BANK FOR INTERNATIONAL SETTLEMENTS

The age-structure–inflation puzzle

Mikael Juselius - Előd Takáts

Bank of Finland - Bank for International Settlements

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Motivation

- Inflation conundrum:
  - Persistent low inflation today – what drives it?
  - Confounding dynamics (Faust and Leeper, 2015 - Jackson Hole)
  - Long-term cycles in inflation?

- Central bankers suggested demography as a potential driver
  - Bank of Japan, Governor Shirakawa (2011a, b)
  - Federal Reserve, St Louis, President Bullard et al (2013)
  - And, policy institutions such as IMF, Anderson et al (2014), Yoon et al (2014), Bank of Spain as Aksoy et al (2015)
  - And C Goodhart (2015)!

- Our contribution is to produce robust empirical evidence:
  - Long sample of 22 countries: **1870-2016**

The findings

- Age-structure co-moves with (low frequency) inflation:
  - The dependents (the young and the old) are inflationary
  - The working age cohorts are disinflationary

- The impact is large economically, it explains:
  - Cca. 1/3 of yearly variation in the post-war sample
  - E.g. around 6.5 percentage point disinflation in the United States from the 1970s to today

- The effect is not spurious and very robust
  - Does not arise due to time trends, oil prices or trending, etc
  - Additional controls, time specifications do not eliminate it

Why would this puzzle matter for monetary policy?

- Main policy objective is less understood than thought

- Inflation persistence
  - Age-structure implies much lower persistence
    - No trending inflation even in the 1970s
  - Questions traditional explanations of trend inflation

- Forecasting low-frequency inflation
  - Inflationary pressures are low for structural reasons today
  - But will rise substantially as populations age and go grey
    - The future looks more like the 1970s than today

- Are inflation targets optimal or set too low?

Roadmap

1. Motivation

2. Empirical analysis
   - Baseline regression
   - Extensions and robustness

3. Potential explanations

4. Conclusion

2. Empirical analysis

- Data
  - 22 advanced economies
  - over 1870-2016
  - Unbalanced panel

- Age-structure in the focus
  - Population share in age specific-cohorts
  - 0-4, 5-9, …., 75-79, 80+

- Notice:
  - Unlike in earlier work more cycles than post-war baby boom
  - But still large heterogeneity across countries

Methodology: population polynominal

- Naïve estimate: separate coefficient for each cohort share $\pi_{tk} = \alpha_0 + \sum_{j=1}^{J} \alpha_j n_{jkt} + \beta' x_{kt} + \varepsilon_t$
  - But this is problematic
    - Inefficient to estimate
    - Correlation and jumps across α estimates

- We use population polynominal to address these issues
  - following Fair and Dominguez (AER, 1991) who used on other macroeconomic variables

    $\pi_{tk} = \alpha_{0i} + \sum_{p=1}^{4} \gamma_p \tilde{n}_{pkt} + \beta' x_{kt} + \varepsilon_t$

    where $\tilde{n}_{pkt} = \sum_{j=1}^{J} \left(j^p n_{jkt} - j^p / J \right)$
  - We use P=4

Benchmark model

- Besides demography some usual drivers of inflation
  - Real interest rate (r)
  - Output gap (y)
  - Time (year) fixed effects
  - Country fixed effects
- And then add age-structure with population polynomial

$$\pi_{jt} = \mu + \sum_{p=1}^{P} \gamma_p \tilde{n}_{pjt} + \beta_1 r_{jt} + \beta_2 \hat{y}_{jt} + \mu_{j.} + \mu_{.t} + \varepsilon_{jt} \qquad (3)$$

population polynomial

Model	1	2	**3**	4	5	6	7
Dependent var.:	π_{jt}	π_{jt}	$\boldsymbol{\pi_{jt}}$	π_{jt}	π_{jt}	π_{jt}	π_{jt}
$\tilde{n}_{1jt}(\times 1)$		0.26 (1.62)	**0.57** **(2.23)**	1.01 (3.36)	0.25 (0.76)	0.18 (0.60)	0.62 (3.55)
$\tilde{n}_{2jt}(\times 10)$		–0.94 (–2.02)	**–1.17** **(–2.60)**	–2.09 (–2.49)	–1.25 (–1.75)	–0.98 (–2.63)	–1.68 (–4.67)
$\tilde{n}_{3jt}(\times 10^2)$		1.03 (2.06)	**1.69** **(2.60)**	1.57 (1.86)	1.43 (2.13)	1.14 (2.96)	1.58 (4.38)
$\tilde{n}_{4jt}(\times 10^3)$		–0.34 (–2.04)	**–0.52** **(–2.52)**	–0.38 (–1.41)	-0.48 (–2.18)	–0.38 (–2.43)	–0.47 (–3.78)
r_{jt}	–0.52 (–3.35)		**–0.56** **(–3.69)**	–1.10 (–15.53)	–0.39 (–2.33)	–0.25 (–2.14)	–0.69 (–8.59)
$\hat{y}_{jt}$	0.08 (3.11)		**0.08** **(3.13)**	0.04 (1.51)	0.06 (1.45)	0.15 (2.80)	0.08 (2.23)
Countries	22	22	**22**	22	22	22	16
Time period*	1870–2016	1870–2016	**1870–2016**	1870–1949	1950–2016	1990–2016	1870–2016
Observations	2219	2474	**2217**	787	1430	584	1257
R^2	0.17	0.02	**0.22**	0.55	0.20	0.21	0.36
Age-structure F-test	N.A.	0.07	**0.00**	0.00	0.00	0.01	0.00
Contr.: natural rate	No	No	**No**	No	No	No	Yes
Country effects	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes
Res. country cluster	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes
Res. time cluster	Yes	Yes	**Yes**	Yes	Yes	Yes	Yes
Estimator	FE	FE	**FE**	FE	FE	FE	FE

Robustness

- Additional controls:
  - Money supply
  - Fiscal balances, hours worked, labor share
- Monetary union
  - Political economic concern
  - Euro area 1999-2016
    - problems: short period, euro area crisis (exclude GR), financial crisis
    - Power of larger countries: small country regression
- Inflation expectations!
- Short-term real interest rates

Model	8	9	10	11	12	13	14
Dependent var.:	π_{jt}	π_{jt}	π_{jt}	π_{jt}	π_{jt}	π^e_{jt}	i_{jt}
$\tilde{n}_{1jt}(\times 1)$	-0.25 (-0.65)	0.14 (0.55)	0.20 (1.68)	0.05 (0.24)	-0.02 (-0.23)	0.31 (1.50)	0.59 (2.46)
$\tilde{n}_{2jt}(\times 10)$	–0.07 (–0.10)	–0.78 (–1.49)	–0.38 (–2.07)	–0.09 (–0.33)	0.06 (0.32)	–0.92 (–2.30)	–1.69 (–2.63)
$\tilde{n}_{3jt}(\times 10^2)$	0.43 (0.84)	0.86 (2.22)	0.27 (1.88)	0.03 (0.19)	-0.04 (-0.28)	0.86 (2.30)	1.61 (2.55)
$\tilde{n}_{4jt}(\times 10^3)$	–0.20 (–1.40)	–0.27 (–2.78)	–0.06 (–1.35)	0.01 (0.26)	0.00 (0.20)	–0.25 (–2.08)	–0.49 (–2.43)
r_{jt}	–0.20 (–1.34)	–0.25 (–3.89)	–0.98 (–5.02)	–1.02 (–4.78)	–0.04 (–1.18)		
$\hat{y}_{jt}$	0.13 (2.33)	0.15 (2.74)	0.15 (3.47)	0.16 (3.97)	0.06 (2.05)		
π^e_{jt}					1.22 (22.87)		
Countries	22	22	10 (EA)	7 (EA small)	22	22	22
Time period*	1951–2010	1980–2010	1999–2016	1999–2016	1990–2016	1990–2016	1870–2016
Observations	988	535	176	122	563	571	2738
R^2	0.24	0.28	0.68	0.72	0.82	0.16	0.10
Age-structure F-test	0.00	0.00	0.06	0.01	0.07	0.00	0.00
Contr: money growth	Yes	No	No	No	No	No	No
Contr: additional	No	Yes	No	No	No	No	No
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Res. country cluster	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Res. time cluster	Yes	Yes	No	No	Yes	Yes	Yes
Estimator	FE	FE	FE	FE	FE	FE	FE

Robustness: dynamics and heterogeneity (2)

- Is the relationship spurious?
  - Possible with two slow-moving / trending variables…
  - Rewrite model in error correction form:

$$\Delta\pi_{jt} = \mu + \mu_{j0} + \varphi_1 \hat{y}_{jt} + \varphi_2 \Delta r_{jt} + \varphi_3 \Delta\pi_{jt}^{oil}$$

$$-\alpha(\pi_{j,t-1} - \lambda_1 r_{j,t-1} - \lambda_2 \pi_{j,t-1}^{oil} - \sum_{p=1}^{P} \gamma_p \tilde{n}_{pj,t-1}) + \varepsilon_{jt} \qquad (4)$$

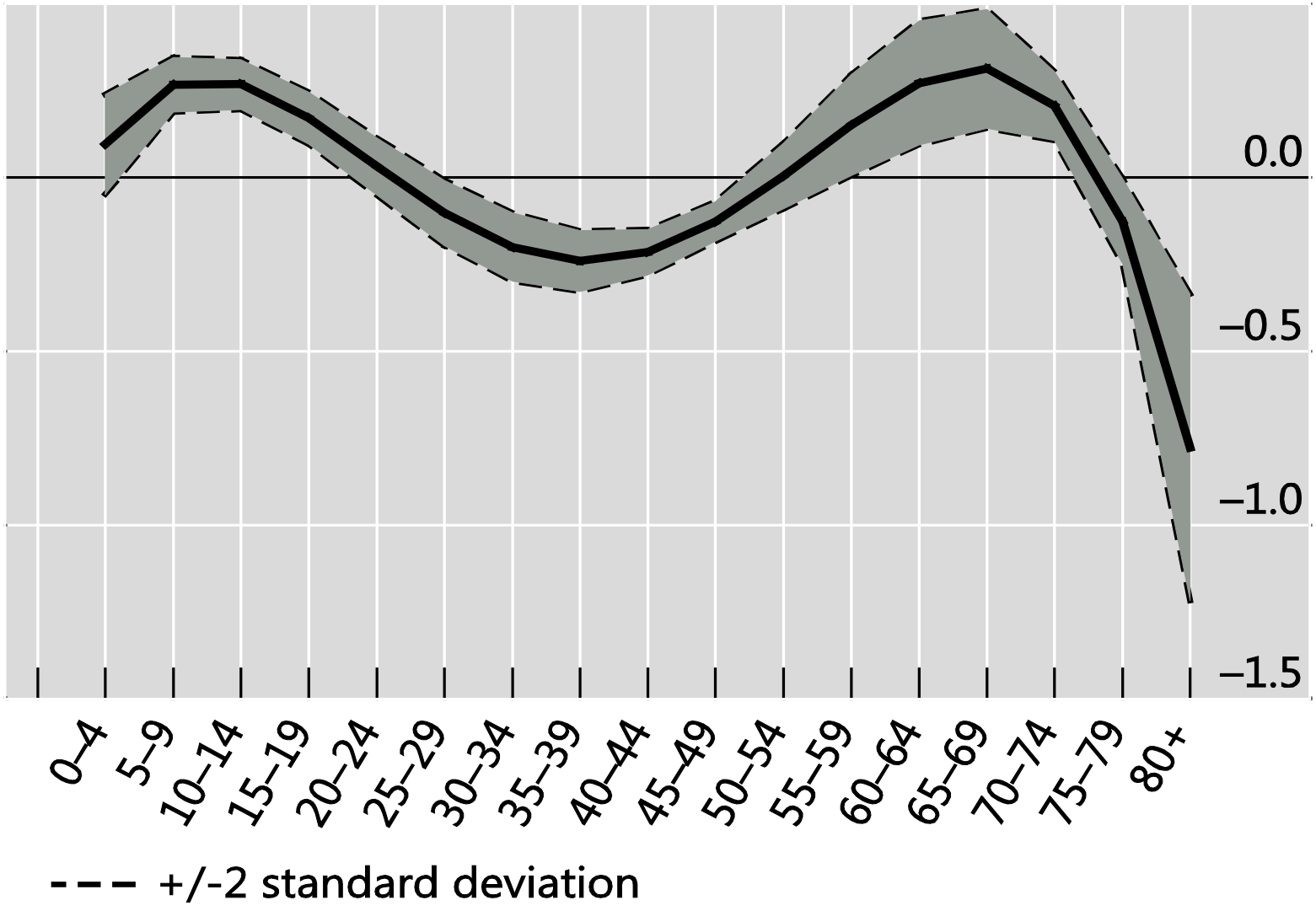
- Mis-specified country heterogeneity drives the result?
  - MG estimator from Pesaran et al (1999)

Model	15	16	17	18	19	20	21
Dependent var.:	π_{jt}	π_{jt}	π_{jt}	π_{jt}	$\Delta\pi_{jt}$	$\Delta\pi_{jt}$	$\Delta\pi_{jt}$
$\tilde{n}_{1jt}(\times 1)$	0.74 (1.41)	0.98 (1.81)	0.87 (1.84)	0.18 (0.60)	0.35 (1.41)	0.36 (2.51)	0.13 (0.41)
$\tilde{n}_{2jt}(\times 10)$	–1.83 (–1.36)	–2.19 (–1.33)	–3.05 (–2.52)	–0.98 (–2.63)	–1.26 (–2.17)	–1.04 (–3.09)	–0.62 (–0.75)
$\tilde{n}_{3jt}(\times 10^2)$	1.68 (1.30)	1.84 (1.03)	3.17 (2.62)	1.14 (2.96)	1.33 (2.45)	1.01 (3.40)	0.66 (0.78)
$\tilde{n}_{4jt}(\times 10^3)$	–0.50 (–1.25)	–0.51 (–0.84)	–1.00 (–2.58)	–0.38 (–2.43)	-0.42 (–2.50)	–0.31 (–3.56)	–0.20 (–0.73)
r_{jt}	–1.04 (–8.44)	–1.16 (–17.19)	–0.42 (–2.03)	–0.25 (–2.14)	–0.47 (–2.68)	–0.68 (–15.04)	–0.63 (–6.76)
$\hat{y}_{jt}$	0.04 (1.35)	0.04 (0.92)	0.04 (0.99)	0.15 (2.80)	0.03 (1.09)	0.05 (2.58)	0.03 (2.16)
$\hat{y}_{jt-1}$					0.05 (2.34)	0.08 (4.11)	0.10 (4.93)
Δr_{jt}					–0.54 (–5.50)	–0.52 (–8.20)	–0.43 (–9.25)
Error correction: α					–0.40 (–7.22)	–0.44 (–10.32)	–0.61 (–15.77)
Countries	16	18	22	22	22	22	22
Time period	1870–1913	1922–1938	1950–1989	1990–2016	1870–2016	1870–2016	1870–2016
Observations	540	247	846	584	2093	2093	2093
R^2	0.32	0.75	0.22	0.21	0.40	N.A.	N.A.
Age-structure F-test	0.06	0.00	0.00	0.01	0.00	0.00	0.04
Additional controls	No	No	No	No	No	No	No
Country effects	Yes	Yes	Yes	Yes	Yes	N.A.	N.A.
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Res. country cluster	Yes	Yes	Yes	Yes	Yes	N.A.	N.A.
Res. time cluster	Yes	Yes	Yes	Yes	No	N.A.	N.A.
Estimator	FE	FE	FE	FE	DFE	PMG	MG

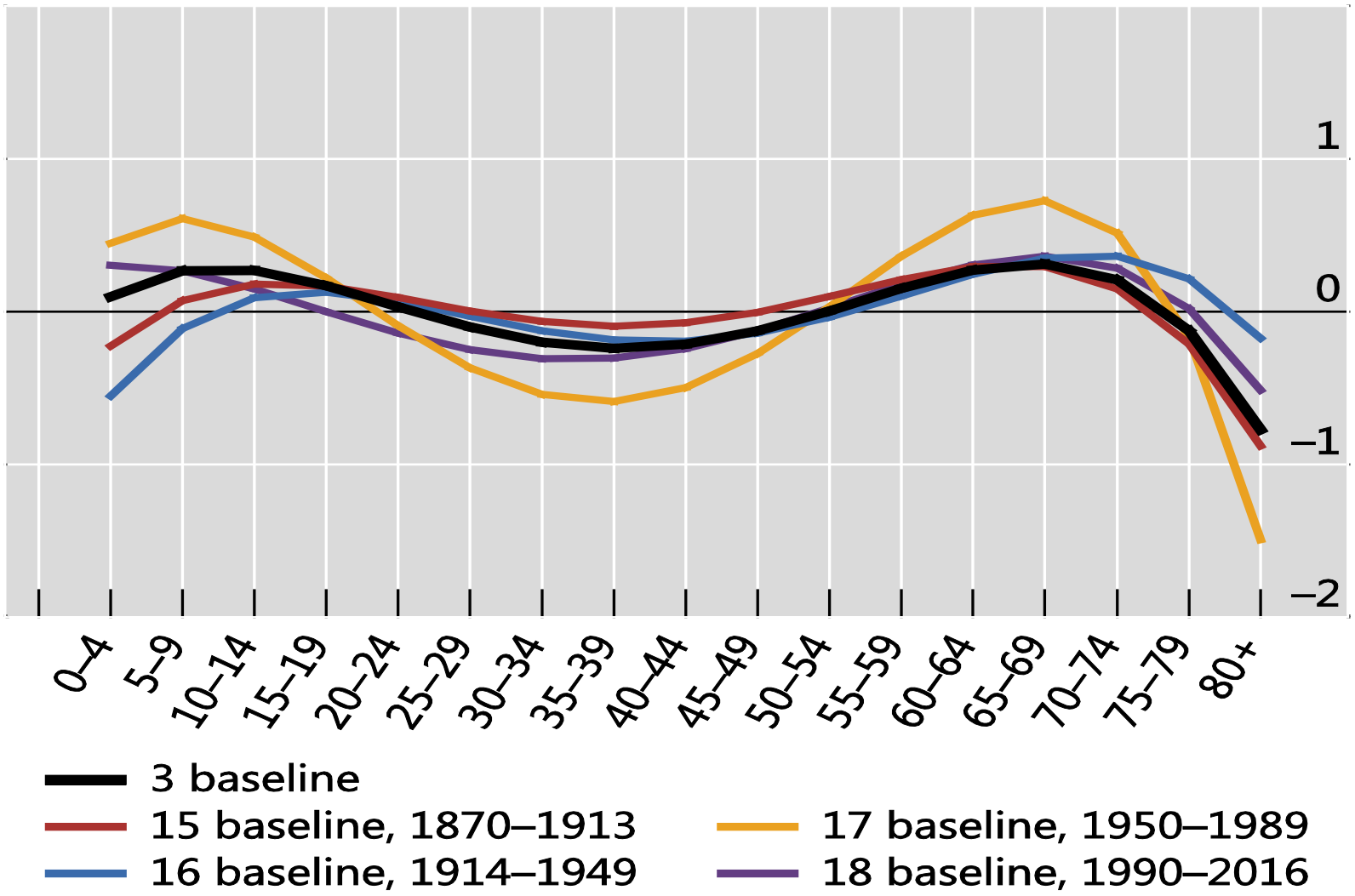
Economic impact

- What is the economic meaning of coefficient estimates?
- How large is the impact of different cohorts?
  - How robust is this impact in different specifications?
- How large is the age-structure impact on inflation?
  - How well panel estimates fit on average?
  - How well they fit for individual country dynamics?

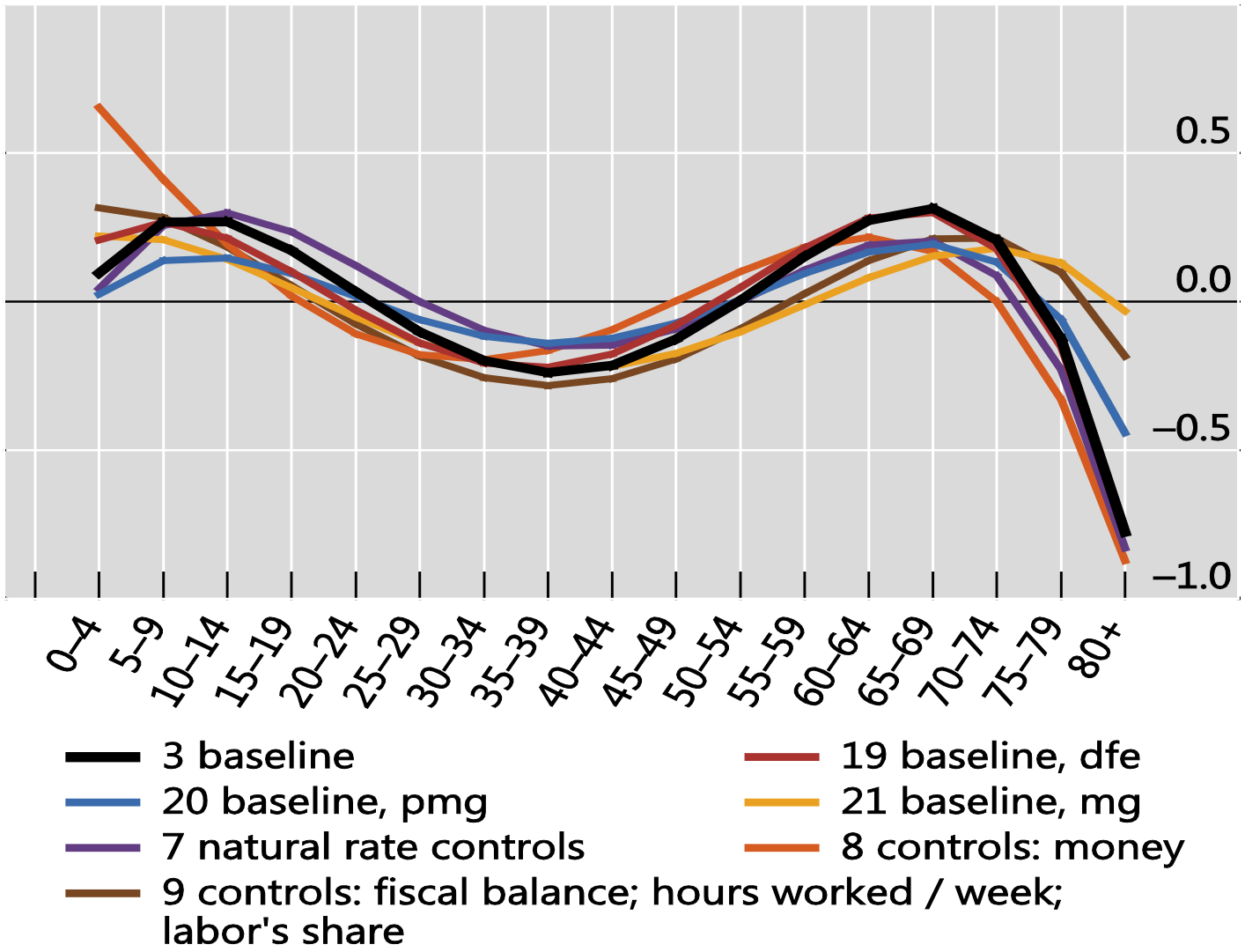
Age cohort effects on inflation works



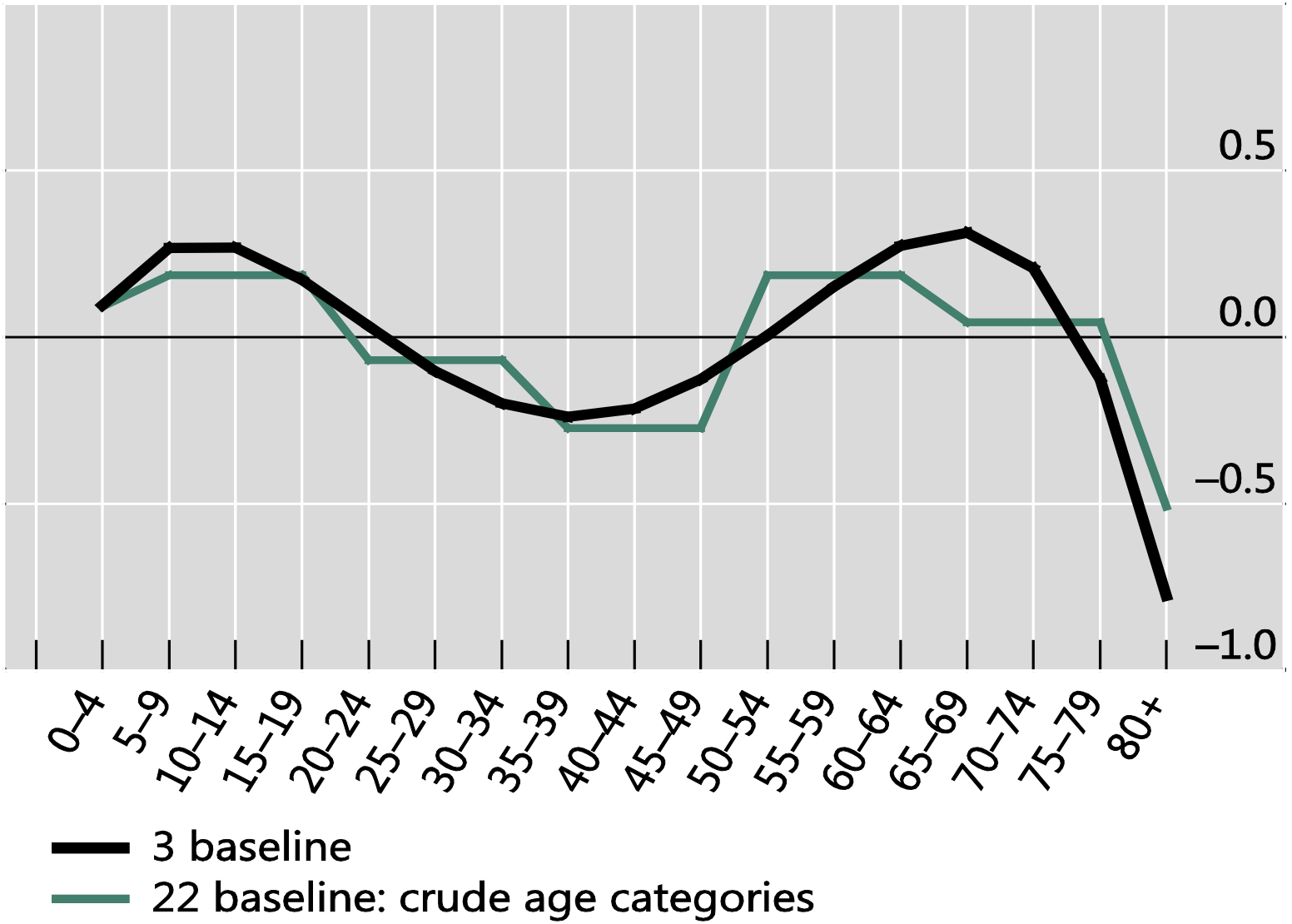
Robust impact across different time periods



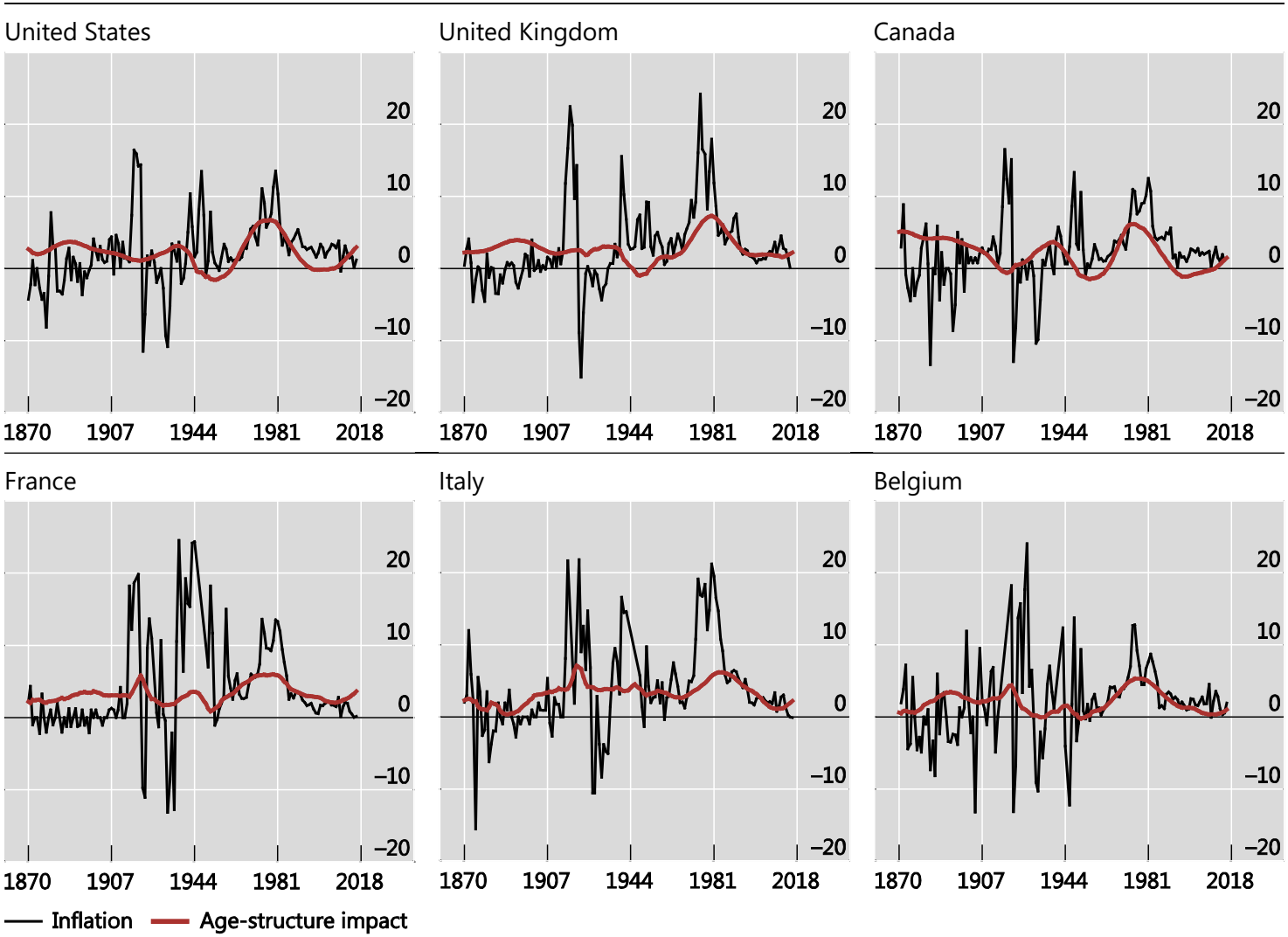
Robust impact across different specifications



Impact does not depend on polynomial structure



Age-structure impact describes low frequency inflation



Old-age cohorts are inflationary, unless young are omitted from the specification

Model	14	15	16	17
Dependent var.:	π_{jt}	π_{jt}	π_{jt}	π_{jt}
n_{jt}^{0-19}			0.28 (14.82)	
n_{jt}^{20-64}			–0.09 (–4.49)	
n_{jt}^{65+}	–0.41 (–12.38)		0.11 (2.24)	
n_{jt}^{0-4}				-0.93 (–8.92)
n_{jt}^{5-19}				0.59 (14.15)
n_{jt}^{20-34}				0.34 (10.15)
n_{jt}^{35-49}				-0.49 (-12.72)
n_{jt}^{50-64}				-0.31 (-6.26)
n_{jt}^{65-79}		0.41 (3.97)		0.58 (6.68)
n_{jt}^{80+}		–1.76 (–12.81)		-0.20 (-1.39)

Age structure impact: what could drive it?

- Political economy (Bullard point)
  - Young prefer jobs and high inflation, old the other way around
  - Central bank implements these preferences

- Non-linear impact of ageing (Shirakawa point)
  - Ageing can lead to fast deterioration of outlook
  - Central bank cannot compensate if close to zero lower bound

- Equilibrium real rates (Goodhart point)
  - Lifecycle: Young and old consume more than what produce, working age cohorts produce more than what consume
  - Change in age structure leads to change in saving-investment balances and in equilibrium real rates
  - Central bank does not take these changes into account

Conclusion

- Age-structure affects inflation
  - The impact is not spurious and very robust
- The impact follows the lifecycle
  - The dependent (i.e the young and the old) are inflationary
  - The working age cohorts are deflationary
- Questions remain about drivers
  - Maybe a combination of existing explanation work?
- Relevant for the current low inflation environment
  - Lower endogenous persistence
  - Forecastable inflation pressure

Thank you for your attention!

"Understanding how to adjust economic policy with respect to future demographic change will be a crucial question for policy makers in the aging industrial countries."

Alvin Hansen (1939)

Presidential address to the American Economic Association

Thank you for your attention!

elod.takats@bis.org