t}$:
  - Real Personal Income from the Bureau of Economic Analysis (BEA)
  - Annual inflation rate from Hazell et al. (2021)
  - GDP from the BEA (annual frequency)
- MP_t are the Romer and Romer (2004) shocks
- State controls $X_{i,t-1}$: lagged dependent variable and population size
- Aggregate controls X_{t-1} as in Ramey (2016): IP, CPI, FFR, unemployment rate and commodity price index
- Standard errors are clustered at state level.

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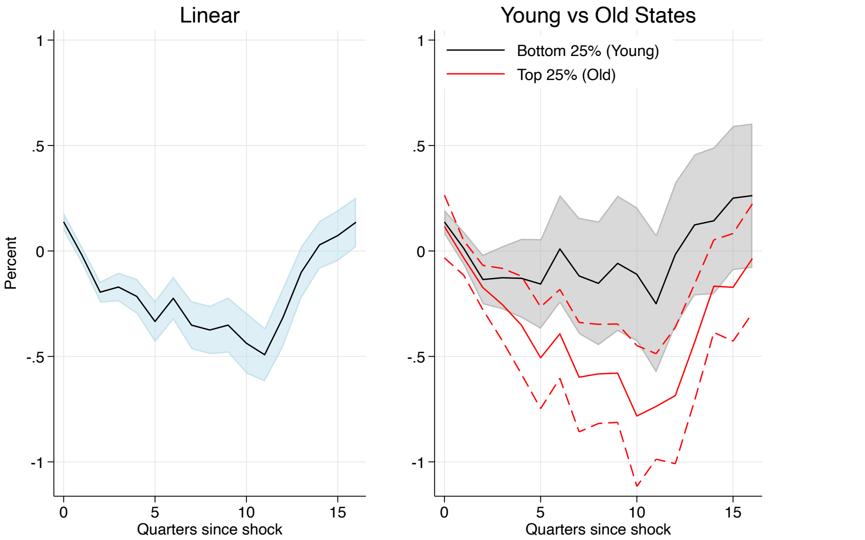
for $h = 1, ..., 16$

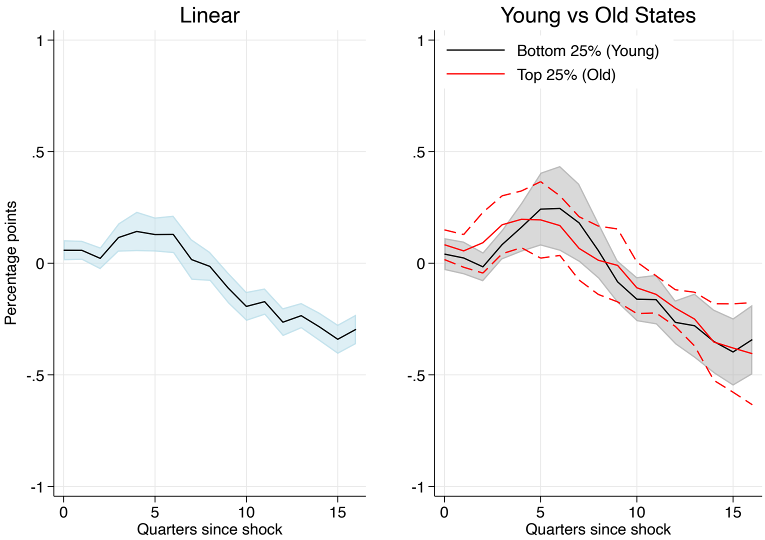
As in Cloyne et al. (2018), we define **dummy variables** for different percentiles P of the old-age dependency ratio distribution and we interact them with our MP shock:

$$y_{i,t+h} = \alpha_{i,h} + \sum_{p=1}^{P} \gamma_h D_{i,t}^{p} + \sum_{p=1}^{P} \beta_h^{p} D_{i,t}^{p} MP_t + \theta_{i,h} X_{i,t-1} + \gamma_h X_{t-1} + \epsilon_{i,t+h}$$

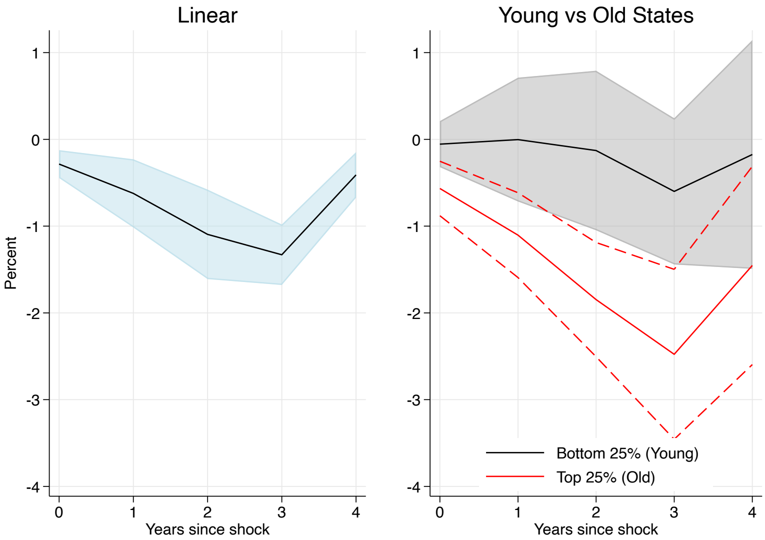
IRF Personal Income



IRF Inflation rate



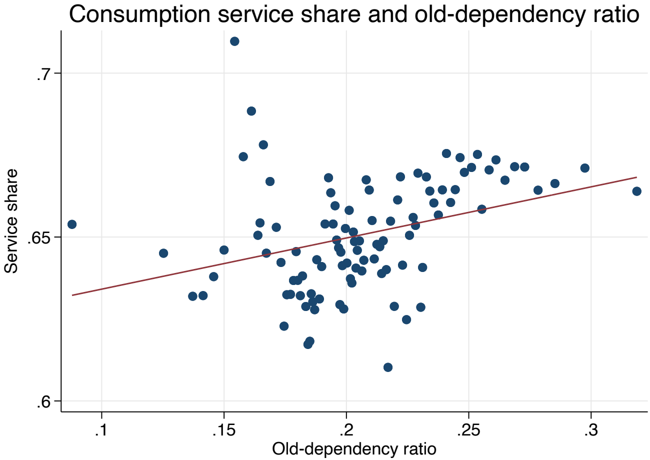
IRF Regional GDP



Robustness checks

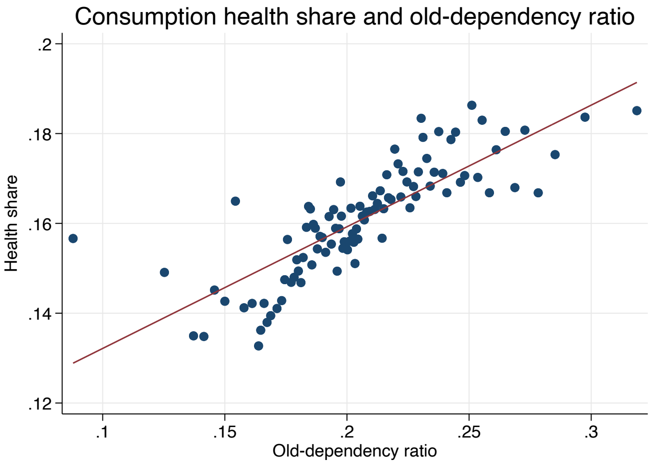
- Above/below median ▸ Go
- Top/bottom 10 % ▸ Go
- Share of working population ▸ Go
- No financial crisis ▸ Go
- Controlling for income ▸ Go
- Excluding small states ▸ Go
- High-frequency identification with IV-LP ▸ Go
- Services ▸ Go

Service share and old-age dependency ratio



▸ Back

Health share and old-age dependency ratio



Back

Firms

The firms side has two sectors:

- **services** and **goods**
- Each sector has competitive final goods firm and a continuum of monopolistically competitive intermediate goods firms (standard NK model)
- Different frequency of price adjustment
- Only the output of the goods-sector can be used for capital investment

Price stickiness: Each period a fraction θ^s of intermediate producers cannot reset their price, $\theta^S > \theta^G$.

Market clearing Back

Market clearing

Both aggregate labor and capital markets clear:

$$L_t = L_t^S + L_t^G = \sum_{j=1}^{jw} N_j h_j n_{t,j}, \qquad K_t = K_t^S + K_t^G = \sum_{j=1}^{J} N_{j-1} a_{t,j}$$

$$beq_t = \sum_{j=1}^{J} (N_{j-1} - N_j) a_{t,j} R_t^a$$

The markets of goods and services clear:

$$Y_t^S = (K_t^S)^\alpha (L_t^S)^{1-\alpha} = C_t^S$$

$$Y_t^G = (K_t^G)^\alpha (L_t^G)^{1-\alpha} = C_t^G + I_t$$

and bonds are in zero net supply, $B_t = 0$.

Back

Investment funds

The FOCs of the representative investment fund are:

$$K_{t+1} = (1-\delta)K_t + \left[1 - \frac{S}{2}(\frac{I_t}{I_{t-1}} - 1)^2\right] I_t$$

$$A_{t+1} = q_t(1-\delta)K_t + I_t + p_t^d$$

$$\frac{R_t^a}{\pi_t} A_t = \left[r_t^k + q_t(1-\delta)\right] K_t + f_t + p_t^d$$

$$R_t q_t = \mathbb{E}_t\left[\left(r_{t+1}^k + q_{t+1}(1-\delta)\right)\pi_{t+1}\right]$$

$$R_t p_t^d = \mathbb{E}_t\left[\left(p_{t+1}^d + f_{t+1}\right)\pi_{t+1}\right]$$

$$1 = q_t\left[1 - \frac{S}{2}(\frac{I_t}{I_{t-1}} - 1)^2 - S(\frac{I_t}{I_{t-1}} - 1)\frac{I_t}{I_{t-1}}\right] + \mathbb{E}_t\left[\frac{\pi_{t+1}}{R_t} q_{t+1} S(\frac{I_{t+1}}{I_t} - 1)(\frac{I_{t+1}}{I_t})^2\right]$$

Back

Government and Monetary Authority

The government funds a **pay-as-you-go social security system**. The tax rate on labor income τ_t is set such that the budget is balanced in each period.

$$pen_t = \bar{d}(1-\tau_t)w_t \sum_{j=0}^{jw} N_j h_j$$

$$\tau_t w_t \sum_{j=0}^{jw} N_j h_j = pen_t \sum_{j=jw+1}^{J} N_j$$

with d_t the amount of pension benefit and $\bar{d}$ the replacement rate.

The central bank follows the following simple **Taylor-type rule**:

$$\frac{R_t}{R} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} e^{\nu_t^r}$$

Back

Phillips Curve

The **sectoral Phillips Curve**:

$$\hat{\pi}_t^S = \beta \mathbb{E}_t \hat{\pi}_{t+1}^S + \kappa^S \hat{mc}_t^S$$

$$\hat{\pi}_t^G = \beta \mathbb{E}_t \hat{\pi}_{t+1}^G + \kappa^G \hat{mc}_t^G$$

with

$$\kappa^S = \frac{(1-\theta^S)(1-\theta^S\beta)}{\theta^S}, \qquad \kappa^G = \frac{(1-\theta^G)(1-\theta^G\beta)}{\theta^G}$$

Since $\theta^S > \theta^G$, it follows that $\kappa^S < \kappa^G$.

Phillips Curve

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Since $\theta^S > \theta^G$, it follows that $\kappa^S < \kappa^G$.
It can be shown that:

$$\hat{\pi}_t = \omega\hat{\pi}_t^S + (1-\omega)\hat{\pi}_t^G = \beta\mathbb{E}_t\hat{\pi}_{t+1} + \left[\omega\kappa^S + (1-\omega)\kappa^G\right](\hat{w}_t - \alpha(\hat{k}_t - \hat{l}_t)) - \lambda\hat{z}_t$$

where $\omega = \sum_j \alpha_j s_j \frac{P_j^{\eta-1}}{\sum_j s_j P_j^{\eta-1}}$, $s_j = \frac{N_j P_j C_j}{\sum_j N_j P_j C_j}$ and $\hat{z}_t = logP_t^G - logP_t^S$.

Phillips Curve

Effect of population aging on the slope of the Phillips Curve

	Baseline 1980	Dem+Pref 2010	Only Dem 2010
Service weight ω	0.4498	0.4953 (+10.11 %)	0.4542 (+0.97 %)
PC slope	1.2759	1.1773 (-7.72 %)	1.2665 (-0.74 %)

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Sensitivity analysis

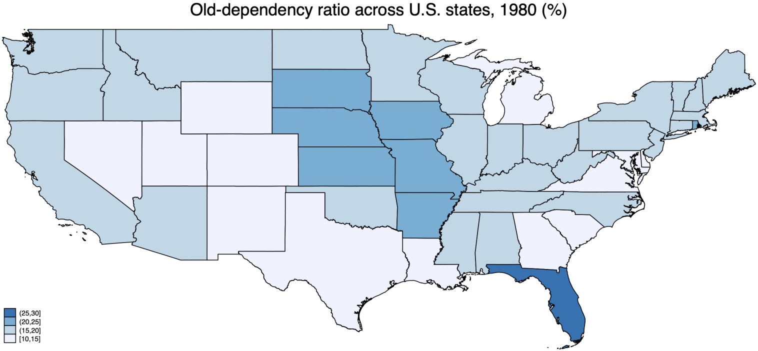
Response of Output and Inflation - Robustness Checks

	Output response (%)			Inflation response (%)		
	Time 0	After 1 year	After 2 years	Time 0	After 1 year	After 2 years
Baseline	6.18	4.30	3.22	-0.12	-0.40	-0.89
Different ψ	5.63	4.01	2.93	-0.07	-0.26	-0.64
Different ϵ	5.07	3.72	2.83	-0.15	-0.34	-0.63
Different ϕ	6.97	4.58	2.95	-0.12	-0.36	-0.82
Constant τ	5.79	4.03	3.02	-0.09	-0.31	-0.71

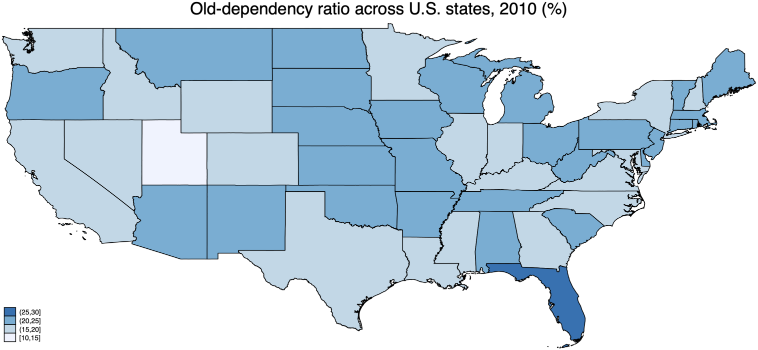
*

Notes: The table reports the percent change in IRFs of output and inflation between 1980 to 2010 under alternative assumptions of the model.

old-age dependency ratio across states



old-age dependency ratio across states



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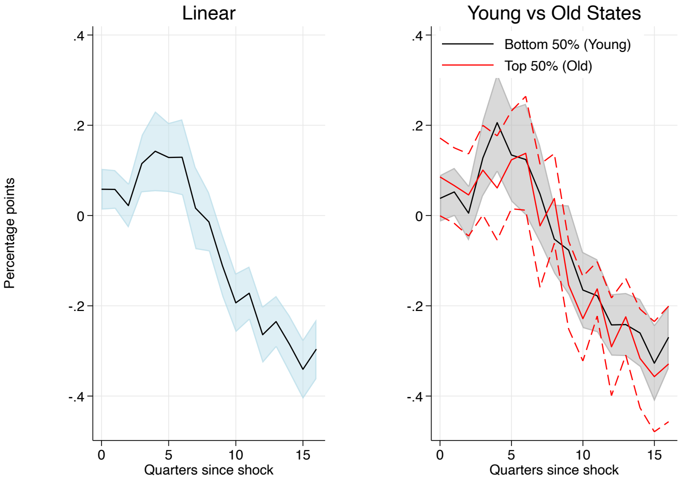
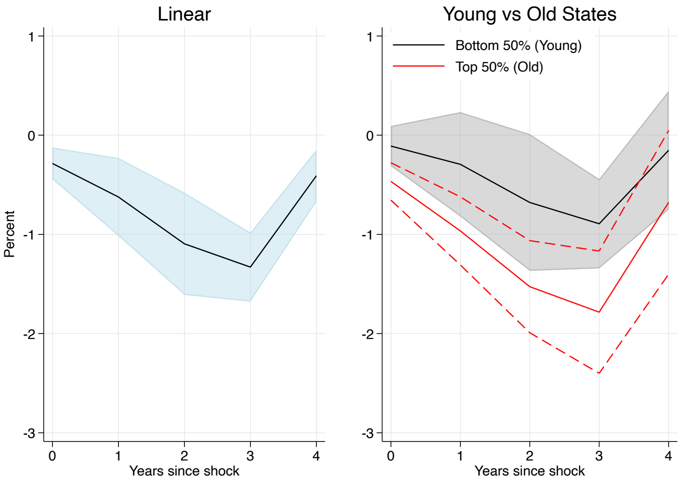
IRF Personal Income, Above/below median

IRF Inflation rate, Above/below median



IRF Regional GDP, Above/below median



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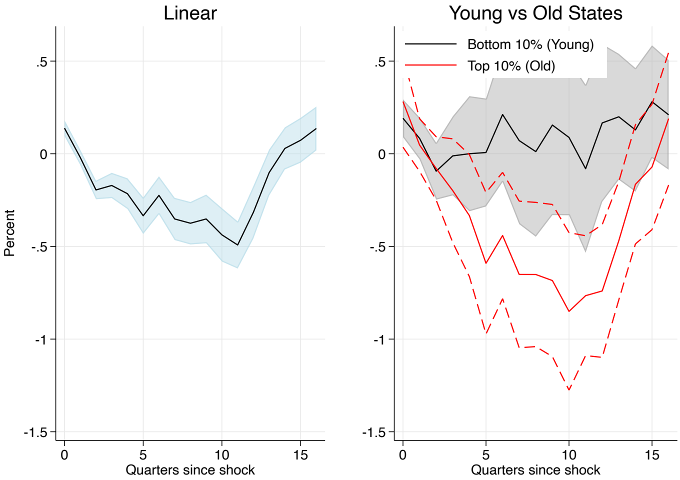
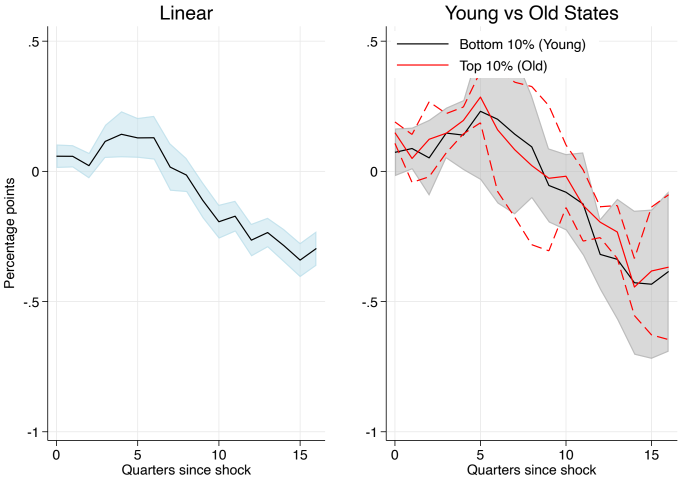
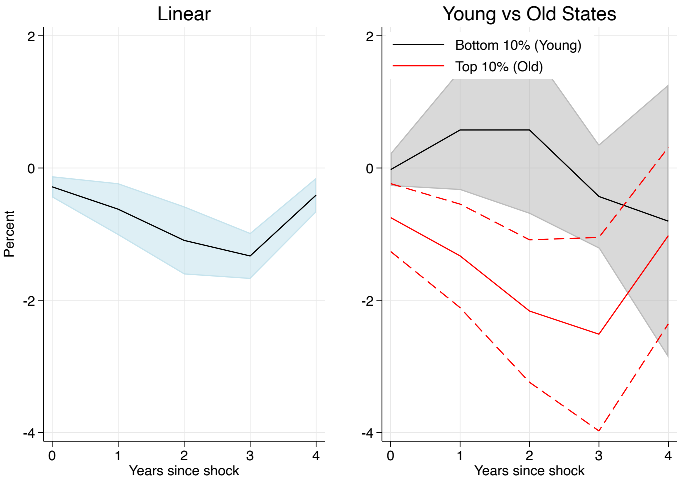
IRF Personal Income, Top/bottom 10 %



IRF Inflation rate, Top/bottom 10 %



IRF Regional GDP, Top/bottom 10 %



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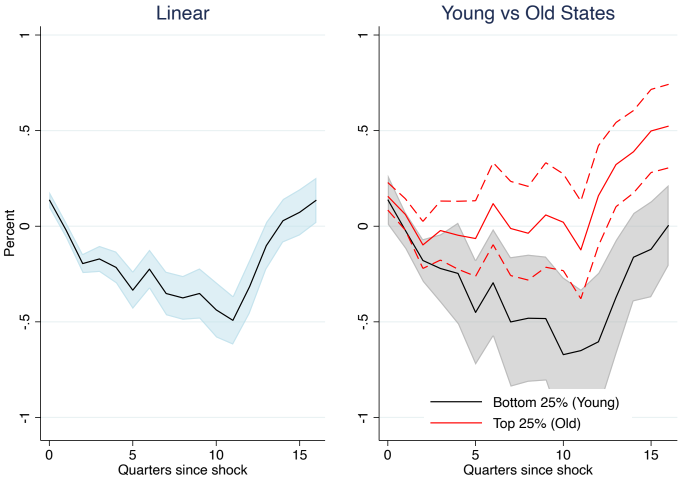
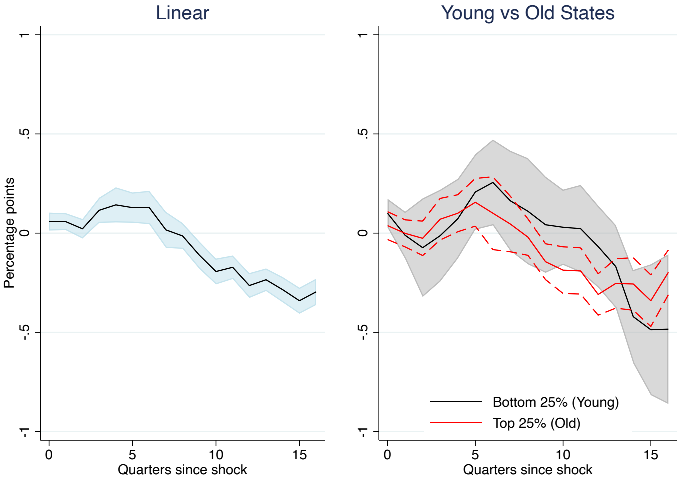
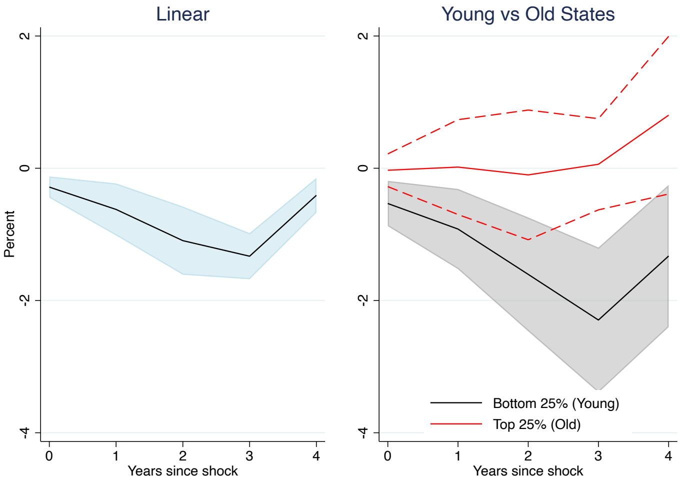
IRF Personal Income, share working population



IRF Inflation rate, share working population



IRF Regional GDP, share working population



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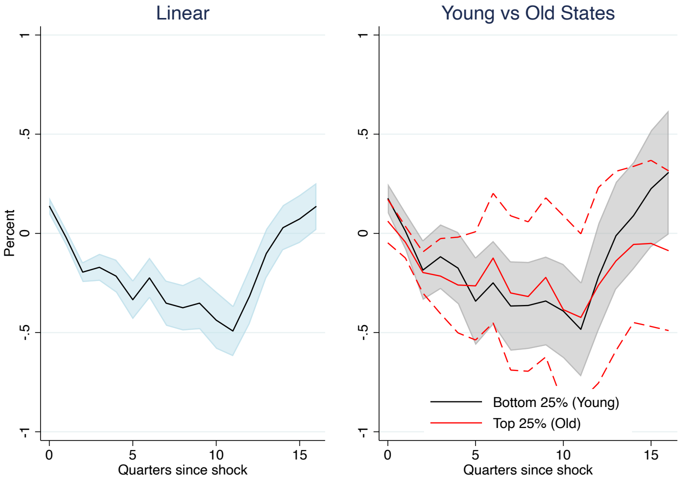
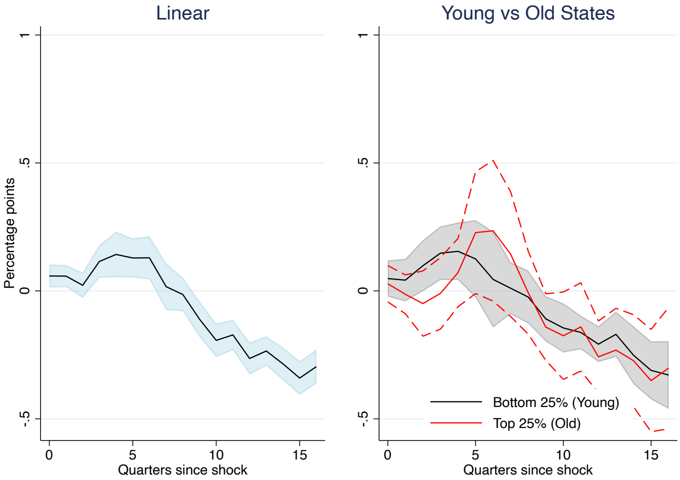
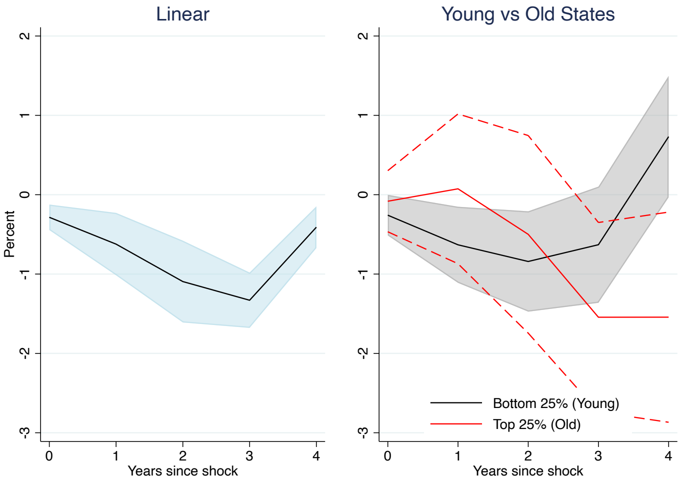
IRF Personal Income, share young



IRF Inflation rate, share young



IRF Regional GDP, share young



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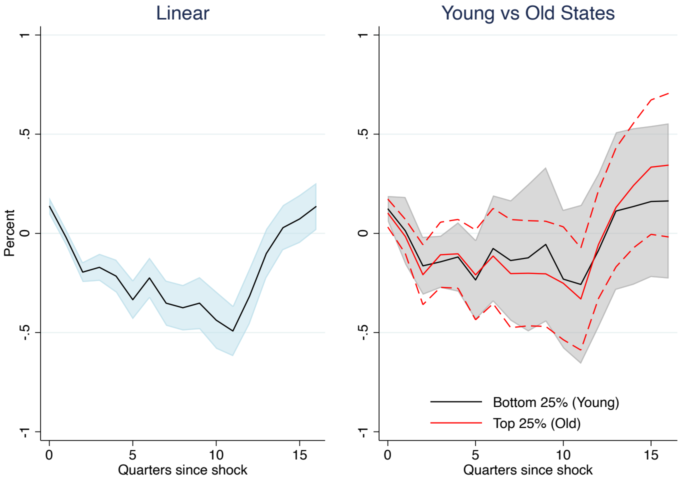
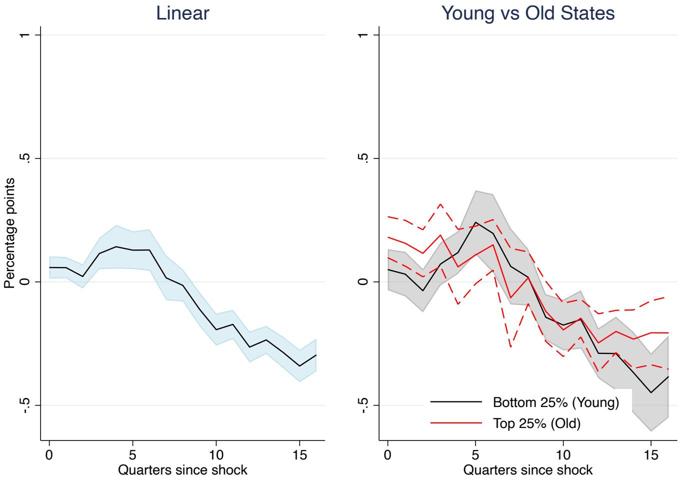
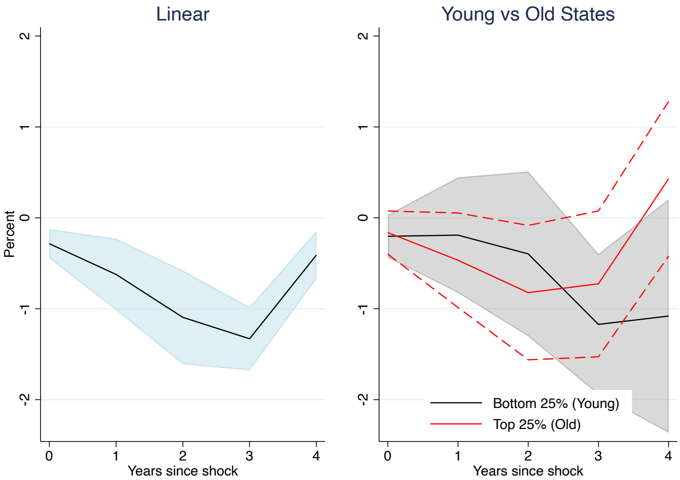
IRF Personal Income, share old



IRF Inflation rate, share old



IRF Regional GDP, share old



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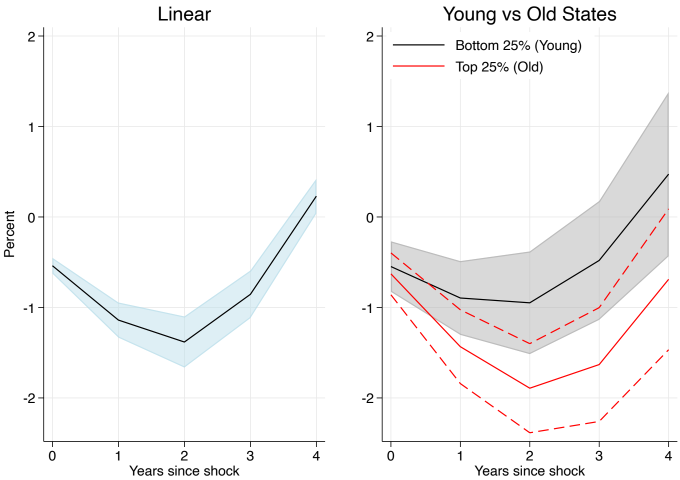
IRF Regional GDP, services



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Lagged birth rates as IV

Baseline regression:

$$y_{i,t+8} = \alpha_i + \beta MP_t + \tau D_{i,t} + \delta MP_t x(D_{i,t} - \bar{D}) + \theta_{i,h} X_{i,t-1} + \gamma X_{t-1} + \epsilon_{i,t}$$

- $y_{i,t+8}$ is the 2 year ahead log of Personal Income
- $D_{i,t}$ share of working population

Regression table:

	(1) OLS	(2) OLS	(3) 2SLS	(4) 2SLS
MP_t	-0.545***	-0.473***	-0.385	
	(0.0905)	(0.0902)	(0.252)	
$D_{i,t}$	-0.000767*	-0.000710*	-0.00747***	-0.00697***
	(0.000434)	(0.000431)	(0.00239)	(0.00229)
$MP_t x(D_{i,t} - \bar{D})$		0.227***	0.649***	1.024*
		(0.0232)	(0.216)	(0.526)
Observations	7701	7701	7392	7392
Controls	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Time FE	NO	NO	NO	NO
First stage F stat.			17.74	22.60

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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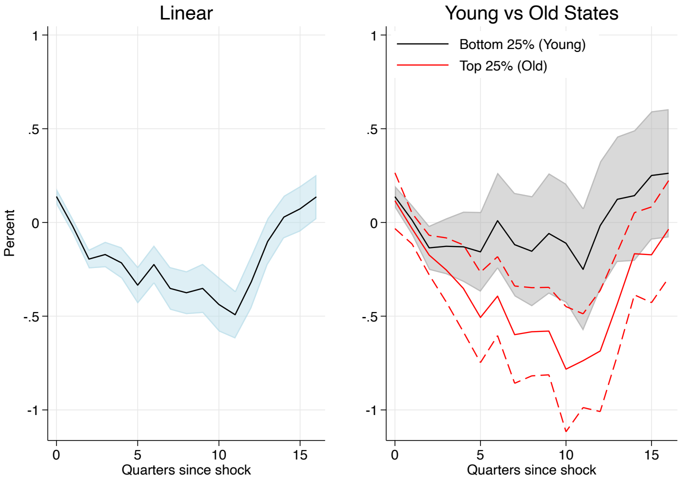
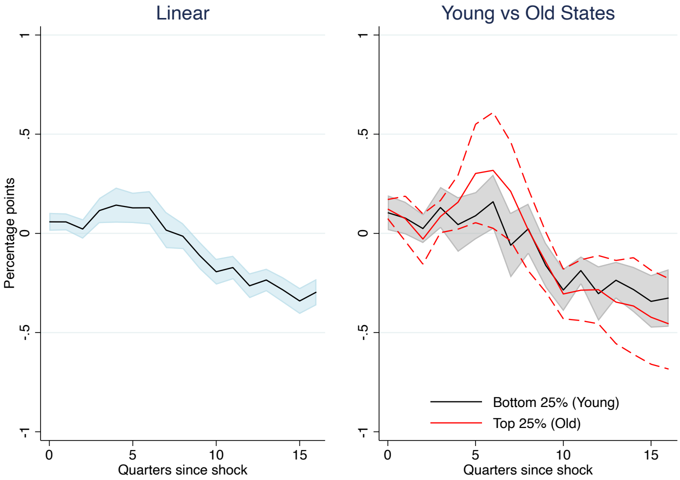
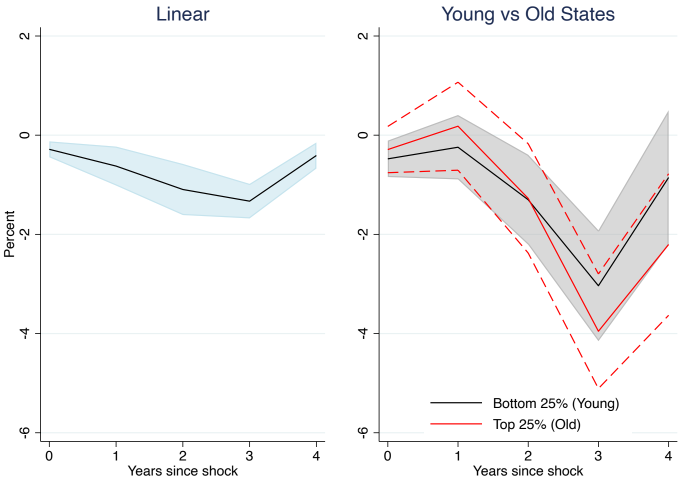
IRF Personal Income, IV



IRF Inflation rate, IV



IRF Regional GDP, IV



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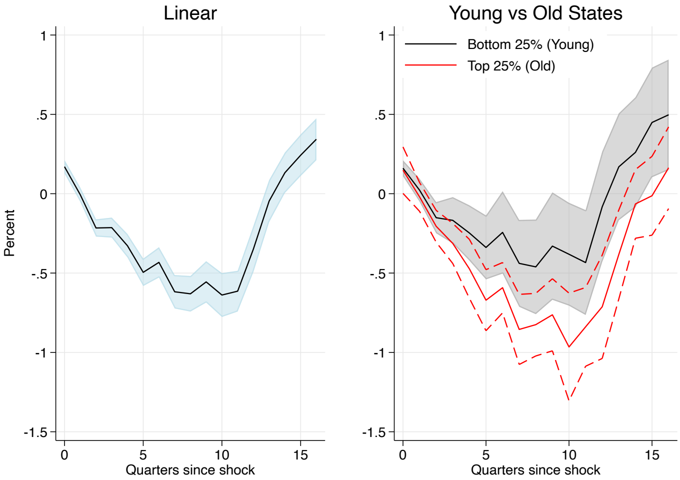
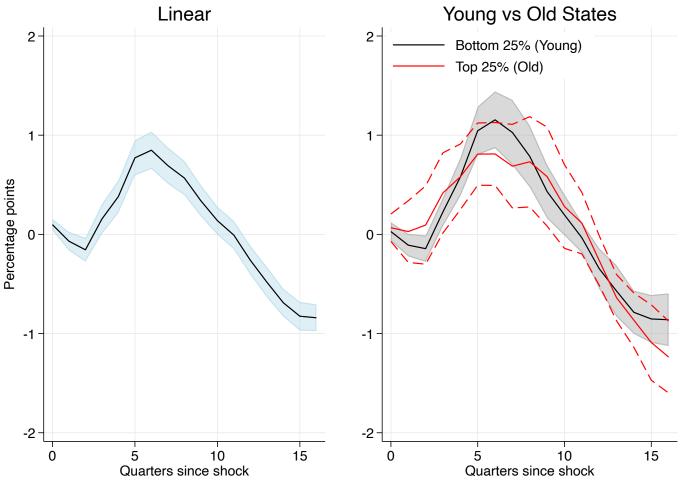
IRF Personal Income, No financial crisis



IRF Inflation rate, No financial crisis



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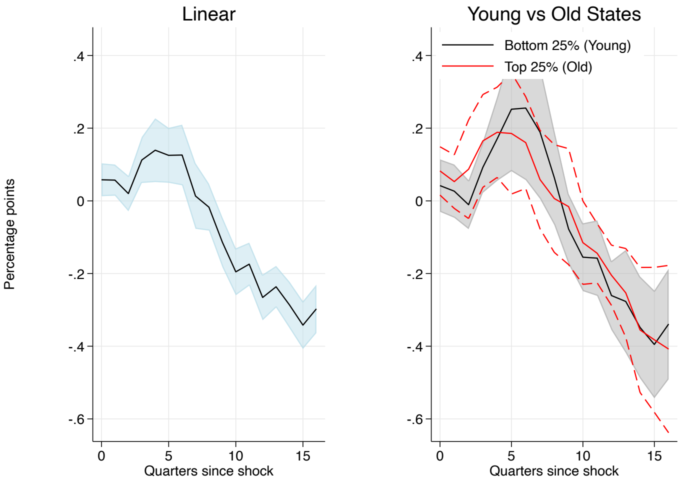
IRF Personal Income, Controlling for income

IRF Inflation rate, Controlling for income



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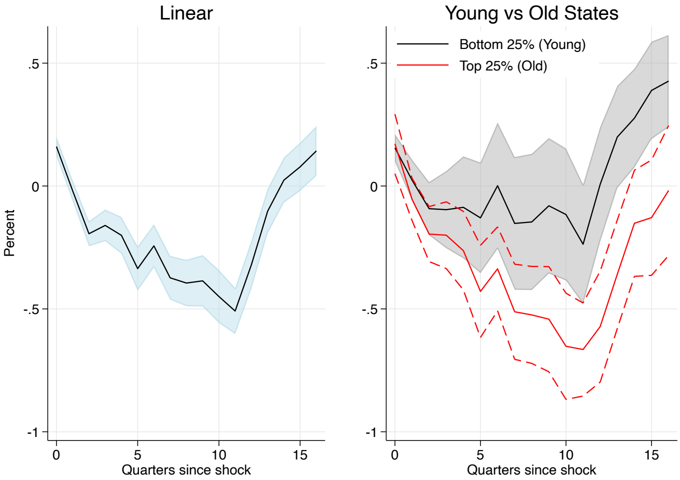
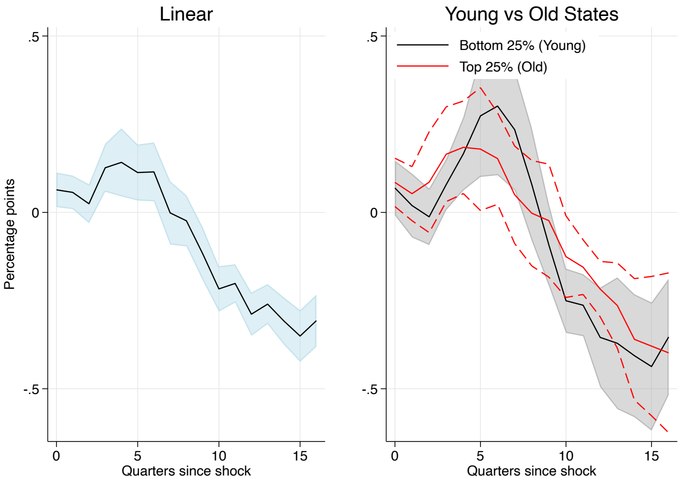
IRF Personal Income, no small states



IRF Inflation rate, no small states



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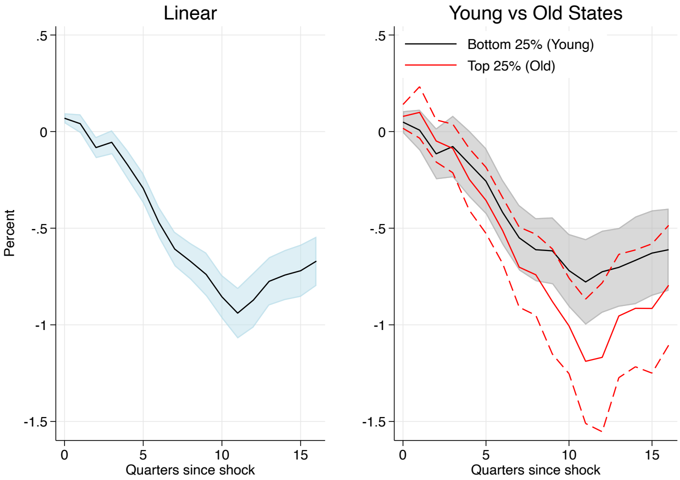
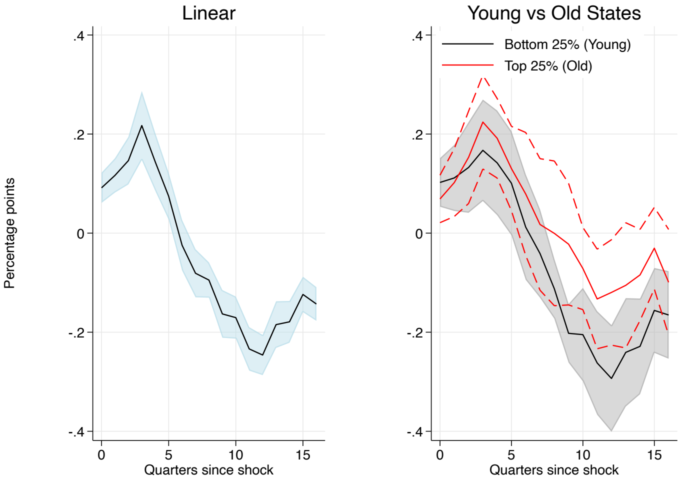
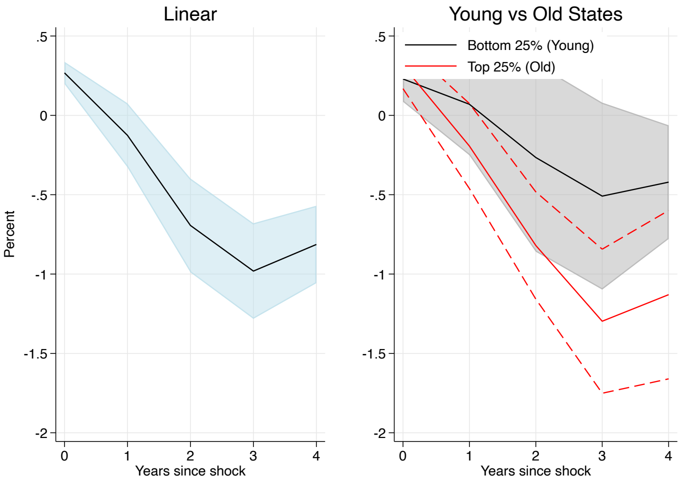
IRF Personal Income, IV-LP



IRF Inflation rate, IV-LP



IRF Regional GDP, IV-LP



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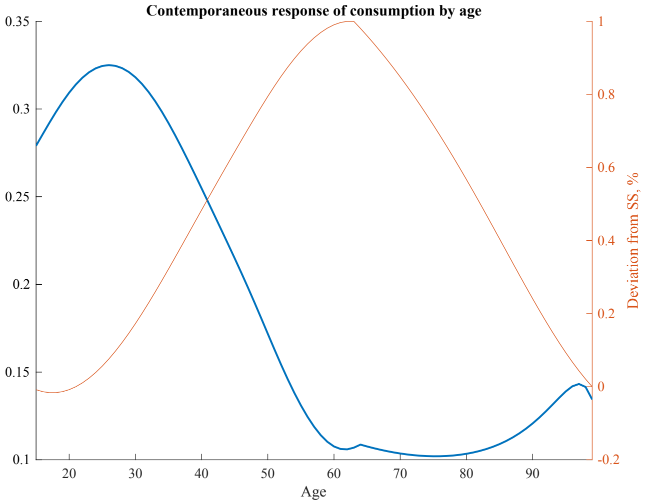
IRF by age



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IRFs across countries

Similarly to Galesi and Rachedi (2018) and Ilzetzki et al. (2013), we build a panel of quarterly data on inflation, output and interest rate from 1985:Q1 to 2015:Q4 for 44 countries

IRFs across countries

Similarly to Galesi and Rachedi (2018) and Ilzetzki et al. (2013), we build a panel of quarterly data on inflation, output and interest rate from 1985:Q1 to 2015:Q4 for 44 countries

We run a structural VAR on $Y_t = [\Delta logGDP_t, \Delta logP_t, R_t]$ with four lags:

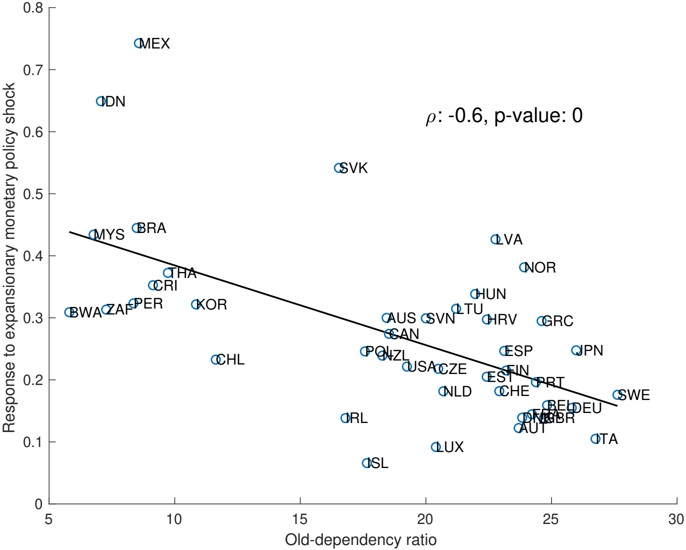
$$Y_t = A(L)Y_t + Bu_t$$

The monetary policy shocks are identified by **sign restrictions** on the impulse responses, a monetary policy shock:

- Increases the nominal interest rate
- Reduces real output growth and the inflation rate on impact as well as in the following quarter.

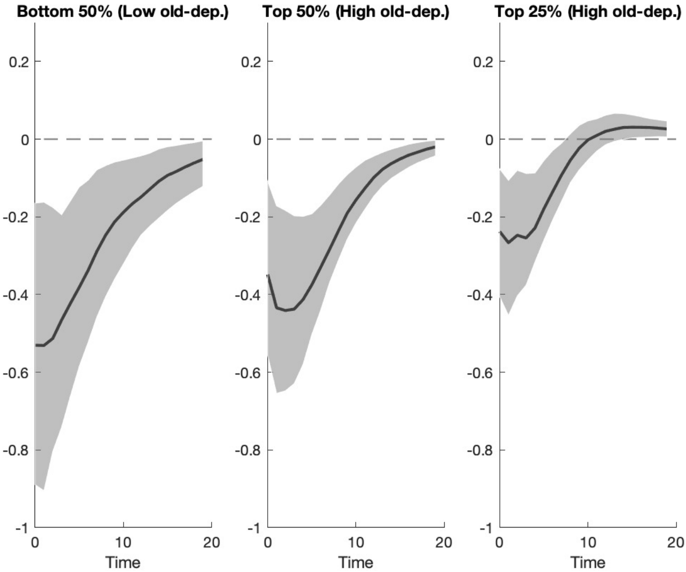
▸ Country data

Contemporaneous response of inflation

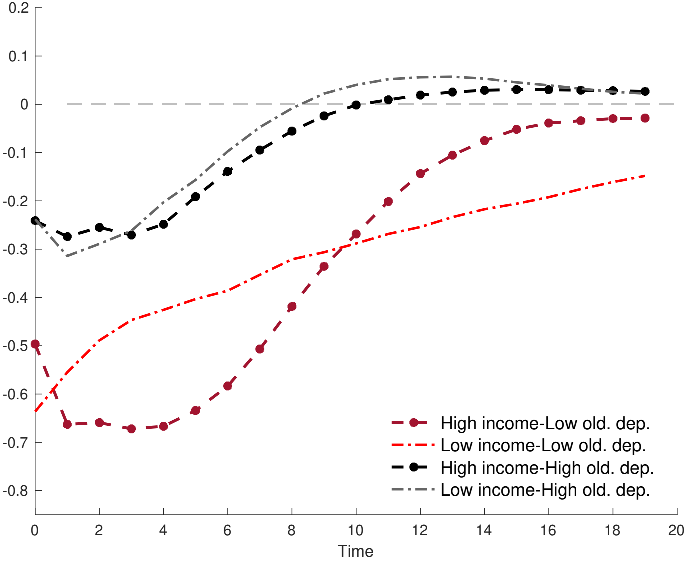


▸ Confidence bands ▸ Maximum response

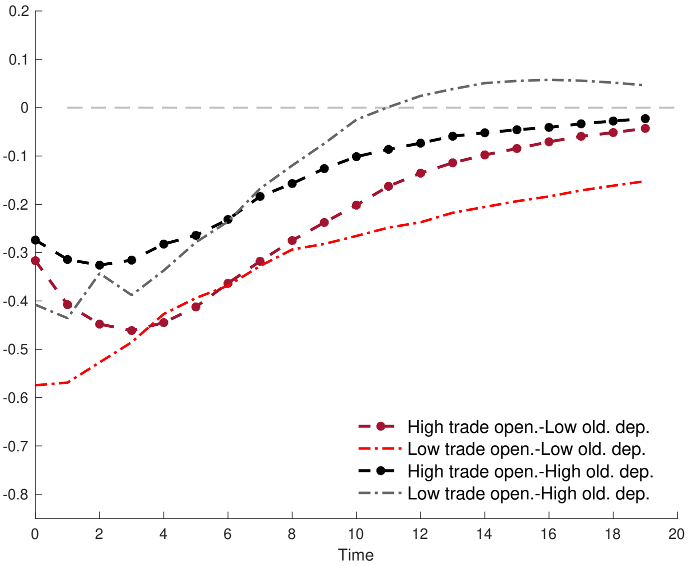
IRFs across countries' characteristics



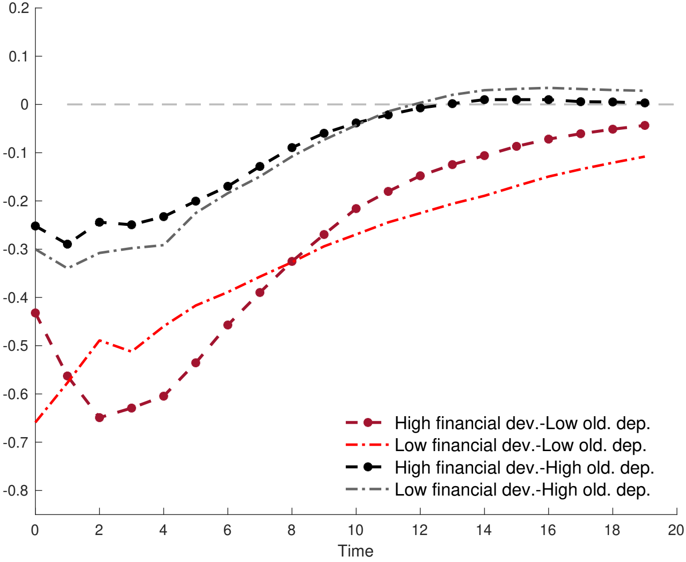
IRFs across countries' characteristics



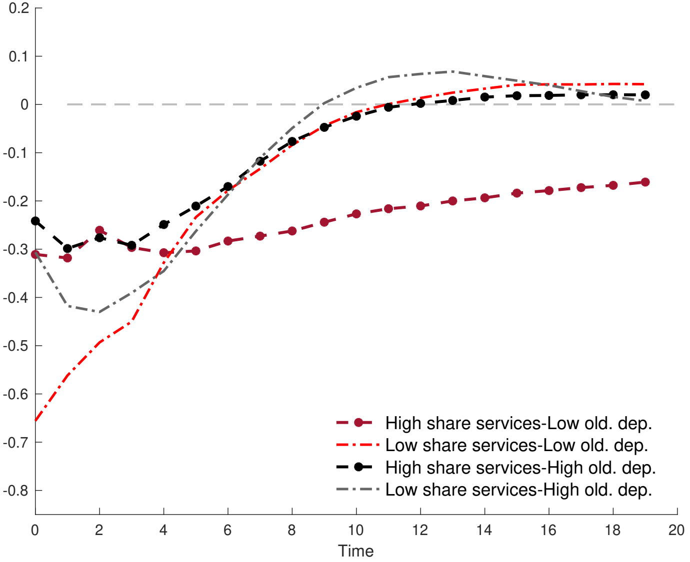
IRFs across countries' characteristics



IRFs across countries' characteristics



IRFs across countries' characteristics



Macro implications

We showed that:

- Older people purchase more from (relatively) **stickier-price sectors**
- Since the demographic structure of the US economy has significantly changed in the last 50 years, this result partially explains the observed **more dampened response of inflation** to monetary shocks

Based on this finding, **two hypothesis** can be tested:

- Inflation in countries with a higher old-age dependency ratio reacts less to MP shocks
- Inflation in Euro Area regions with a higher old-age dependency ratio reacts less to MP shocks.

Euro Area

IRFs for the Euro Area

Dataset of CPI at NUTS-1/NUTS-2 level for 69 regions in the Euro Area (22 in Italy, 19 in Spain, 16 in Germany, 7 in Portugal and 5 in Finland) from 1999 to 2016

IRFs for the Euro Area

Dataset of CPI at NUTS-1/NUTS-2 level for 69 regions in the Euro Area (22 in Italy, 19 in Spain, 16 in Germany, 7 in Portugal and 5 in Finland) from 1999 to 2016

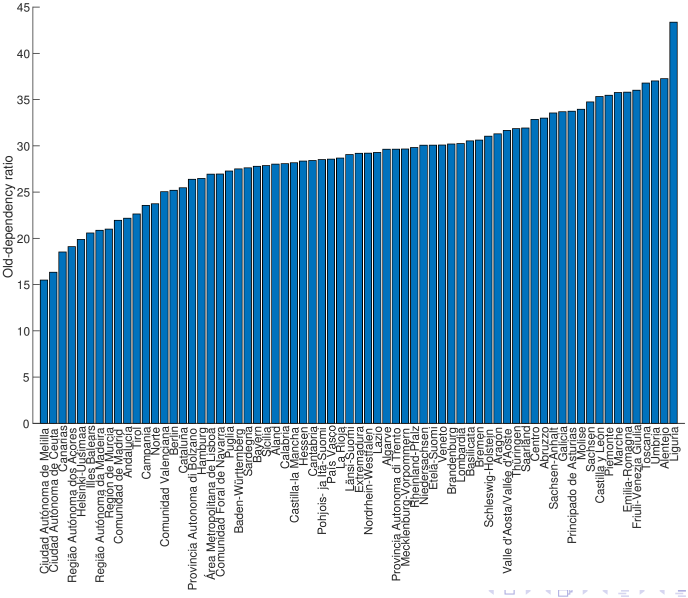
Estimate the empirical specification proposed by Hauptmeier et al. (2020):

$$y_{i,t+h} = \alpha_i + \beta_h \epsilon_t^{MP} + \gamma_h X_{i,t} + \delta_h X_{j,t} + \theta_h X_{k,t} + u_{i,t+h}$$

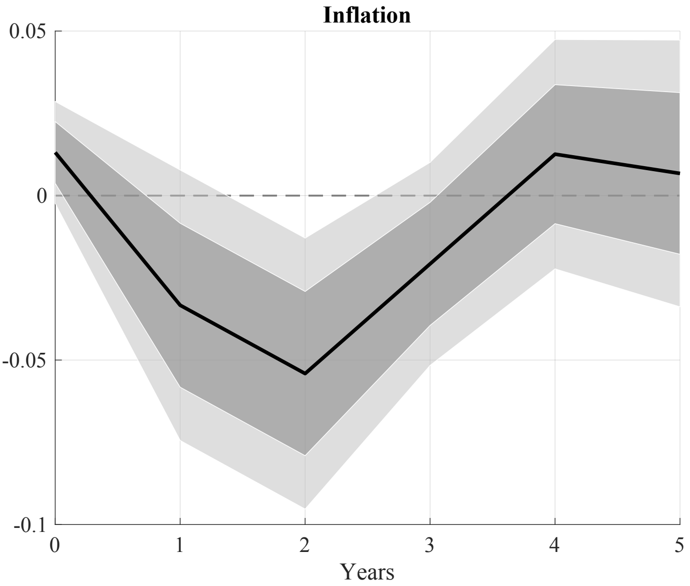
- ϵ_t^{MP} the high-frequency montary policy shocks computed by Jarociński and Karadi (2020)
- $X_{i,t}$, $X_{j,t}$ and $X_{k,t}$ are vectors of time-variant control variables at the region-, country- and euro area-level (i.e. region fixed effects, population size, employment, share of services in gross value added, country and Euro Area GDP, Euro Area CPI).

▸ Data ▸ Regions available

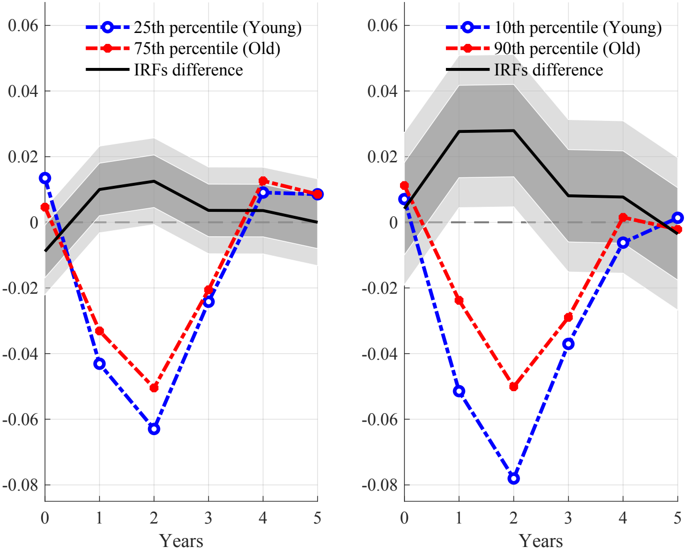
old-age dependency ratio across European regions



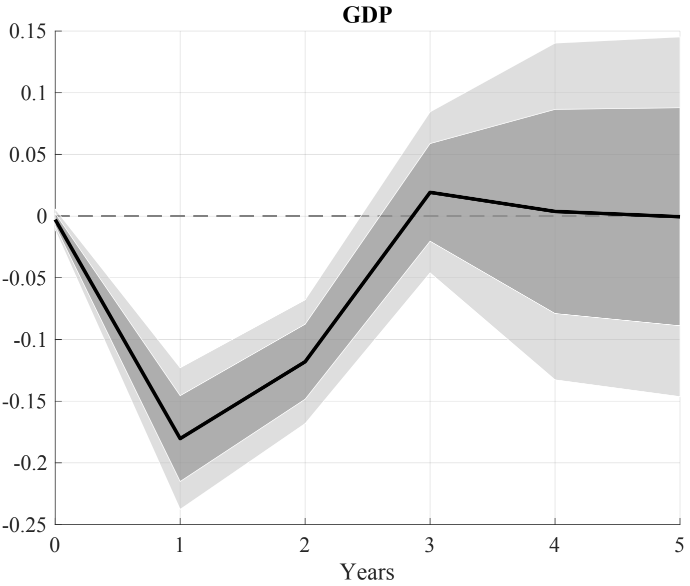
IRFs for the Euro Area



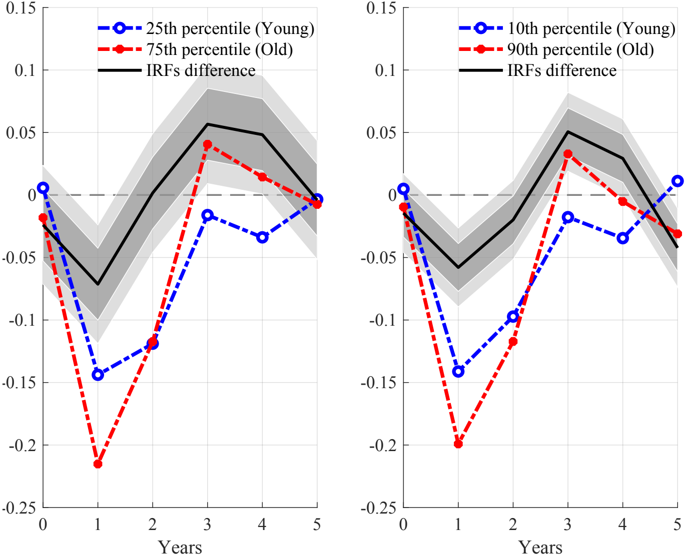
IRFs for the Euro Area



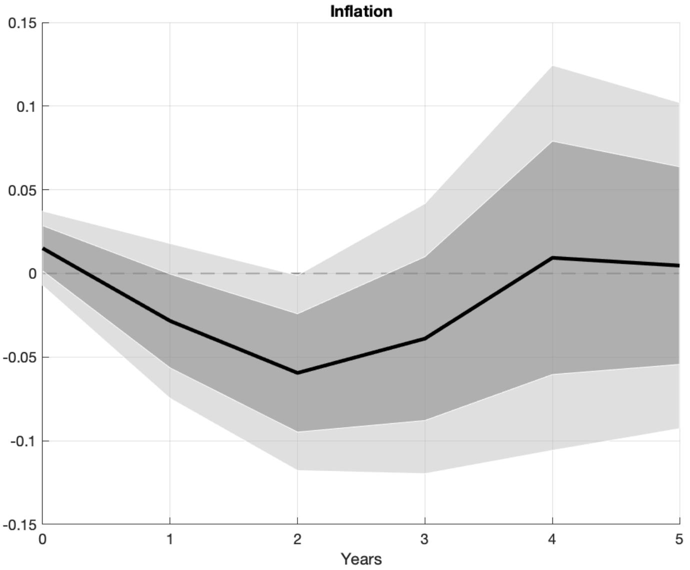
IRFs for the Euro Area



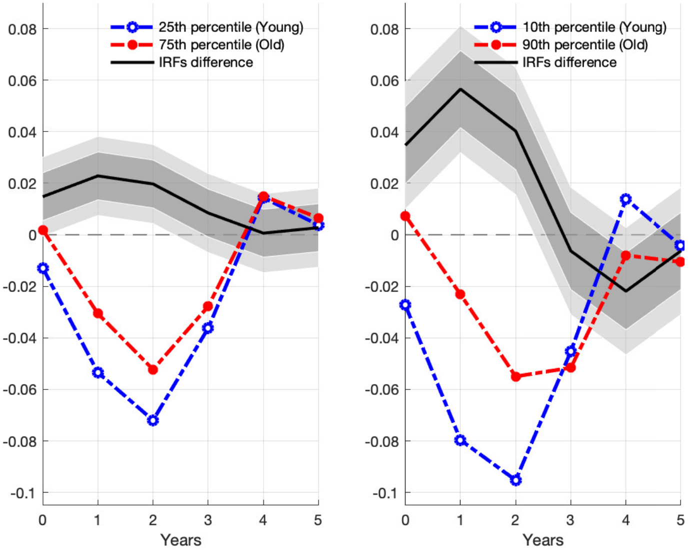
IRFs for the Euro Area



IRFs for the Euro Area, 3-month Eonia OIS



IRFs for the Euro Area, 3-month Eonia OIS



Population distribution

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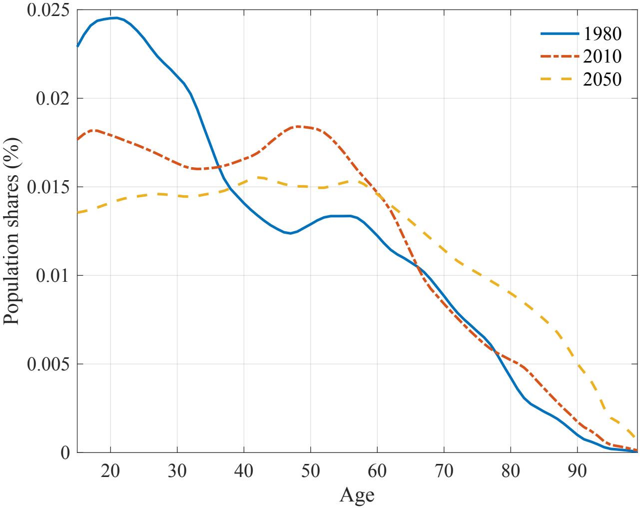

Source: UN (2017) World Population Prospects

Mortality rate across age groups

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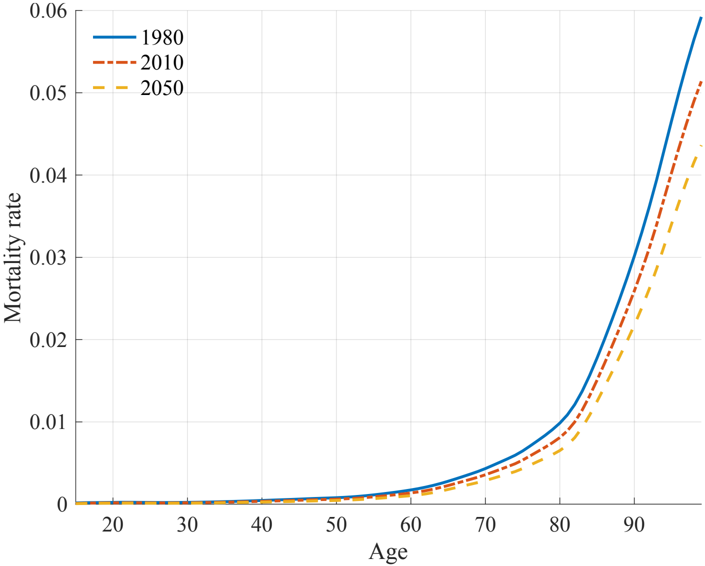

Labor efficiency

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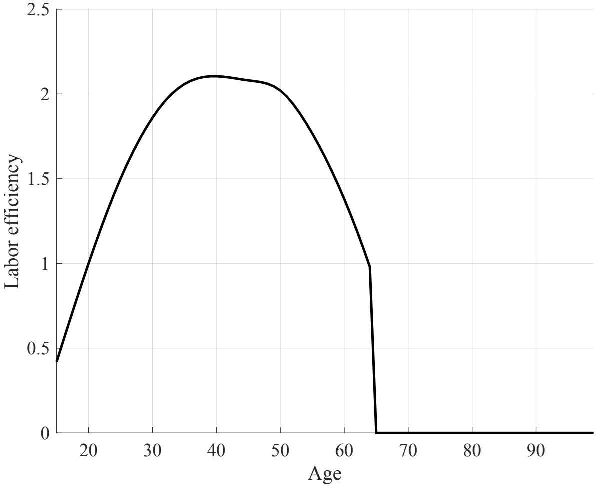

Source: Fullerton (1999)

Service consumption share

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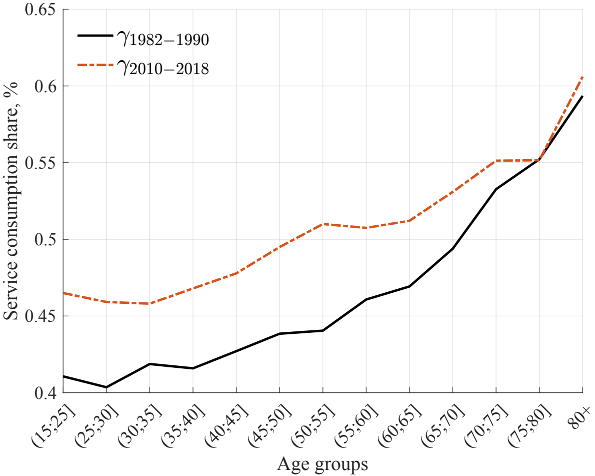
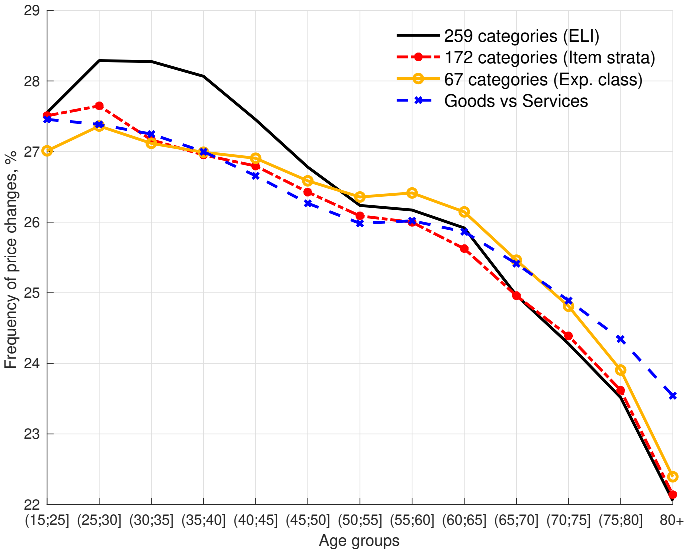


Source: Own calculation, CEX data

Summary results

Parameters	1980 → 2010	Parameters ↗	
		π^{IRF}	$Output^{IRF}$
Service preference α_j	↗	↘	↗
Survival probabilities s_j	↗	↗	↘
Retirement age jw	↗	↗	↘

Frequency of price adjustment across age groups



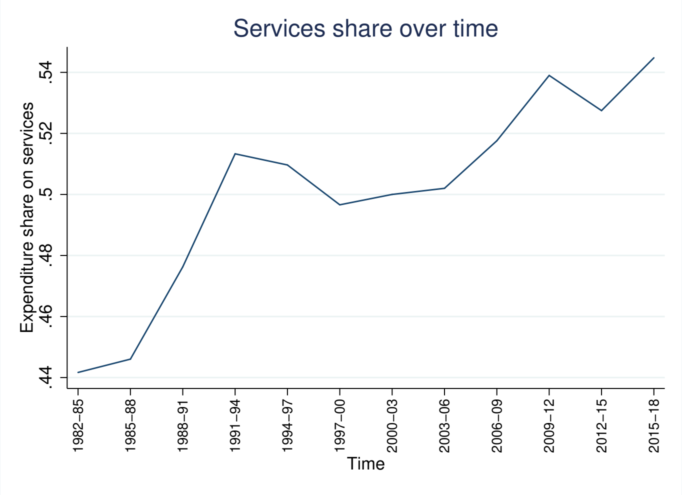
Back Robustness Back

Freq year

Frequency of price adjustment over time
95% CI
Price adj.
Frequency of price changes, %
30.5
30
29.5
29
28.5
28
27.5
27
26.5
26
25.5
25
1982-85
1985-88
1988-91
1991-94
1994-97
1997-00
2000-03
2003-06
2006-09
2009-12
2012-15
2015-18

Services vs Goods, share

$\theta_{Services}$: 14, θ_{Goods}: 39



Services vs Goods, price stickiness

Age group level inflation rate

The BLS procedure to compute CPI consists in calculating:

$$X_j^a = \frac{\sum_i fwt_i^a \sum_t c_{i,j,t}^a}{\sum_i fwt_i^a \; MO\_SCOPE_i^a} \times 12$$

where fwt_i^a is the frequency weight for household i at age group a, $c_{i,j,t}^a$ refers to the annual consumption on category j by household i at age group a and $MO\_SCOPE_i^a$ identify the number of months per year household i reported its expenditures.
The age group level expenditure weight for category j can be then computed as:

$$w_j^a = \frac{X_j^a}{\sum_j X_j^a}$$

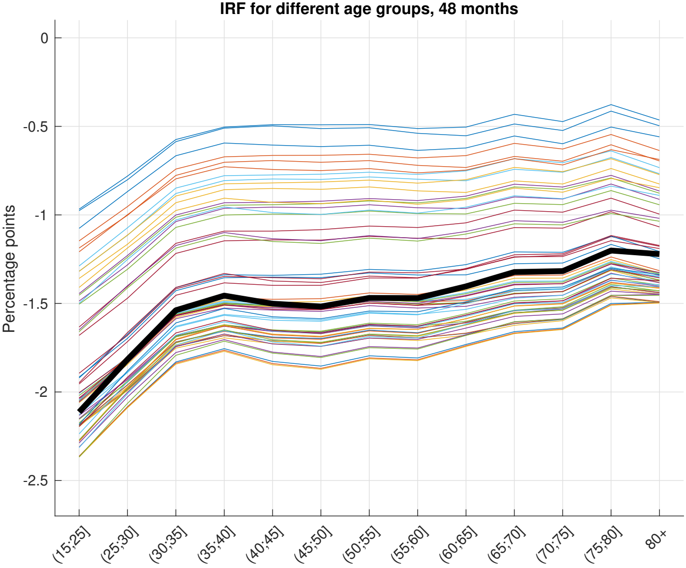
Age group level inflation rate

Finally, the the age-group level price index is given by:

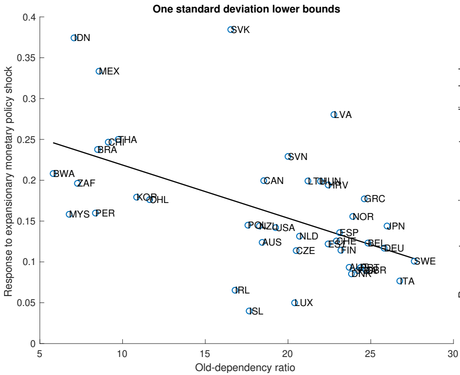
$$CPI_t^a = CPI_\nu^a \sum_j (w_{j,\beta}^a \times \frac{P_{j,t}}{P_{j,\nu}})$$

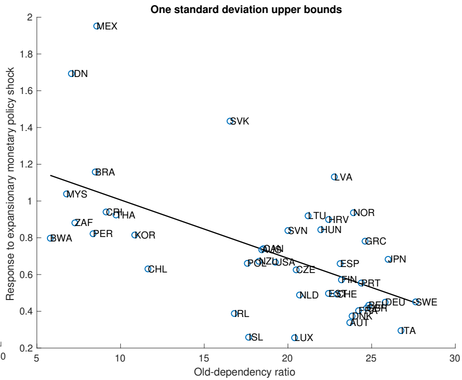
where ν is the pivot year and month prior to the month when expenditure weights from reference period β are first used, β is the predetermined expenditure reference period, $w_{j,\beta}^a$ is the age group level expenditure weight for category j during the predetermined expenditure reference period β and $P_{j,t}$ is the price of item j at time t. Back

IRFs by age groups, robustness



Contemporaneous response of inflation - Confidence bands





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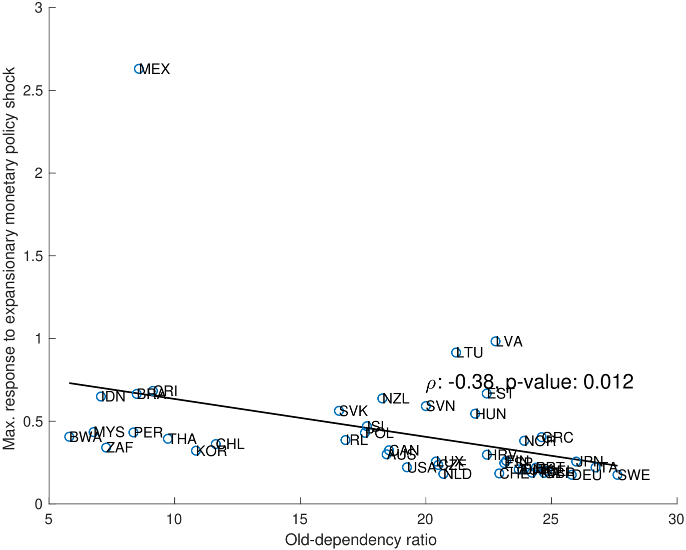
Maximum response of inflation



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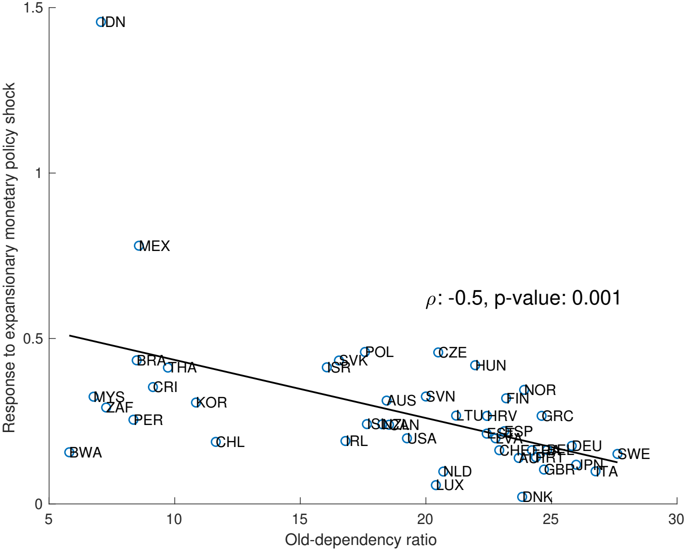
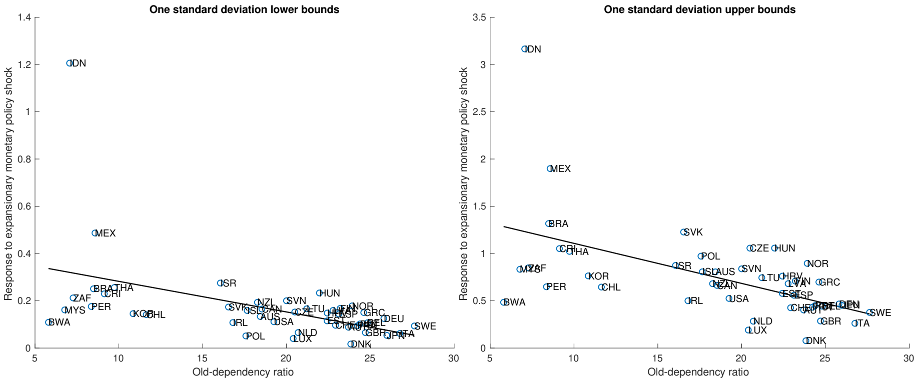
Contemporaneous response of inflation



Contemporaneous response of inflation - Confidence bands



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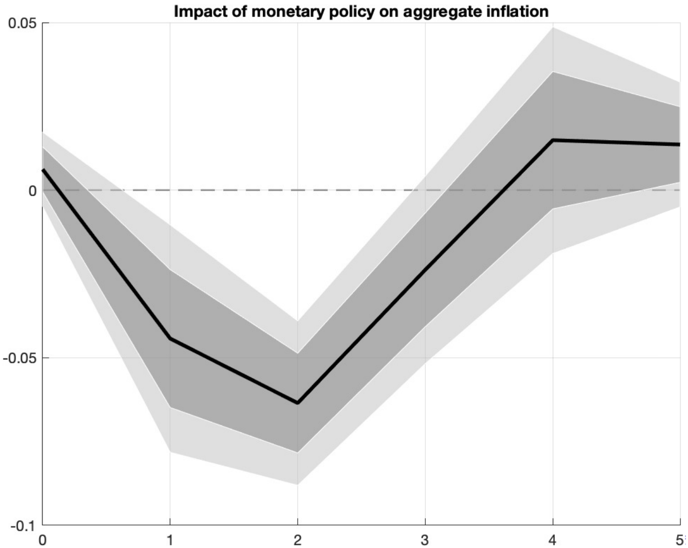
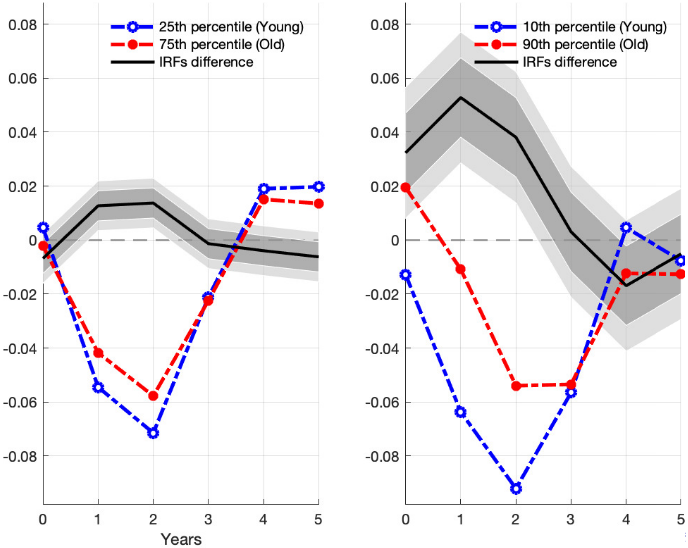
IRFs for the Euro Area with additional controls, high-frequency shocks



IRFs for the Euro Area with additional controls, high-frequency shocks



Expenditure weights

	Age groups						
	25-	(30,35]	(40,45]	(50,55]	(60,65]	(70,75]	80+
Alcohol	2.1	1.4	1.2	1.2	1.2	1.1	0.6
Apparel	5.1	4.8	4.7	4.2	3.8	3.1	2.3
Education	6.7	1.5	2.4	3.9	1.0	0.6	0.4
Energy	3.8	5.0	5.4	5.5	6.0	6.7	7.9
Entertainment	5.9	7.0	7.5	6.9	6.8	6.0	4.4
Food Away	6.1	5.6	5.8	5.8	5.6	5.1	4.1
Food at Home	11.4	12.5	13.0	12.1	12.3	12.9	13.5
Medical	3.4	5.4	6.4	7.6	10.7	15.1	19.0
Household F&O	6.4	9.9	9.1	9.0	9.8	10.1	11.1
Other Lodging	1.2	1.0	1.4	2.0	1.8	2.0	0.9
Owned Dwellings	1.8	6.5	7.5	7.7	8.1	7.6	5.9
Other Expenses	0.9	1.1	1.3	1.4	1.6	1.8	2.4
Personal Care	1.9	1.9	2.0	1.9	1.9	2.0	2.1
Private Transportation	20.5	21.8	21.7	21.6	20.8	17.5	11.3
Public Transportation	1.2	1.3	1.4	1.5	1.8	1.7	1.1
Reading	0.3	0.4	0.4	0.5	0.6	0.7	0.7
Rented Dwellings	19.4	10.8	6.4	4.4	3.7	3.9	10.2
Tobacco	1.3	1.0	1.1	1.2	1.1	0.8	0.4
Water	0.6	1.1	1.2	1.2	1.3	1.5	1.7

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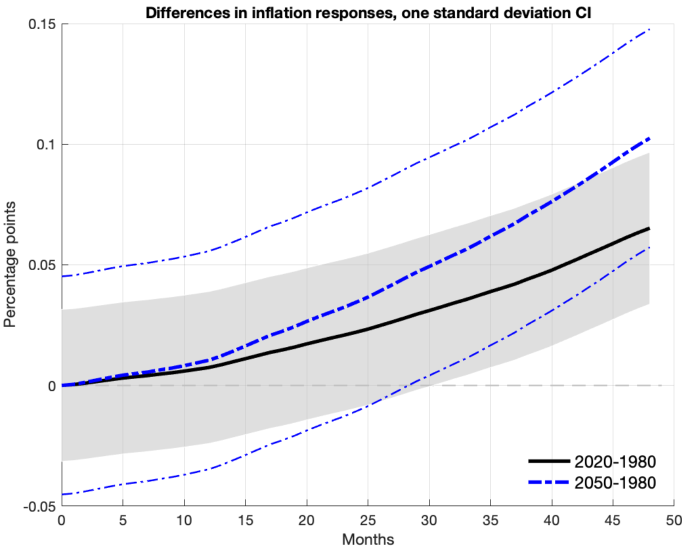
Differences in IRFs



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Country data

	old-age dependency ratio (%)	GDP per capita	Trade open.	Financial dev.	Share services
BWA	5.6	Low	High	Low	-
MYS	6.8	Low	High	High	-
IDN	7.1	Low	Low	Low	Low
ZAF	7.3	Low	Low	High	-
PER	8.4	Low	Low	Low	-
BRA	8.5	Low	Low	Low	Low
MEX	8.6	Low	Low	Low	Low
CRI	9.1	Low	High	Low	-
THA	9.7	Low	High	High	-
KOR	10.8	Low	High	Low	Low
CHL	11.6	Low	Low	Low	-
ISR	16.1	High	Low	Low	-
SVK	16.5	Low	High	Low	Low
IRL	16.8	High	High	High	High
POL	17.6	Low	Low	Low	Low
ISL	17.7	High	High	High	-
NZL	18.3	Low	Low	High	-
AUS	18.4	High	Low	High	High
CAN	18.5	High	Low	High	High
USA	19.2	High	Low	High	High
SVN	20	Low	High	Low	Low
LUX	20.4	High	High	High	High
CZE	20.5	Low	High	Low	Low
NLD	20.7	High	High	High	High
LTU	21.2	Low	High	Low	Low
HUN	22	Low	High	Low	Low
EST	22.4	Low	High	Low	-
HRV	22.4	Low	Low	Low	Low
LVA	22.8	Low	Low	Low	High
CHE	22.9	High	High	High	High
ESP	23.1	High	Low	High	Low
FIN	23.2	High	Low	Low	Low
AUT	23.7	High	High	High	High
DNK	23.8	High	High	High	High
NOR	23.9	High	High	High	Low
FRA	24.2	High	Low	High	High
PRT	24.4	High	Low	Low	High
GRC	24.6	High	Low	Low	High
GBR	24.7	High	Low	High	High
BEL	24.8	High	High	Low	High
DEU	25.8	High	Low	High	High
JPN	26	High	Low	High	Low
ITA	26.8	High	Low	Low	Low
SWE	27.6	High	High	High	High

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AMECO data

Summary statistics

	Mean	St. dev.	Min.	Max.	Obs.
Population	2.916	3.175	26	17.885	1.240
Employment	1.330	1.581	16	9.299	1.240
GDP	85.376	112.197	1.046	651.455	1.240
Share services	0,70	0,08	0,52	0,89	1.240

Note: The data are sourced from the European Regional Database of Cambridge Econometrics and cover the period 1999-2016. Population and employment are in thousands of people. The GDP and the share of services in GVA are valued at market prices before being deflated to 2015 constant price euros.

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Regions available

Finland (5 NUTS II Regions)
Regions: Etelä-Suomi, Helsinki-Uusimaa, Länsi-Suomi, Itä-Suomi, Åland **Data source**: Statistics Finland
Germany (16 NUTS I Regions)
Regions: Baden-Württemberg, Bayern, Berlin, Brandenburg, Bremen, Hamburg, Hessen, Mecklenburg-Vorpommern, Niedersachen, Nordrhein-Westfalen, Rheinland-Pfalz, Saarland, Sachsen, Sachsen-Anhalt, Schleswig-Holstein, Thüringen **Data source**: Statistical offices of the individual German states
Italy (22 NUTS II Regions)
Regions: Abruzzo, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Lazio, Liguria, Lombardia, Marche, Molise, Piemonte, Provincia Autonoma di Bolzano, Provincia Autonoma di Trento, Puglia, Sardegna, Sicilia, Tirol, Toscana, Umbria, Valle d'Aosta, Veneto **Data source**: Istituto Nazionale di Statistica (ISTAT)
Portugal (7 NUTS II Regions)
Regions: Acores, Algarve, Altenejo, Centro, Lisboa, Madeira, Norte **Data source**: Instituto Nacional de Estatistica (INE)
Spain (19 NUTS II Regions)
Regions: Andalucia, Aragon, Canarias, Cantabria, Castilla y Leon, Castilla La Mancha, Cataluna, Ciudad Autonoma de Ceuta, Ciudad Autonoma de Melilla, Comunidad Foral de Navarra, Comunidad Valenciana, Comunidad de Madrid, Extremadura, Galicia, Illes Balears, La Rioja, Pais Vasco, Principado de Asturias, Región de Murcia **Data source**: Instituto Nacional de Estadistica (INE)

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Australia (1985Q1-2015Q4), Austria (1996Q1-2015Q4), Belgium (1985Q1-2015Q4), Canada (1985Q1-2015Q4), Costa Rica (1997Q1-2015Q4), Czech Republic (1996Q1-2015Q4), France (1985Q1-2015Q4), Germany (1991Q1-2015Q4), Greece (1995Q1-2015Q4), Hungary (1995Q1-2015Q4), Iceland (1995Q1-2015Q4), Portugal (1995Q1-2015Q4), Israel (1991Q1-2015Q4), Italy (1985Q1-2015Q4), Lithuania (1999Q1-2015Q4), Luxembourg (1999Q1-2015Q4), Latvia (1998Q1-2015Q4), Poland (1995Q1-2015Q4), Netherlands (1995Q1-2015Q4), New Zealand (1985Q1-2015Q4), Norway (1985Q1-2015Q4), Slovakia (1995Q1-2015Q4), Switzerland (1985Q1-2015Q4), United Kingdom (1985Q1-2015Q4), United States (1985Q1-2015Q4), South Africa (1993Q1-2015Q4): The interest rate is the short term rate from the OECD, the CPI is from the OECD, and the seasonally-adjusted real GDP comes from the IFS.

Mexico (1985Q1-2015Q4), Indonesia (2000Q1-2015Q4), Ireland (1995Q1-2015Q4), Denmark (1995Q1-2015Q4), Finland (1990Q1-2015Q4), Japan (1985Q1-2015Q4), Korea (1985Q1-2015Q4), Spain (1995Q1-2015Q4) and Sweden (1993Q1-2015Q4): The interest rate is the money market rate from the IFS, the CPI is from the OECD, and the seasonally-adjusted real GDP comes from the IFS.
Brasil (1996Q1-2015Q4): The interest rate is from the Ilzetzki et al. (2013) dataset. The CPI is from the OECD and the seasonally-adjusted real GDP comes from the IFS.
Data for Botswana (1993Q1-2015Q4), Chile (1996Q1-2015Q4), Croatia (1997Q1-2015Q4), Estonia (1999Q1-2015Q4), Peru (1995Q1-2015Q4), Slovenia (1992Q1-2015Q4) and Thailand (1993Q1-2015Q4) are taken from Ilzetzki et al. (2013).
Malaysia (1999Q1-2015Q4): The interest rate is the money market rate from the IFS. Real GDP and CPI from Ilzetzki et al. (2013).