Joined at the hip?
Inflation and demography through time

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Introduction

- Consensus view on trend inflation: CB target and inflation expectations
  - Eg rise and fall of inflation in 60s-90s
  - CBs lost control over inflation expectations and only regained it when they started to combat inflation
- We document an empirical regularity that challenges this view
  - Demographics accounts for large share of trend inflation
  - *Positive* effect of dependent population; *negative* effect of working population
  - Relationship does not appear to be spurious
  - Consistent with delayed monetary policy responses to movements in the natural interest rates

Related literature

- Aging reduces inflation
  - Anderson et al (2014); Yoon et al (2014); Bobeica et al (2017)
- Dependency ratio positively related to inflation
  - McMillan and Baesel (1990); Lindh and Malmberg (2000); Juselius and Takáts (2015, 2018); Goodhart et al (2015); Aksoy et al (2018)
- Demographics and natural rates
  - Summers (2014); Rachel and Smith (2015); Carvalho et al (2016); Eggertsson et al (2017); Lisack et al (2017)
- Fiscal theory of the price level and political economy
  - Bullard (2012); Leeper (1991); Davig et al (2010)

Contributions

- We address several empirical concerns
  - **Spurious results?** Long sample (1870-2016); dynamics; sub-sample stability; time-fixed effects
  - **Omitted variables?** Non-overlapping averages; Phillips curve specifications (forward and backward looking); additional controls; time-fixed effects
  - **Other measures:** Money growth; nominal rates; inflation expectations
- We discuss possible explanations
  - Natural rate and policy mistakes; political economy; fiscal theory
- We assess its economic significance
  - Trend inflation; inflation persistence; global inflation

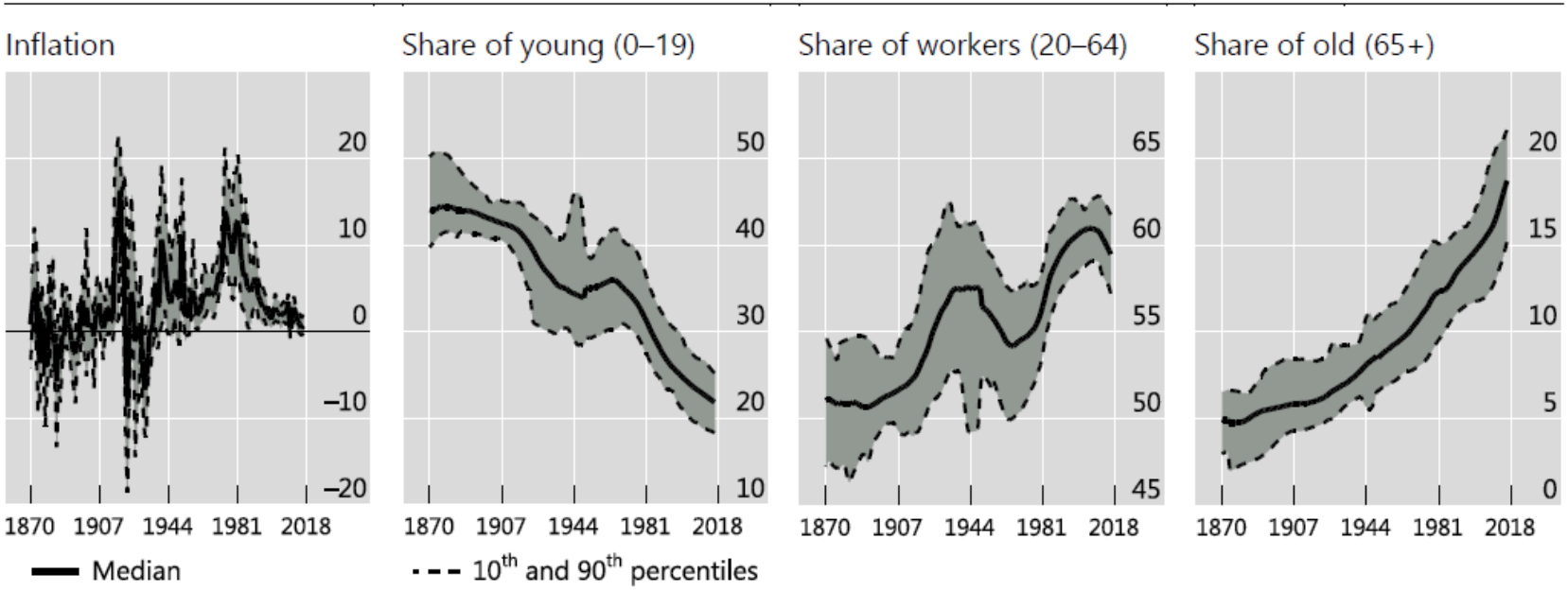
Data

- Sample:
  - 22 advanced economies, 1870-2016
  - Unbalanced panel
- Variables:
  - **Inflation**
  - **Demographics:** Age-structure (0-4, 5-9, …., 75-79, 80+); population growth; life expectancy
  - **Phillips curve:** output gap (HP-filter); inflation expectations (Consensus forecasts)
  - Other: excess money growth; nominal interest rate; fiscal balance; public debt; hours wkd / week; tfp growth; income inequality; labor's share

Key variables

Age structure and inflation in the 1870–2016 data

Figure 1



Specification

- Naïve specification for age-structure:

$$\pi_{jt} = \sum_{k=1}^{17} \beta_k n_{kjt} + \ldots + \varepsilon_{jt}$$

  - Collinearity with constant and inefficient
  - Fair and Dominguez (1991) population polynomial:

$$\beta_k = \sum_{p=1}^{P} \gamma_p k^p$$

- General specification:

$$\pi_{jt} = \sum_{l=1}^{L} \rho_l \pi_{jt-1} + \rho_f \pi_{jt}^e + \mu + \mu_j + \mu_t + \sum_{p=1}^{P} \gamma_p \tilde{n}_{pjt} + \beta_1 \hat{n}_{jt} + \beta_2 l_{jt}^e + \beta_3 \hat{y}_{jt} + \beta_4' x_{jt} + \varepsilon_{jt}$$

- Estimator: system GMM (Arellano & Bover (1995); Blundell & Bond (1998))

The link between demography and inflation

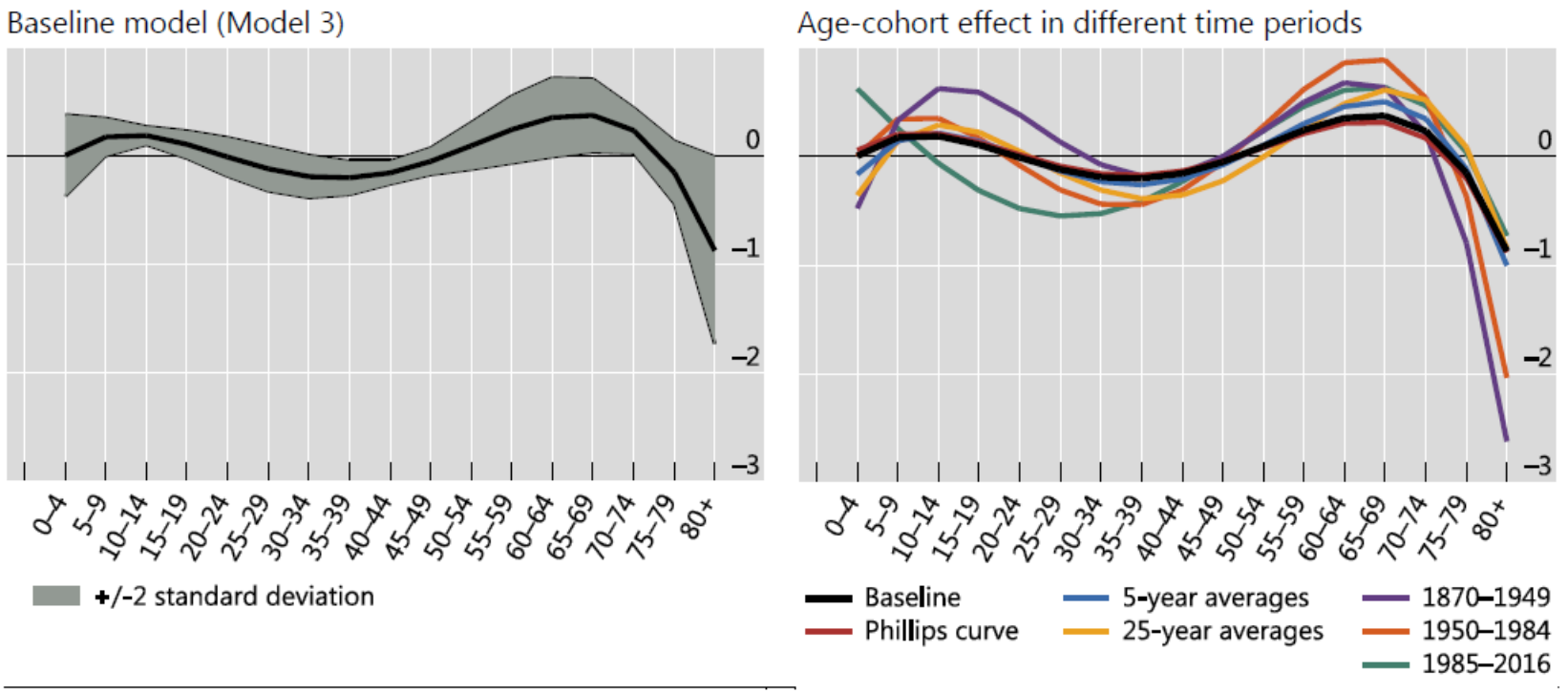
Demography and inflation: the link — Table 1

Model	1	2	3	4	5	6	7
	Baseline	Dynamic	1870-1949	1950-1984	1985-	5-year avg	25-year avg
$\tilde{n}_{1jt}(\times 1)$	0.56**	0.22**	1.99***	1.17**	-0.37	0.87**	1.29**
	(0.21)	(0.09)	(0.68)	(0.52)	(0.51)	(0.36)	(0.62)
$\tilde{n}_{2jt}(\times 10)$	–1.66***	–0.66***	-4.93**	–3.54***	–0.13	-2.37***	–3.32**
	(-0.50)	(-0.14)	(-1.77)	(-1.25)	(-0.66)	(-0.82)	(-1.37)
$\tilde{n}_{3jt}(\times 10^2)$	1.65***	0.66***	4.48**	3.59***	0.73**	2.27***	3.03**
	(0.49)	(0.12)	(1.66)	(1.17)	(0.33)	(0.75)	(1.16)
$\tilde{n}_{4jt}(\times 10^3)$	-0.52***	-0.21***	-1.34**	-1.14***	-0.33***	-0.69***	-0.89**
	(-0.16)	(-0.04)	(-0.561	(-0.37)	(-0.08)	(-0.23)	(-0.33)
$\hat{n}_{jt}$	1.31***	0.50***	1.03**	1.60**	2.04*	1.90***	1.96**
	(0.37)	(0.09)	(053)	(0.65)	(1.121)	(0.58)	(0.87)
l^e_{jt}	-0.01	0.01	-0.21**	0.10	-0.22	-0.06	-0.05
	(0.08)	(0.03)	(0.08)	(0.44)	(0.47)	(0.09)	(0.10)
π_{jt-1}		0.53***					
		(0.04)					
Countries	22	22	18	22	22	22	22
Time period[1]	1870–2016	1870–2016	1870–1949	1950–1984	1985–2016	1870–2016	1870–2016
Observations	2,193	2,075	788	710	695	461	97
R^2	0.07	0.37	0.05	0.16	0.21	0.14	0.30
R^2 without age-str.	0.04	0.36	0.02	0.06	0.03	0.07	0.08
R^2 age-str.	0.04	0.01	0.03	0.10	0.18	0.07	0.22
Age structure F-test[2]	0.00	0.00	0.03	0.04	0.18	0.01	0.04
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimator	FE	FE	FE	FE	FE	FE	FE

Notes: t-values in parenthesis. *, **, *** denote statistical significance of the coefficient estimate at 10, 5, and 1 percent level, respectively. R^2-values refer to the within variation and do not include the fixed effects. Residuals clustered along the country and the time dimension [1] Maximum time span across panels reported. [2] F-test of the joint hypothesis that $\tilde{n}_{pjt}$ for all p. [3] FE denotes fixed effect estimator.

Baseline results

Estimated age-cohort effects (β_{1k} coefficients, equation (2)) Figure 2



Demography and the Phillips curve

Demography in the Phillips curve — Table 2

Model	8	9	10	11	12	13	14
π_{jt-1}	0.42***	0.48***	0.53***	0.18***	0.18***	0.49***	0.52***
	(0.05)	(0.06)	(0.04)	(0.04)	(0.04)	(0.06)	(0.05)
π_{jt-2}	-0.04*	-0.00	0.04*	-0.02	-0.03	0.02	-0.03
	(0.02)	(0.03)	(0.02)	(0.06)	(0.06)	(0.02)	(0.05)
π^e_{jt}				0.74***	0.74***		
				(0.11)	(0.13)		
$\tilde{n}_{1jt}(\times 1)$		0.28***	0.20**		0.14***	0.36***	0.40***
		(0.09)	(0.08)		(0.04)	(0.11)	(0.14)
$\tilde{n}_{2jt}(\times 10)$		-0.86***	-0.63***		-0.25***	-1.11***	-1.11***
		(0.25)	(0.14)		(0.07)	(0.31)	(0.30)
$\tilde{n}_{3jt}(\times 10^2)$		0.85***	0.63***		0.18***	1.12***	1.04***
		(0.27)	(0.11)		(0.06)	(0.32)	(0.25)
$\tilde{n}_{4jt}(\times 10^3)$		-0.27***	-0.20***		-0.04***	-0.35***	-0.31***
		(0.09)	(0.04)		(0.02)	(0.11)	(0.07)
$\hat{n}_{jt}$		0.18	0.44***		0.08	0.25	0.23
		(0.18)	(0.11)		(0.09)	(0.20)	(0.28)
l^e_{jt}		-0.02	0.02		-0.06**	-0.02	-0.08
		(0.02)	(0.02)		(0.03)	(0.02)	(0.14)
$\hat{y}_{jt}$	0.17***	0.21***	0.07***	0.13***	0.12***	0.25***	0.20***
	(0.06)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)	(0.06)
Government debt							-0.02
							(0.02)
Fiscal balance							-0.04
							(0.07)
Hours worked (100)							0.26**
							(0.11)
Labour part. (100)							-0.38
							(1.50)
TFP growth							-0.20***
							(0.06)
Inequality							-0.12*
							(0.06)
Constant	-0.06	-0.03	-0.03***	-0.01	-0.01	-0.04	-0.12
	(0.14)	(0.12)	(0.00)	(0.03)	(0.03)	(0.12)	(0.09)
Countries	22	22	22	19	16	16	22
Time period[1]	1870–2016	1870–2016	1870–2016	1990–2016	1990–2016	1870–2016	1985–2016
Observations	2,230	1,955	1,955	521	521	1,633	514
Age structure F-test[2]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Res. country cluster[5]	Yes	Yes	Yes	Yes	Yes	N.A.	N.A.
Res. time cluster[6]	Yes	Yes	Yes	Yes	Yes	N.A.	N.A.
Sargan	0.00	0.14		0.39	0.45	0.60	0.00
Hansen	0.31	0.49		0.25	0.32	0.86	1.00
AR(2)	0.14	0.66		0.90	0.96	0.99	0.03
Estimator	BB	BB	Within	BB	BB	BB	BB

Notes: t-values in parenthesis. R^2-values refer to the within variation and do not include the fixed effects. π_{jt-2} is applied as a control in all specifications, coefficient estimates are available upon request. [1] Maximum time span across panels reported. [2] F-test of the joint hypothesis that $\tilde{n}_{pjt}$ for all p. [5] Residuals clustered along the country dimension. [6] Residuals clustered along the time dimension.

Demography and other measures

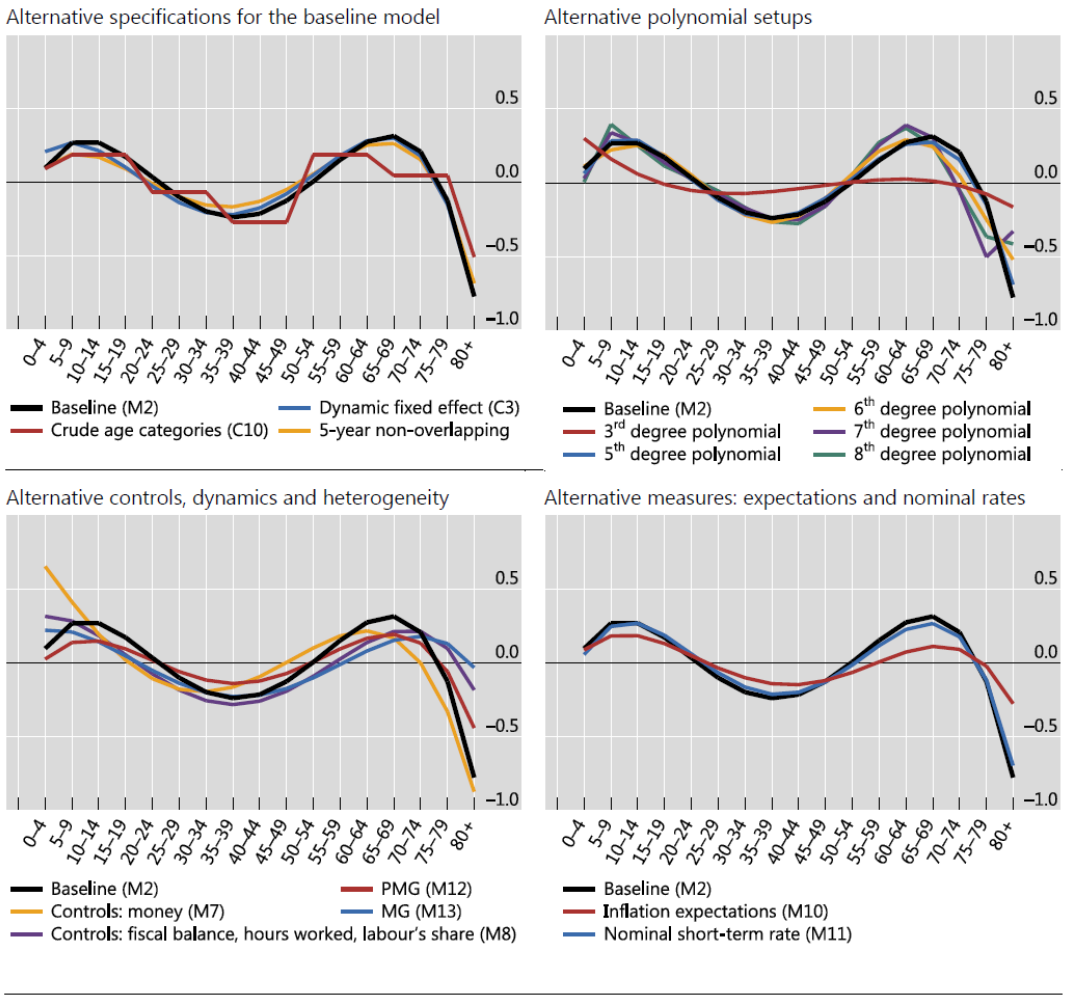
Demography, monetary variables and inflation expectations — Table 3

Model	15	16	17	18	19
	Money	Real rate	Nominal rate	Fiscal balance	Inflation expectation
$\tilde{n}_{1jt}(\times 1)$	0.50*	0.23	0.80***	-0.20	0.28*
	(0.29)	(0.26)	(0.25)	(-0.18)	(0.16)
$\tilde{n}_{2jt}(\times 10)$	–1.41**	–0.43	-2.04***	0.57	–0.64**
	(–0.60)	(–0.57)	(-0.28)	(0.50)	(–0.26)
$\tilde{n}_{3jt}(\times 10^2)$	1.35**	0.24	1.82***	-0.52	0.52***
	(0.53)	(0.48)	(0.63)	(-0.50)	(0.17)
$\tilde{n}_{4jt}(\times 10^3)$	–0.41**	–0.03	-0.26***	0.15	-0.14***
	(–0.16)	(–0.13)	(0.09)	(0.16)	(-0.05)
$\hat{n}_{jt}$	1.00**	0.80**	0.55**	0.65*	0.53**
	(0.42)	(0.33)	(0.25)	(0.38)	(0.24)
l^e_{jt}	-0.05	-0.11*	-0.17	-0.24**	-0.22*
	(-0.12)	(-0.06)	(-0.11)	(-0.10)	(-0.11)
Countries	22	22	22	22	22
Time period[1]	1870–2016	1870–2016	1870–2016	1870–2016	1990–2016
Observations	1939	2136	2103	1983	515
Age structure F-test[2]	0.04	0.01	0.00	0.34	0.02
Time effects	Yes	Yes	Yes	Yes	Yes
Res. country cluster[5]	Yes	Yes	Yes	Yes	Yes
Res. time cluster[6]	Yes	Yes	Yes	Yes	Yes
Sargan					
Hansen					
Estimator	FE	FE	FE	FE	FE

Notes: t-values in parenthesis. R^2-values refer to the within variation and do not include the fixed effects. π_{jt-2} is applied as a control in all specifications, coefficient estimates are available upon request. [1] Maximum time span across panels reported. [2] F-test of the joint hypothesis that $\tilde{n}_{pjt}$ for all p. [5] Residuals clustered along the country dimension. [6] Residuals clustered along the time dimension.

Robustness

The age cohort effects in alternative specifications (β_{1k} coefficients, equation (2)) Figure 3



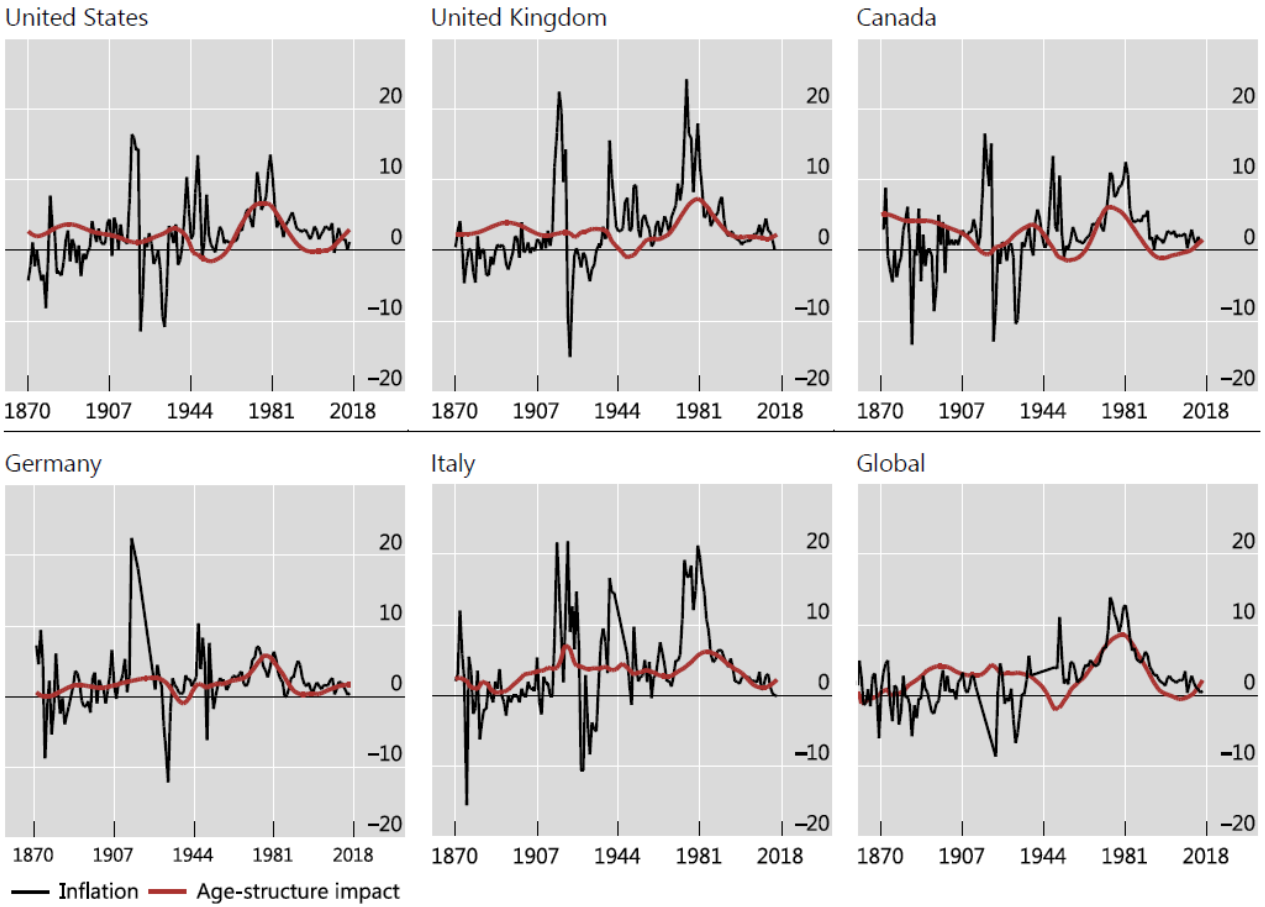
Economic significance

- Assess effect by dropping time fixed effects
  - Common global cause only problematic if it enters both inflation and demographics
  - Hard to think of such factors
- Findings
  - Same pattern, but more pronounced
  - Accounts for about 30% of inflation variation at both global and county specific levels
  - Reduces auto-regressive persistence in inflation by a lot!

Age-structure effect

Age structure effect accurately describes low-frequency inflation

Figure 4



The fitted demographic effects from the benchmark model are normalised to have the same mean as actual inflation. Figures in percent.

Demography and persistence

Demography and endogenous inflation persistence — Table 4

Model /sample	Full sample	Global	1870–1949	1950–2016
Phillips curve	0.88***	0.90***	0.36***	0.93***
	(0.02)	(0.04)	(0.11)	(0.02)
Phillips curve and demography	0.48***	0.62***	0.26**	0.65***
	(0.04)	(0.08)	(0.11)	(0.06)
Estimator	Arellano-Bond	Arellano-Bond	Arellano-Bond	Arellano-Bond

Notes: estimated auto-regressive parameters. The numbers in parenthesis are t-values based on robust residuals.

Conclusions

- Demography affects inflation
  - Population growth and dependency ratio positive impact
  - The impact does not appear to be spurious or related to omitted factors
  - Possibly relevant for low frequency inflation today
- Possible explanations
  - Consistent with delayed MP responses to slow movements in the natural rate
  - Not fully in line with political economy explanation or the fiscal theory of the price level
- Economically large effects
  - Accounts for a large share of trend inflation / inflation persistence across countries and globally

Annex

Variables and measurement

Variable definitions and data sources — Table A.1

Variable	Series	Data sources
π_{jt}	CPI annual growth	The Global Financial Data[1]; Mitchell's International Historical Statistics[1]; national authorities
N_{kjt}	Number of people in cohort $k = 1, \ldots, 17$, where the age-brackets are 0–4, 5–9, 10–14, …, 75–79 and 80+	United Nations; Human Mortality Database; Mitchell's International Historical Statistics
N_{jt}	Total population; sum of N_{kjt} over k	See N_{kjt} above
n_{kjt}	N_{kjt}/N_{jt}	See N_{kjt} above
$\tilde{n}_{pjt}$	$\sum_{k=1}^{17} \left(k^p n_{kjt} - k^p/17\right)$	See N_{kjt} above
i_{jt}	Short-term interest rates (three-month government bill yields, or closest proxies)	Global Financial Data[1]; Jordà, Schularick and Taylor (2017); Bordo et al (2001); national authorities
$E_t\pi_{jt+1}$	Projected one-year-ahead rolling estimates (20-year window) of a AR(1) process capped at 0.9 for π_{jt}	See π_{jt} above
r_{jt}	$i_{jt} - E_t\pi_{jt+1}$	See i_{jt} and π_{jt} above
y_{jt}	Real GDP	The Global Financial Data[1]; the Maddison Project; national authorities; OECD *Economic Outlook*; IMF WEO; Datastream[1]
y_{jt}^*	Hodrick-Prescott-filtered y_{jt} with $\lambda = 100$	See y_{jt} above
$\hat{y}_{jt}$	$y_{jt} - y_{jt}^*$	See y_{jt} and y_{jt}^* above
π_{jt}^e	Survey-based expectations of one-year-ahead inflation	Consensus Forecasts[1]
Productivity	Total factor productivity	Bergeaud et al (2016)
Population growth	N_{jt} annual growth	See N_{jt} above
Life expectancy	Life expectancy at birth	Human Mortality Database; Our World in Data; The Human Life-Table Database
Inequality	Top 1% income share, or closest proxies	Roine & Waldenström (2015); World Wealth & Income Database; Lindert (2000); Chartbook of Economic Inequality
Broad money	M2 or closest equivalent	Jordà, Schularick and Taylor (2017); European Central Bank; OECD Economic Outlook; IMF IFS; Global Financial Data[1]; national authorities
Money growth	Broad money annual growth minus y_{jt} growth	See Broad money and y_{jt} above
Fiscal balance	Fiscal balance as a share of GDP	IMF WEO
Hours worked	Hours worked per person	Conference Board Total Economy Database
Labour's share	Share of wages in national income	OECD Economic Outlook; Datastream[1]; national authorities

Notes: [1] Proprietary data available for purchase. References: Bergeaud, A, G Cette and R Lecat (2016): "Productivity trends in advanced countries between 1890 and 2012", Review of Income and Wealth, vol 62(3), pp 420-444; Bordo, M, B Eichengreen, D Klingebiel and M Martinez-Peria (2001): "Is the crisis problem growing more severe?", Economic Policy, vol 16(32); Jordà, O, M Schularick, and A Taylor (2017): "Macrofinancial history and the new business cycle facts", NBER Macroeconomics Annual 2016, vol 31, edited by Martin Eichenbaum and Jonathan A. Parker, Chicago: University of Chicago Press; Lindert, P (2000): "Three centuries of inequality in Britain and America", in Atkinson, A B and F Bourguignon (eds.) Handbook of Income Distribution, vol. 1, Amsterdam; Roine, J and D Waldenström (2015): "Long-run trends in the distribution of income and wealth", in Atkinson, A B and F Bourguignon (eds.) Handbook of Income Distribution, vol 2A, Amsterdam: North-Holland.

Data coverage

Data coverage: series start dates

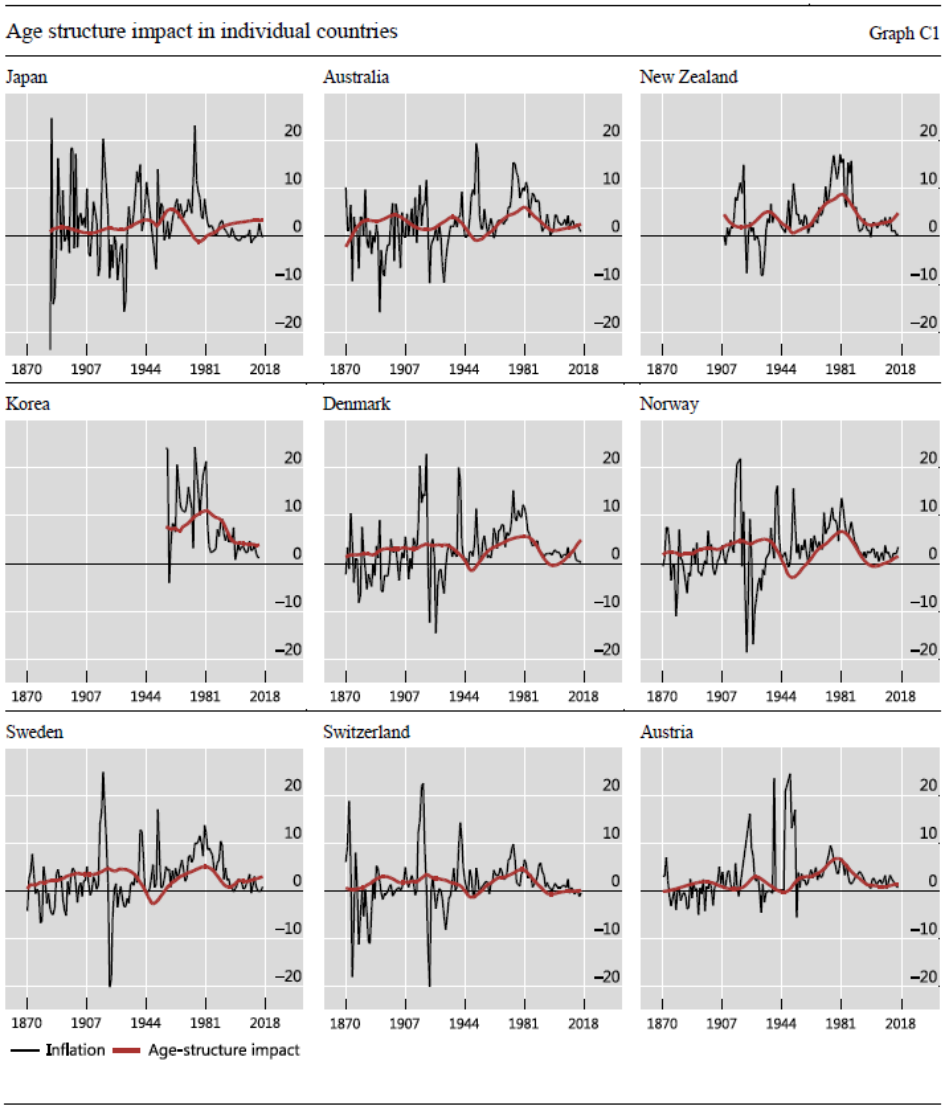
Table A.2

Countries	AU	AT	BE	CA	CH	DE	DK	ES	FI	FR	GB
π_{jt}	1864	1862	1871	1871	1851	1851	1851	1851	1901	1851	1851
N_{kjt}	1869[5]	1861[5]	1850	1851[5]	1860[5]	1871[5]	1850	1877[5]	1850[5]	1850	1851[5]
i_{jt}	1850	1851	1850	1934	1850	1850	1875	1880	1870	1860	1850
y_{jt}	1870	1850	1850	1870	1851	1850	1850	1850	1860	1850	1850
π^e_{jt}	1990	1990	1990	1990	1990	1990	1990	1990	1990	1990	2004
Productivity		1891	1891	1891	1891	1891	1891	1891	1891	1891	1891
Life expectancy[1]	1870	1885	1850	1850	1876	1875	1850	1882	1850	1850	1850
Inequality[2]		1921		1920	1933	1891[6]	1870[6]	1981	1865[6]	1900[6]	1850
Broad money[3]	1959	1959	1969	1968	1975	1950	1962	1969	1980	1961	1982
Fiscal balance[3]	1988	1988	1980	1980	1983	1991	1980	1980	1980	1980	1980
Hours worked[4]	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950
Labour's share[4]	1970	1960	1970	1981	1990	1991	1981	1964	1975	1960	1975

Countries	GR	IE	IT	JP	KR	NL	NO	NZ	PT	SE	US
π_{jt}	1950	1950	1862	1870	1956	1851	1851	1908	1931	1851	1851
N_{kjt}	1950	1950	1861[5]	1884[5]	1950	1850	1850	1874[5]	1864[5]	1850	1870[5]
i_{jt}	1950	1950	1885	1879	1951	1860	1870	1950	1880	1870	1850
y_{jt}	1950	1950	1850	1870	1953	1850	1850	1870	1865	1850	1850
π^e_{jt}	1993	1990	1990	1990	1990	1990	1990	1990	1990	1990	1990
Productivity			1891	1891		1891	1891		1891	1891	1891
Life expectancy[1]			1872	1865		1850	1850	1901	1940	1850	1880
Inequality[2]			1901	1886		1914	1875[6]	1921	1976	1903[6]	1913
Broad money[3]	1980	1960	1950	1955	1960	1956	1950	1988	1979	1961	1950
Fiscal balance[3]	1980	1980	1988	1980	1995	1995	1980	1985	1986	1980	1980
Hours worked[4]	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950	1950
Labour's share[4]	2000	2002	1961	1960	1975	1968	1978	1986	1995	1960	1960

Notes: [1] Sample ends in 2015. [2] Sample ends in 2014. [3] Sample ends in 2010. [4] Sample ends in 2013. [5] Annual sample starts in: AU 1921; AT 1950; CA 1921; CH 1876 ; DE 1950; ES 1908; FI 1878; GB 1922; IT 1871; JP 1947; NZ 1948; PT 1950; US 1933. Prior to these dates, interpolated values from lower frequency series if available. [6] Interpolated values: DE 1920-2000; DK 1870-1917; FI 1865-1920; GB 1850-1950; IT 1901-1973; NO 1875-1948; SE 1903-1943.

Age-structure effect: other countries



Age-structure effect: other countries