Mikael Juselius – Elod Takats

The age-structure–inflation puzzle

Bank of Finland Research
Discussion Paper
4 • 2016

The age-structure–inflation puzzle[*]

Mikael Juselius[**] and Előd Takáts[***]

1 March 2016

Abstract

We uncover a puzzling link between low-frequency inflation and the population age-structure: the young and old (dependents) are inflationary whereas the working age population is disinflationary. The relationship is not spurious and holds for different specifications and controls in data from 22 advanced economies from 1955 to 2014. The age-structure effect is economically sizable, accounting eg for about 6.5 percentage points of US disinflation from 1975 to today's low inflation environment. It also accounts for much of inflation persistence, which challenges traditional narratives of trend inflation. The age-structure effect is forecastable and will increase inflationary pressures over the coming decades.

Keywords: demography, ageing, inflation, monetary policy

JEL codes: E31, E52, J11

* The views expressed here are those of the authors and do not necessarily represent those of the Bank for International Settlements or the Bank of Finland. We are grateful for comments from Claudio Borio, Mathias Drehmann, Ray Fair, Kiyohiko Nishimura, Hyun Song Shin, Philip Turner, Christian Upper and Fabrizio Zampolli, and from seminar participants at the Austrian National Bank, Bank for International Settlements, Basel University, Central Bank of Hungary, Central Bank of the Republic of Turkey, European Central Bank and from participants at the "Cointegration: Theory and Applications" conference at the University of Copenhagen and LACEA (Latin American and Caribbean Economic Association) Meeting at Santa Cruz (Bolivia) for useful comments. We are indebted for comments at the roundtable discussion of the Monetary Policy Committee, Financial Policy Committee, and Prudential Regulation Authority of the Bank of England chaired by Governor Carney. We thank Emese Kuruc for excellent research assistance. All remaining errors are our own.

** Bank of Finland; e-mail: mikael.juselius@bof.fi

*** Bank for International Settlements; e-mail: elod.takats@bis.org

1. Motivation

Inflation has long cycles: it was low during the 1950s, climbed up in the 60s and 70s and has become low again today. This pattern happens to coincide with the birth of the large baby-boomer generations and their transition from youth into working age. And the current episode of low inflation comes at a time when these generations are nearing retirement. Could there be a connection between these slow moving trends, as recently suggested by senior policymakers such as Bullard et al. (2012) and Shirakawa (2011a,b)? If so, this could change the way we view the inflation process and conduct monetary policy (eg Faust and Leeper, 2015).

Recent studies have suggested that the age-structure and inflation might be linked. This is in contrast to conventional economic thinking, which suggests that central banks could offset any inflationary pressure coming from the age-structure. For instance, Bullard et al (2012) argue that the inflationary preferences of dominant voter groups, such as the old's preference for lower inflation, might influence central banks' monetary policy decisions. This would lead to lower inflation in aging societies. Shirakawa (2011a, 2011b) offers an alternative view, suggesting that a rising share of old in the population can lead to non-linear deterioration of the economic outlook, which in turn exerts deflationary pressures. Yet a third alternative is that the age-structure has slow moving influence on equilibrium interest rates (eg Goodhart et al. (2015)). For instance, lifecycle consumption-saving patterns (Modigliani and Brumberg (1954) and Ando and Modigliani (1963)) would suggest that cohorts that are net consumers drive up the real equilibrium interest rate, whereas net savers reduce it. If central banks fail to fully account for such systematic movements when setting actual rates, it could generate low-frequency trends in inflation. While these arguments have received some empirical support (see eg, Anderson et al (2014), Yoon et al (2014) and Aksoy et al (2015)), no comprehensive empirical assessment of the possible age-structure–inflation link has yet emerged.

We fill this gap by undertaking a careful empirical analysis of the link between age-structure and inflation on a sample of 22 advanced economies over the 1955-2014 period. We find that the age-structure is a systematic driver of inflation. Specifically, a larger share of young or old population (ie dependents) is inflationary, and a larger share of working age population is disinflationary, all else equal. The inflationary effect of the old population, in particular, is surprising and contrasts with previous findings.

The age-structure pattern accounts for the bulk of low-frequency inflation and implies historically low inflationary pressures currently. For instance, in the United States age-structure increased yearly inflation by 7 percentage points between 1960 and 1975 and decreased it back again by 6.5 percentage points between 1975 and 2014. However, our findings suggest that low inflation today is not the result of the increasing share of old, but rather due to the decreasing share of young. In fact, according to our estimates average inflationary pressures will increase by several percentage points over the next few decades in advanced countries, as the large baby-boomer generation gradually retires.

The uncovered relationship between inflation and the age-structure is highly robust. For example, it survives in more recent sub-samples or when time fixed effects are added. Hence, it does not spuriously capture any global trends that coincide with the inflationary episode in 60s and 70s or the recent episode of low inflation. Moreover, it does not change when controlling for economic variables, such as the output gap, real interest rates, money aggregates, government debt and deficits, or other indicators. Instead, the age-structure effect is largely complementary to these factors. Also, the effect does not depend on the particular estimation technique: it is, for instance, the same if we estimate it from age-cohorts directly or use more advanced population polynomials as in Fair and Dominguez (1991). Equally, the effect survives controlling for spurious regression or allowing for full heterogeneity in the panel as in Pesaran and Smith (1995) and Pesaran et al (1999).

None of the suggested explanations in the literature can alone account for the observed link between the age-structure and inflation. For instance, the inflationary effect of the old-age cohorts contradicts one of the key predictions of the Bullard et al (2012) model, casting some doubt on a political economy explanation. This conclusion is also strengthened by the fact that the age-structure–inflation relationship survives in the idiosyncratic component of inflation in small euro area countries – countries which could hardly sway monetary policy at the euro area level. Similarly, the inflationary effect of the old is also hard to reconcile with Shirakawa (2011a,b), especially as we find little evidence that the age-structure effects has switched in recent periods. Nor can the age-structure link be explained by systematic monetary policy mistakes. If this was the case, and the age-structure effect would proxy for low-frequency movement in the real equilibrium interest rate, it should not be significant on its own, but only jointly with actual real interest rates. Yet we find that the effect remains on its own even when we drop actual rates from the estimations. Moreover, the age-structure impact looks very different from standard estimates of equilibrium real rates.

More broadly, the age-structure–inflation link has implications for how we think about inflation persistence. The dependence of inflation on its past realizations is much lower once we control for the age-structure. And, most important, the remaining endogenous persistency can no longer account for past inflation trends. Put differently, inflation exhibits no trending, not even in the 1970s, after controlling for the population age-structure. This casts some doubt on the relevance of conventional explanations, such as central bank credibility or inflation targeting (e.g. Williams, 2006) as key drivers of trend inflation. Still shifts in monetary policy frameworks do coincide with some declines in endogenous inflation persistence that cannot be attributed to the age-structure.

Even if the underlying reasons for the age-structure–inflation relationship remain unclear, it nevertheless implies that the low frequency component of inflation is forecastable. While this result is not entirely new – McMillan and Baesel (1990) and Lindh and Malmberg (2000) have already established the forecasting power of demographics for low-frequency inflation – the policy implications are not trivial. Due to the ageing of advanced economies, inflationary pressures will rise from their current lows to levels close to those seen in the 1970s by the 2050s. Given that we find little association between trend inflation and monetary policy, central banks may find it difficult or costly to offset these pressures in line with current inflation targets. A more modest goal could be to preserve price stability over the business cycle.

The rest of the paper is organised as follows. The second section describes the data and presents the empirical results. The third section discusses potential explanations and the fourth the implications for inflation persistence and forecasting. The final one concludes.

2. Empirical analysis

2.1 Data

Since we are interested in a potential connection between low-frequency inflation and the age-structure, we collect the longest possible balanced sample with respect to these variables for a large number of countries. The sample covers 22 advanced economies[1] and spans the postwar period from 1955 to 2010.[2]

The main variable of interest is the yearly inflation rate obtained from Global Financial Data and national data sources. We denote it by π_{jt}, where $j=1,\dots,N$ is a country index and $t=1,\dots,T$ is a time index. The other key variable of interest is the age structure of the population: to investigate it we obtain demographic data from the UN population database. The total population (denoted as N_{jt} for each country and year) is divided into 17 five-year age cohorts (denoted by N_{kjt} where $k = 1, \dots, 17$) where the N_{kjt} shows the number of people in cohorts 0–4, 5–9, 10–14, ..., 75–79 and 80+. We also denote the share of cohort k in the total population, N_{kjt}/N_{jt}, by n_{kjt}. Besides historical data we also use the medium fertility version of the population forecast up until 2050.

In addition to the inflation rate and the population variables, our baseline econometric specification includes standard variables from monetary policy models. In line with most Phillips curve specifications, we use a measure of the output gap, $\hat{y}_{jt} = y_{jt} - y^*_{jt}$, where y_{jt} is real GDP and y^*_{jt} is potential GDP. We obtain real GDP data for the full sample from a variety of sources from the OECD's *Economic Outlook*, the IMF's *World Economic Outlook* (WEO), Datastream, Global Financial Data, and national data sources and use the Hodrick-Prescott filter (with λ = 100) to filter out its potential trend. We also use the real ex-post interest rate defined as $r_{jt} = i_{jt} - \pi_{jt}$,[3] where i_{jt} is the nominal policy rate which we obtain from national data sources, Datastream and Global Financial Data to get full time coverage. In extensions, we also use one-year ahead inflation expectations data from Consensus Economics. Finally, we also control for oil prices, i.e. the West Texas Intermediate (WTI) price, which we obtain from the IMF/IFS databases and Global Financial Data.

---

[1] The countries are: Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[2] Observations are available from 1950 onwards. However, many economies, including the US, experienced abnormal hikes in inflation between 1950 and 1955 following the onset of the Korean war. However, the choice to drop the first five years from the sample does not drive our results: using all available observations yields quantitatively and qualitatively similar estimates, albeit with marginally reduced precision.

[3] We obtain nominal interest rates from national data sources, Datastream and Global Financial Data to get full time coverage. While one would ideally use ex ante interest rates to avoid endogeneity, this is not available for the full sample. A more detailed treatments of this issue appears in the companion paper of Juselius and Takáts (2015)

2.2 Benchmark specification

In order to account for the impact of the age-structure, one could include the population shares for each age category at each point of time, as well as, the real interest rate, the output gap and the oil price:

$$\pi_{jt} = \mu + \mu_{j0} + \sum_{k=1}^{17} \beta_{1k} n_{kjt} + \beta_1 r_{jt} + \beta_2 \hat{y}_{jt} + \beta_3 oil_t + \varepsilon_{jt} \quad (1)$$

However, estimating equation (1) directly involves two problems. First, the precision of the estimates is lost if the number of population cohorts gets large compared to the number of time periods. Second, the finer the division of the total population, the larger the correlation between consecutive age cohorts becomes.

A way of overcoming the estimation problems associated with equation (1) is suggested by Fair and Dominguez (1991) and applied later by Higgins (1998) and more recently by Arnott and Chaves (2012). The idea is to restrict the population coefficients, β_{1k}, to lie on a *P*:th degree polynomial (*P* < *K*) of the form

$$\beta_{1k} = \sum_{p=0}^{P} \gamma_p k^p \quad (2)$$

where the gammas are the coefficients of the polynomial. Equation (1) and (2), together with the restriction $\sum_{k=1}^{17} \beta_{3k} = 0$, which removes the perfect colinearity between the constant and the age shares, yield

$$\pi_{jt} = \mu + \mu_{j0} + \sum_{p=1}^{P} \gamma_p \tilde{n}_{pjt} + \beta_1 r_{jt} + \beta_2 \hat{y}_{jt} + \beta_3 oil + \varepsilon_{jt} \quad (3)$$

where $\tilde{n}_{pjt} = \sum_{k=1}^{17} \left(k^p n_{kjt} - k^p/17 \right)$. Once estimates of the γ_p coefficients have been obtained, the β_{1k} coefficients can be directly obtained from equation (2). In addition, since the β_{1k}:s are linear transforms of the γ_p:s, their standard errors can be calculated using standard formulas (formal derivations these formulas appear in the Appendix of Juselius and Takáts (2015)).

In the subsequent analysis, we will use equation (3) with $P = 4$ as our benchmark specification. The results are robust to higher order population polynomials as shown in Juselius and Takáts (2015).

2.3 Regression results

Before estimating equation (3) directly, we estimate both a version that does not include the age-structure terms and one that only includes these terms (Table 1). In the specification without the age-structure terms (Model 1), the real interest rate is very significant whereas the output gap is not. This specification, can account for 39% of the within variation of inflation in the panel. In the second specification (Model 2), the age-structure terms are also highly significant (not only jointly as the F-test shows but even the individual terms) and explain 29% of the within variation.

The age-structure variables remain highly significant when estimating the full benchmark equation (3). Moreover, they contain almost orthogonal information to the other variables: the explained variation increases by 23 percentage points from 39% in Model 1 to 62% in Model 3 – a difference which is close to the explanatory power of the age-structure variables in isolation (Model 2). Furthermore, both the output gap and the real interest rates become more significant when we add the population polynomial. Thus, by accounting for the low-frequency variation in inflation, its cyclical properties become more visible.

Robust link between age-structure and inflation Table 1

Model	1	2	**3**	4	5	6	7
Dependent var.:	π_{jt}	π_{jt}	$\boldsymbol{\pi_{jt}}$	π_{jt}	π_{jt}	$\Delta\pi_{jt}$	$\Delta\pi_{jt}$
$\tilde{n}_{1jt}(\times 1)$		2.03 (12.75)	**2.01** **(17.88)**	0.56 (3.94)	0.59 (4.30)	1.61 (3.42)	1.87 (1.99)
$\tilde{n}_{2jt}(\times 10)$		–4.80 (–13.69)	**–4.35** **(–17.25)**	–1.24 (–4.35)	–2.04 (–6.75)	–4.24 (–3.92)	–4.67 (–1.75)
$\tilde{n}_{3jt}(\times 10^2)$		4.03 (13.45)	**3.40** **(15.58)**	0.98 (4.11)	2.08 (8.14)	3.80 (4.01)	3.86 (1.43)
$\tilde{n}_{4jt}(\times 10^3)$		–1.10 (–12.79)	**–0.87** **(–13.87)**	–0.25 (–3.68)	-0.65 (–8.88)	–1.09 (–3.95)	–1.01 (–1.14)
r_{jt}	–0.72 (–11.62)		**–0.73** **(–12.96)**	–0.17 (–2.71)	–0.75 (–10.21)	–0.76 (–6.39)	–0.37 (–1.43)
$\hat{y}_{jt}$	0.06 (1.39)		**0.06** **(1.54)**	0.13 (4.17)	0.04 (1.10)	0.12 (8.13)	0.20 (8.12)
oil_t	0.01 (2.16)		**0.01** **(2.10)**	0.01 (3.63)		0.23 (5.74)	0.05 (2.28)
$-\alpha$						–0.10 (–7.56)	–0.34 (–11.03)
Δr_{jt}						–0.85 (–60.27)	–0.72 (–14.49)
Δoil_t						0.02 (11.36)	0.02 (8.74)
Age-structure F-test		0.000	**0.000**	0.000	0.000	0.000	0.000
Country effects	Yes	Yes	**Yes**	Yes	Yes	Yes	NA
Time effects	No	No	**No**	No	Yes	No	NA
R^2	0.37	0.29	**0.63**	0.30	0.79	NA	NA
Observations	1320	1320	**1320**	440	1320	1320	1320
Estimator	FE	FE	**FE**	FE	FE	DFE	MG
Time period	1955–2014	1955–2014	**1955–2014**	1995–2014	1955–2014	1955–2014	1955–2014

Terms from regression 1 and for models 6 and 7 from regression 4.

An obvious concern is that the significance of the age-structure variables might be spuriously related to past policy mistakes. For instance, in the 1970s monetary policy did not fully recognise the importance of expectations. Thus, policy mistakes at the time might have generated the inflationary episode. If so, the age-structure effect should disappear in the data after the widespread adoptance of inflation targeting in the 1990s.

With this in mind, we re-estimate equation (3) for the recent 1995-2014 period (Model 4) and find that the age-structure variables remain significant. We also show below that the age-structure pattern remains intact, even if it is slightly weaker. Hence, the age-structure effect does not merely reflect past policy mistakes. While Model 4 only explains around one-third of inflation variation, this is not surprising: the baby-boomer generations have been moving through working age in this period and their effect on inflation has been fairly stable. Hence, much of the variation in inflation over this period comes from other sources.

The age-structure–inflation link might still be spurious, even though it survives in post 1990's samples. We use two approaches to safeguard against this possibility. First, we complement our benchmark equation (3) with time-fixed effects (Model 5). This approach also removes any common global trends such as increasing global trade linkages or common structural breaks in monetary policy. Thus, it also controls for oil prices changes so we drop oil prices in this specification. Still, the age-structure impact remains highly significant and its pattern more or less unchanged.

Second, we consider a dynamic error correction specification of (3) in order to formally ensure that the relationship is not spurious (Model 6). Specifically, we add lags of inflation, the real interest rate and the output gap to the right-hand side, as well as lag the polynomial terms by one period and rewrite the result in error correction form:

$$\Delta\pi_{jt} = \mu + \mu_{j0} + \varphi_1 \hat{y}_{jt} + \varphi_2 \Delta r_{jt} + \varphi_3 \Delta\pi_{jt}^{oil}$$
$$-\alpha(\pi_{j,t-1} - \lambda_1 r_{j,t-1} - \lambda_2 \pi_{j,t-1}^{oil} - \textstyle\sum_{p=1}^{P} \gamma_p \tilde{n}_{pj,t-1}) + \varepsilon_{jt} \qquad (4)$$

In equation (4), the term in parenthesis captures deviations from an empirical long-run relationship between inflation and the real interest rate, oil prices, and the population polynomial. We place the output gap outside the long-run relationship already at the outset as it is of higher frequency.[4] Apart from the exclusions of the output gap the long-run relationship in the parenthesis has the same format as equation (3). The coefficient α describes how fast deviations from the estimated steady-state translate into changes in inflation. The remaining terms capture short-run dynamics. Note that we do not allow the population terms in (4) to have any short-term effects.

The dynamic fixed effects specification supports the finding that the estimated age-structure effect is not spurious. The age-structure coefficients remain significant and robust (Model 6) and imply an almost identical pattern as before. In specification (4) the left-hand side variable is clearly stationary so that only stationary right-hand side variables can be relevant for explaining it. If the relationship between the age-structure is spurious, the steady-state deviations would be non-stationary and, hence, the adjustment coefficient α would be zero. Yet, α is both significant and negative, indicating that deviations from the long-run relationship correct into changes in inflation.

Another concern might be that misspecified country heterogeneity is driving the results. To address this concern we use mean group (MG) estimator by Pesaran et al (1999) that pools the information from individual country estimates of the dynamic specification in (4). Hence, this estimator allows for full heterogeneity with respect to all coefficients, as well as safeguards against spurious results. Again, the age-structure effects remain significant and its pattern unchanged (Model 7).

The MG estimator also produces country-specific estimates as an auxiliary output.[5] These results show that the age-structure variables are significant in all countries except for Portugal. In addition, the adjustment coefficients are insignificant for Greece, Italy and Portugal – all of which have experienced long episodes of exceptionally low real interest rates and high inflation rates in the earlier part of the sample. Overall, the results are remarkably strong given that the estimates for each country are based on 60 observations.

---

[4] Including the output gap in the parenthesis does not change the results (Juselius and Takáts, 2015).

[5] The details are available upon request and – for a slightly different specification – also in Juselius and Takáts (2015).

The age-structure effect is also robust to the inclusion of a number of additional control variables: ex-ante real interest rates, labour's share of income, labour productivity per hour worked, hours worked per person, the fiscal balance, fiscal debt to GDP ratio, residential property price inflation, equity price inflation, oil price inflation and three broad money stock measures (Juselius and Takáts, 2015). While none of these variables change the effects of the age-structure, some of them do provide additional explanatory power over inflation. In addition, the results are also robust to the inclusion of the population growth rate. The population growth rate in itself is statistically significant but accounts for, at most, 1 percentage point of the fluctuation in inflation over the sample period for any individual country (results available upon request).

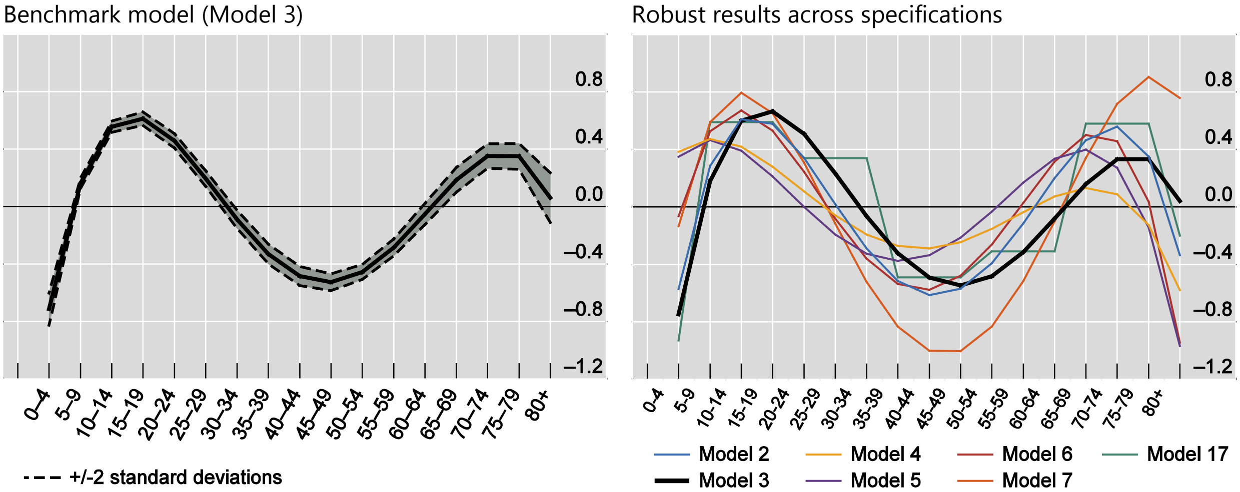
Only by including survey-based inflation expectations from Consensus Economics in the model, can we make the age-structure variables insignificant. But these inflation expectations are, in turn, driven by the age-structure variables (Appendix Table A1, models 8-10). There are two possible explanations for the strong link between current inflation and expected future inflation, and both of them suggest that the age-structure is the fundamental exogenous driver. The first possibility is that inflation expectations are a forward-looking driver of inflation. But then, since market participants condition their forecasts on the age-structure it must be a fundamental driver. The second possibility is that inflation expectations are naïve (e.g. backward looking) and do not drive inflation. In this case, the age-structure drives inflation directly and expectations only reflect this.

2.4 Age-cohort effects and economic impact

We compute the impact of each age cohort on inflation using equation (2). Apart from the two extremes of the age distribution (i.e. the very young and the very old), a U-shaped relationship appears: the young and the old age cohorts are inflationary, whereas the working age cohorts are disinflationary (Graph 1, left-hand panel).

Age cohort effects on inflation show robust U-shaped pattern

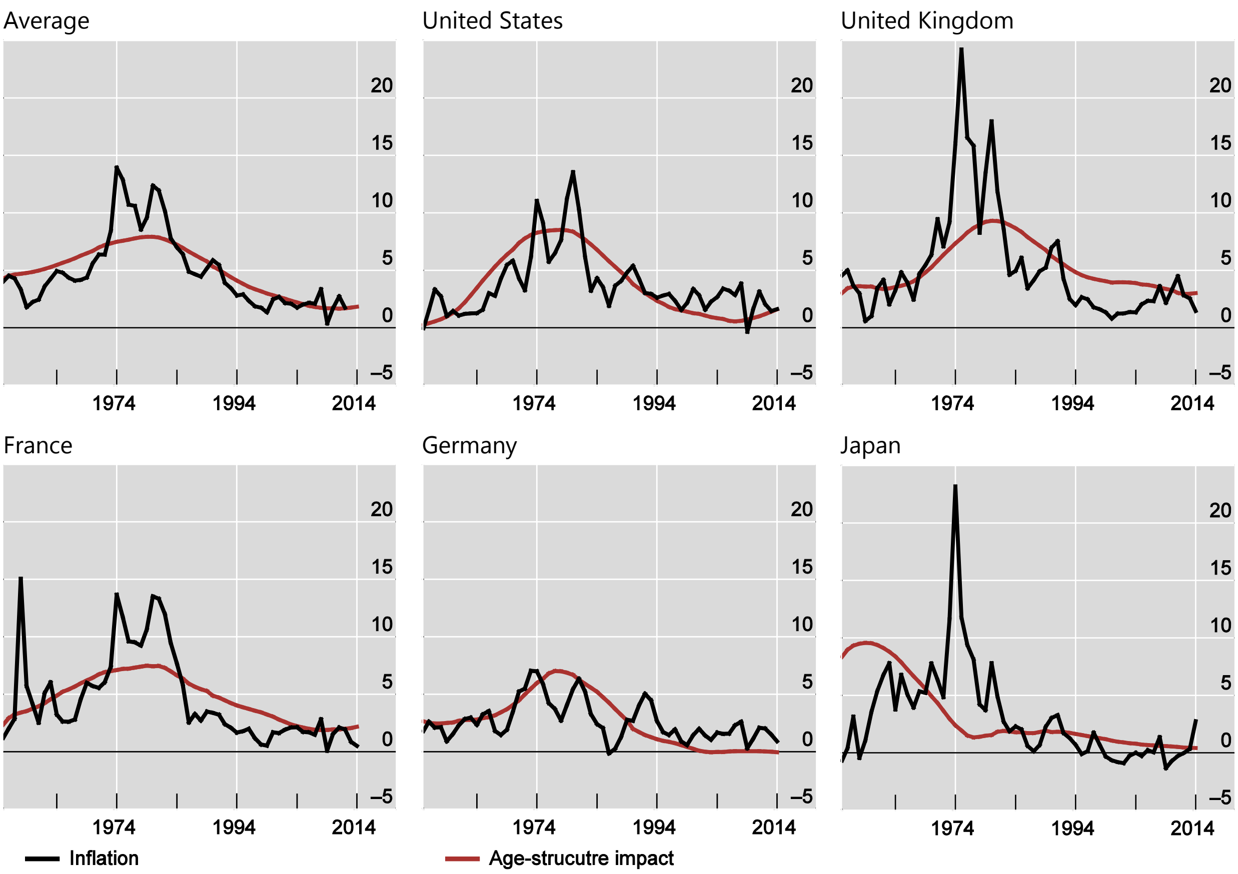
Graph 1



This U-shaped benchmark age-structure effect is also robust to changes in the specification (Graph 1, right-hand panel). The benchmark result (Model 3, thick black line) remains virtually unchanged when the additional controls are dropped (Model 2, blue line), time fixed-effects are applied (Model 5, dark blue line), or the dynamic specification issued (Model 6, red line). The 1995-2014 period estimates (Model 4, yellow line), though follows the same U-shaped pattern as the benchmark model, are more muted and slightly skewed to the left – reflecting the effect of omitting the commonalities in age-structure movements.[6] The MG estimator, which allows for heterogeneity, show a similar pattern but with larger swings across cohorts (Model 7, orange line). Finally, the age-cohort effects do not depend on the population polynomial specification: estimating (1) with 7 broad age-cohorts yields essentially the same patter (Model 17 from Appendix Table A2).

However, the estimates over different specifications also highlight that the age-cohort effects for extreme tails of the age distribution (i.e. for the very young and the very old) are less robust. This does not seem to arise due to end-point problems of the polynomial estimate: higher degree polynomials show virtually unchanged results (see Juselius and Takáts (2015) for details). A more likely explanation for this problem is that declining infant mortality and increasing life expectancy has had a large effect on these age-cohorts and their economic behaviour. Hence, we should treat the estimates for these cohorts cautiously.

Age-structure impact describes low frequency inflation well | Graph 2



Results from the benchmark specification (model 3). The fitted demographic effects from the benchmark model are normalised to have the same mean as actual inflation. Figures in percent.

[6] The estimated time fixed effects are negative before the 1980's and positive afterwards. This implies that the latent global factor runs counter to the age-structure effect (see upper-left-hand panel of Graph 2) and thereby global factor is a complement to the age-structure and not a substitute.

The estimated age-structure effect of our benchmark Model 3 explains the low-frequency evolution of inflation well, not only on average, but even in individual countries (Graph 2). This is striking because we have used the panel coefficients to calculate it for each country. The effect is also large: it accounts, on average, for around five percentage point reduction in the rate of inflation from the late 1970s to the early 2000s. That is, it explains around half of the total average reduction in inflation from its peak (upper left-hand panel).

The age-structure effect is particularly strong in the United States, where it accounts for around 6 percentage point increase in inflation from 1960 to 1975 and a 6.5 percentage point reduction from 1975 until today (upper middle panel). Furthermore, demographic developments seem to explain much of the cross-country variation in low-frequency inflation. For instance, the larger swings in US low-frequency inflation compared to German movements (lower left-hand panel) mostly reflect larger demographic changes in the United States.

Interestingly, the estimates show quite stable inflationary pressures for Japan over the past three decades (lower right-hand panel).[7] The lack of deflationary pressures arises because the deflationary impact of the declining share of the young roughly offset the inflationary impact of the increasing share of the old. This also suggests that the low inflation seen in Japan did not arise due to ageing pressures, as opposed to Shirakawa (2011a, 2011b).

3 Potential explanations

It is interesting to relate the empirical findings to the three potential explanations that has been suggested in the literature: political economic pressures, non-linear declines in economic prospects and equilibrium real rates. We do this in this section and find that none of these explanations can account for the link between the age-structure and inflation in the data.

3.1 Political economy

Bullard et al (2012) suggest that the inflation preferences of dominant voter age-cohorts may influence monetary policy. In their model different age groups have different inflationary preferences and the central bank adopts the median voter's preference for its inflation target. The working age cohorts (i.e. borrowers) prefer more inflation and the older cohorts (i.e. lenders) less inflation. Hence, an increasing share of working age population drives the central bank to target higher inflation, whereas a higher share of old population drives it to target lower inflation.

The evidence is not, however, fully in line with this type of political economy explanation. For one, if the political economy explanation were correct, then the real interest rate would account for the age-structure effect. But the age-structure effect survives even after controlling for the real interest rate (Table 1). Moreover, we find that the old are inflationary in contrast to one of the models key predictions (Graph

[7] Furthermore, the country-specific results of the MG estimator suggest that the dynamics in Japan are not very different from the other advanced economies in the sample. Hence, the panel estimates seem to be representative for the Japanese experience.

1). Furthermore, the creation of the euro area in 1999 offers a natural experiment to further test the political economy explanation. If the preferences of dominant age-cohorts drive the inflation patters, the age-structure effect should only be visible in the common euro area inflation trend. However, it should not be visible in the idiosyncratic inflation components of, say, small Euro Area countries which could hardly sway area wide monetary policy. We first confirm that the age-structure effect is present for all euro area countries (Model 11), even when we focus on their idiosyncratic inflation experiences by adding time fixed effects (Model 12). The effect remains even if we exclude the three largest euro area economies, ie France, Germany and Italy, and focus on smaller countries (Model 13).

The potential disinflationary impact of the old deserves still more attention not only due to its connection to the secular stagnation hypothesis, but also because some empirical studies found such an impact (Yoon et al, 2014). While we are able to replicate the disinflationary effect of the old, reported in these studies, we also find that it is not robust (Table A2 in the Appendix). While the old seem to be disinflationary when their share is estimated alone (Model 14), this effect disappears immediately if we control for the full age-structure (Model 16).[8] The simple three age category model yields very similar results as Aksoy et al (2015). In more granular age-cohort breakdowns, not only the old become inflationary again (Model 17), but the estimated age-structure impact pattern starts to resemble the results from the population polynomials (see Graph 1, right-hand panel).

3.2 Non-linear impact of ageing

A second possible explanation is that ageing deteriorates economic prospects and confidence in a non-linear fashion (Shirakawa, 2011a,b). If monetary policy is unable to counter this shock forcefully, because, for instance, it is constrained by already low interest rates, then this can depress inflation. However, the empirical evidence suggests that lowering inflationary pressures in the past decades are explained not by the rising share of the old, but rather the declining share of the young (as discussed earlier), which contradicts to the main assertion of this theory.

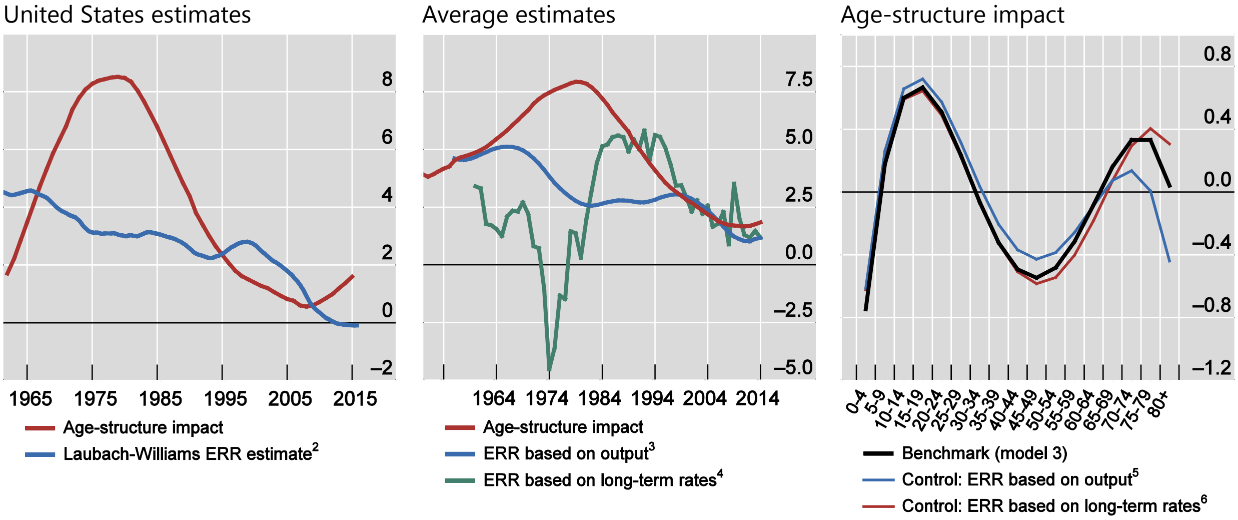
3.3 Equilibrium real rates

A third possible explanation for the age-structure–inflation effect is that it reflects a failure of central banks to adjust policy to slow moving shifts in the unobservable equilibrium real interest rate (Goodhart et al, 2015). Such slow changes may in themselves reflect eg life-cycle consumption-savings behavior and, hence, be related to the age-structure. This would generate persistent deviation between actual and equilibrium real interest rates and, therefore, persistent inflation trends. While this explanation is hard to reconcile with the view that sophisticated central banks have the tools to detect such persistent policy mistakes, it nevertheless deserves additional scrutiny. If this explanation is valid, then trend inflation should be the result of persistent deviations between the actual rates and the age-structure terms that are a proxy for the unobservable equilibrium rate.

---

8 Already splitting the old into two categories weakens the effect (Model 15): only the 80+ have a negative effect, whereas the 65-79 year olds have a positive impact.

Age-structure impact differs from equilibrium real rate[1] Graph 3



ERR = equilibrium real rate [1] In per cent [2] Two-sided natural rate estimates with 2015 Q3 as final data point. Model based on Laubach and Williams (2006). [3] Growth rate of potential output is defined as equilibrium real rate. [4] Long-term real rates are used as measure for equilibrium real rate. Long-term rate is defined as the difference between nominal 10-year yields and contemporaneous inflation. Greece and Korea are excluded due to data availability constraints. [5] Age-structure impact from model 3 expanded with trend output growth as defined in footnote 3. [6] Age-structure impact from model 3 expanded with real long-term rate as defined in footnote 4.

The observed empirical pattern suggests that persistent deviations between actual and equilibrium real interest rates cannot fully account for the age-structure–inflation puzzle. First and most important, the age-structure effect remains intact even when actual real interest rates are excluded from the specification (Table 1, Model 2). Second, the age-structure impact is very different from standard measures of the equilibrium real rate. In the United States, for example, the age-structure effect differs substantially from the standard Laubach and Williams (2006) natural rates (Graph 3, left-hand panel). For other economies, we can compare the age-structure effect to two proxies for the equilibrium real interest rate: the growth rate of potential output and long-term real interest rates.[9] Again the differences are substantial (centre panel). Finally, the age-structure effect also survives after controlling for these equilibrium real interest rate proxies in the estimations (right-hand panel). Hence, the age-structure seems to capture a different impact than equilibrium real interest rates.

4. Implications

In this section, we discuss some direct implications of the age-structure–inflation link. First, we show that this link accounts for a large part of inflation persistence. Second, we use population projections to quantify the future inflationary consequences of ageing.

[9] Again, data availability constrains us to ex-post realized real rates instead of ex-ante rates.

4.1 Inflation persistence

Given the slow moving evolution of the age-structure, it is natural to ask how much of observed inflation persistence can be attributed to it and how much is endogenous. This is relevant for monetary policy because endogenous persistence matters for inflation control. Moreover, given the widely held view that endogenous inflation persistence has come down in recent decades due to increasing credibility of monetary policy, it is also interesting to study how it has changed over time.

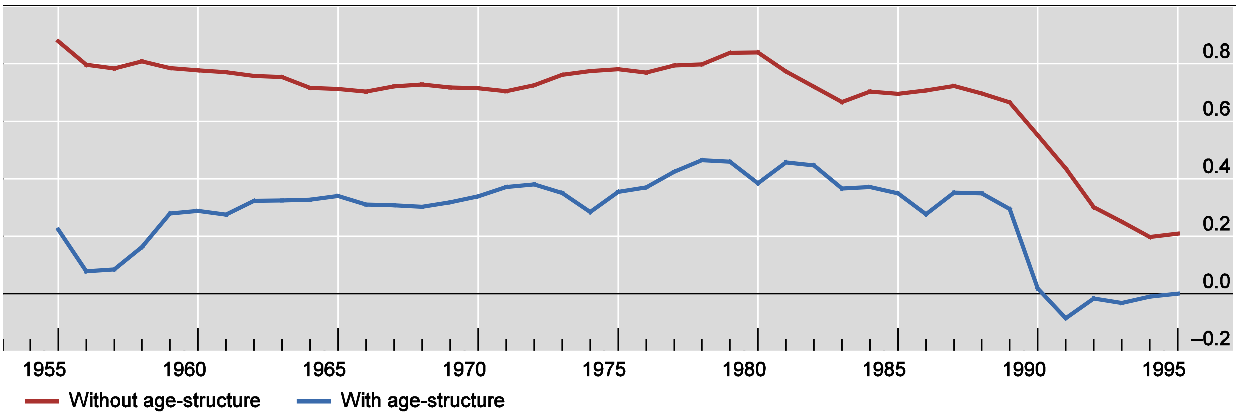
To see how the age-structure affects endogenous inflation persistence, we add a lagged inflation to equation (3) in an alternative dynamic specification

$$\pi_{jt} = \rho\pi_{jt-1} + \mu + \mu_{j0} + \sum_{k=1}^{17} \beta_{1k} n_{kjt} + \varepsilon_{jt} \quad (5)$$

where ρ captures the degree of endogenous inflation persistence.[10] Furthermore, to capture changes in persistency over time, we use rolling regressions with a 20-year rolling window. To facilitate the comparison between different time periods, we have dropped all other variables from the specification. We also employ the MG estimator, due to the large variation with respect to the degree of endogenous inflation persistence across the different countries in the panel.

Controlling for the age-structure lowers estimated inflation persistence consistently and substantially across time periods (Graph 4). This holds even if we add the output gap, the real interest rate, and oil price inflation to specification (5). Adding the age-structure variables reduces average inflation persistence from near unit-root dynamics (0.76) to a clearly stationary region (0.36), where inflation reverts quickly to the estimated age-structure trend.

Inflation persistence drops consistently after controlling with age-structure — Graph 4



Rolling MG estimates of the first-order autoregressive parameter (ρ) in equation (5). The estimates use a 20-year rolling window. The y-axis shows the initial date of the rolling window.

However, controlling for the age-structure does not change the time-pattern of the persistence estimates. Hence, the earlier findings (see, for instance, in Barsky (1987), Taylor (2000), and Benati (2008)) on the rise and decline of inflation persistence over the past half-century survive the addition of the age-structure term.

[10] Admittedly, this does not account for inflation persistence coming from unmodelled factors such as latent variables or persistent shocks. An alternative approach would be to assess inflation persistence (and account for the impact of shocks) in a structural model, as for instance, in Benati (2008).

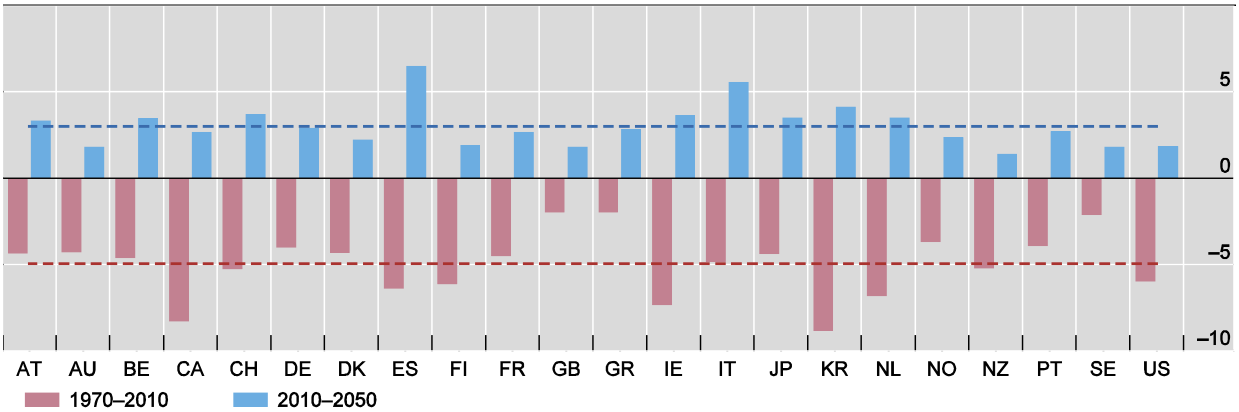
The lower persistence levels after controlling for the age-structure, suggests that shifts in monetary policy frameworks had less profound impact than conventionally thought. According to the conventional view, the loss of central bank credibility in the 60s and 70s generated higher inflation, which in turn manifested itself in a higher inflation persistence. Central banks had to regain credibility over the following decades and lower inflation persistence to be able to control inflation reasonably (Williams, 2006). Our results, in contrast, suggest that these efforts only affected the part inflation persistence that is unrelated to the age-structure. If so, trend inflation has not yet been conquered – it has merely been dormant.

4.2 Future inflation

A second practical implication of the age-structure effect is that it can be forecasted over long horizons, even extremely long ones by traditional macroeconomic standards. Barring catastrophes, we can estimate how many people will enter the different age-cohorts twenty years down the road as they have all been born – and thereby we can also forecast the age-structure impact on inflation in the future.

Combining our estimates with population forecasts suggests that the age-structure effect on inflation will reverse over the coming decades (Graph 5). Over the past forty years, the increasing share of working age population has lowered average inflationary pressures by around five percentage points (red dotted line below the line). Currently, the shrinking number of young largely offsets the increasing number of old – which holds inflation pressures steady at historically low levels. Over the next forty years, the growing share of the old would dominate and increase the inflationary pressures by approximately 3 percentage points on average (blue dotted line).

Age-structure impact will turn from disinflationary to inflationary — Graph 5



AT = Austria; AU = Australia; BE = Belgium; CA = Canada; CH = Switzerland; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; GR = Greece; IE = Ireland; IT = Italy; JP = Japan; KR = Korea; NL = Netherlands; NO = Norway; NZ = New Zealand; PT = Portugal; SE = Sweden; US = United States.

Percentage point difference in the age-structure–inflation effect between the 1970 and 2010, and 2010 and 2014, respectively. The estimates use the age-structure impact from benchmark Model 3 combined with UN Human Population Projections. The dashed lines show averages of the above economies.

Though country-specific estimates vary, the reversal of past disinflationary pressures to inflationary pressures is present in all individual country estimates (see red and blue bars). However, there are important cross-country differences. In the United States, the baby boomer generation was relatively large and its entry to the labour force reduced inflation more than average. And, although the baby boomers are about to retire, their comparatively high past fertility rates ensure that inflationary pressures increase less than average in the United States. The largest future inflationary effects are not expected in countries which are already old (such as Germany or Japan), but in those which are expected to age the fastest (Greece, Italy, Korea and Spain).

These projections should, however, be treated cautiously. Population projections are in themselves inherently uncertain and often miss the mark over longer horizons. Moreover, the future inflation effect increasingly depends on the estimated impact of the very old, as this population cohort is expected to increase most rapidly - but as we note before, the coefficient for this age-cohort is very hard to pin down precisely.

4. Conclusion

Data from 22 advanced economies reveal a puzzle: there is a statistically significant relationship between the age-structure of the population and low-frequency inflation. Specifically, the young and old (ie dependents) are inflationary while working age cohorts are disinflationary. This relationship can account for the bulk of past low-frequency inflation and partly explains why inflationary is so low today: the inflationary pressure from the increasing share of old people is not yet strong enough to offset the disinflationary pressures from the declining share of young people. Looking ahead, our results also imply that inflationary pressures will rise as the baby boomer generations retire.

The uncovered relationship begs for an explanation. The literature has suggested a few possible explanations for the link between the age-structure and inflation, such as the influence of voter preferences or slow moving changes in real equilibrium interest rates. Unfortunately, the observed empirical pattern is not fully consistent with any of these explanations. The closest that we come to an economic interpretation for the age-structure effect is its near analogy to life-cycle consumption and savings behaviour. If shifts in the age-structure do not only move equilibrium real interest rates, but also affect the trade-offs of inflation control, it could potentially account for the observed empirical pattern. Studying this analytically is, however, beyond the scope of the present paper and left for future research.

While it is unclear what drives the relationship, controlling for the age-structure substantially lowers estimates of endogenous inflation persistence, both today and in the 1960s and the 1970s. Put differently, monetary policy may not be responsible for trend inflation after all. But if so, this raises a more chilling possibility: central banks may discover that controlling inflation is more complex than conventionally thought.

Appendix

The role of inflation expectations and age-structure effect in the euro area — Table A1

Model	8	9	10	11	12	13
Dependent var.:	π_{jt}	π_{jt}^{e}	π_{jt}^{e}	π_{jt}	π_{jt}	π_{jt}
$\tilde{n}_{1jt}(\times 1)$	0.03	0.46	0.25	0.34	0.50	0.66
	(0.32)	(4.45)	(2.60)	(1.82)	(2.39)	(2.70)
$\tilde{n}_{2jt}(\times 10)$	-0.11	-1.21	-0.85	−0.88	−1.06	−1.24
	(-0.59)	(-6.40)	(-5.44)	(−2.37)	(−2.51)	(−2.78)
$\tilde{n}_{3jt}(\times 10^2)$	0.12	1.04	0.85	0.78	0.84	0.92
	(0.83)	(6.80)	(6.62)	(2.41)	(2.47)	(2.73)
$\tilde{n}_{4jt}(\times 10^3)$	-0.04	-0.29	-0.26	−0.23	−0.23	−0.24
	(-1.04)	(-6.38)	(-6.25)	(−2.36)	(−2.40)	(−2.64)
r_{jt}	-0.12	0.03	-0.06	−0.49	−0.53	−0.50
	(-5.16)	(0.94)	(-1.54)	(−4.20)	(−2.47)	(−2.43)
$\hat{y}_{jt}$	0.06	0.13	0.13	0.19	0.05	0.06
	(2.80)	(5.59)	(4.68)	(6.66)	(1.22)	(1.18)
oil_t	0.002	0.003		0.008		
	(1.15)	(1.70)		(1.88)		
π_{jt}^{e}	1.13					
	(23.32)					
Age-structure F-test	0.41	0.00	0.000	0.000	0.18	0.11
Country effects	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	No	No	Yes	No	Yes	Yes
R^2	0.79	0.53	0.65	0.66	0.85	0.86
Observations	550	550	550	176	176	128
Countries	All	All	All	Euro Area	Euro Area	Small Euro Area
Time period	1989-2014	1989-2014	1989-2014	1999-2014	1999-2014	1999-2014

Old-age cohorts are inflationary, unless young are omitted from the specification Table A2

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)
r_{jt}	–0.69 (–11.18)	–0.68 (–10.01)	–0.65 (–10.79)	–0.73 (–12.91)
$\hat{y}_{jt}$	0.07 (1.47)	0.06 (1.45)	0.08 (1.65)	0.07 (1.90)
oil_t	0.02 (2.79)	0.01 (2.40)	0.01 (2.67)	0.01 (1.39)
Country effects	Yes	Yes	Yes	Yes
Time effects	No	No	No	No
R^2	0.42	0.45	NA	NA
Observations	1320	1320	1320	1320
Estimator	FE	FE	FE	FE
Time period	1955–2014	1955–2014	1955–2014	1955–2014

References

Aksoy, Y., H. S. Basso, T. Grasl, and R. P. Smith (2015): "Demographic Structure and Macroeconomic Trends," Manuscript, Birkbeck, University of London, January

Anderson, D, D Botman and B Hunt (2014) "Is Japan's Population Aging Deflationary?" IMF Working Paper 14/139, August

Ando, A and F Modigliani (1963) "The 'life cycle' hypothesis of saving: aggregate implications and tests", *American Economic Review*, vol 53 pp 55–84.

Arnott, R D and D B Chaves (2012) "Demographic Changes, Financial Markets, and the Economy", *Financial Analysts Journal*, Volume 68, Number 1, 23–46.

Barsky, R B (1987) "The Fisher Hypothesis and the Forecastibility and Persistence of Inflation" Journal of Monetary Economics 19, 3-24.

Benati, L (2008) "Investigating inflation persistence across monetary regimes" Quarterly Journal of Economics, 123 (3), 1005-1060

Bullard, J, C Garriga and C J Walker (2012) "Demographics, Redistribution, and Optimal Inflation" Federal Reserve Bank of St. Louis Review, November/December 2012, 94(6), pp. 419–39.

Fair, R and K Dominguez (1991) "Effects of the changing U.S. age distribution on macroeconomic equations", *American Economic Review*, vol 81, 1276–94

Faust, J and E M Leeper (2015) "The myth of normal: the bumpy story of inflation and monetary policy" Prepared for the Federal Reserve Bank of Kansas City's Jackson Hole Symposium, August 2015

Goodhart, C, M Pradhan, and P Pardeshi (2015) "Could Demographics Reverse Three Multi-Decade Trends?" Morgan Stanley Global Research, September

Higgins, M (1998) "Demography, National Savings, and International Capital Flows." International Economic Review, vol. 39, no. 2 (May):343–369.

Juselius, M and E Takáts (2015) "Can demography affect inflation and monetary policy?", BIS Working Paper 485, February

Laubach, T and J C Williams (2003) "Measuring the natural rate of interest", The Review of Economics and Statistics, vol. 85(4), pages 1063–1070, November.

Levin A and J Piger (2004) "Is inflation persistence intrinsic in industrial economies"

Lindh, T and B Malmberg (2000) "Can age structure forecast inflation trends?", Journal of Economics and Business, 52, pp 31–49.

McMillan, H and J Baesel (1990) "The macroeconomic impact of the baby boom generation", Journal of Macroeconomics, vol 12, no 2, pp 167–95.

Modigliani, F and R Brumberg (1954) Utility Analysis and the Consumption Function: An Interpretation of Cross-Section Data, in KK Kurihara (ed), *Post-Keynesian Economics*, Rutgers University Press, New Brunswick, pp 388–436.

Pesaran, M H, and R P Smith (1995) "Estimating long-run relationships from dynamic heterogeneous panels", Journal of Econometrics 68: 79–113.

Pesaran, M H, Y Shin, and R P Smith (1999) "Pooled mean group estimation of dynamic heterogeneous panels" Journal of the American Statistical Association 94: 621–634.

Shirakawa, M (2011a) "Bubbles, Demographic Change and Natural Disasters", Opening Speech at 2011 Annual International Conference hosted by the Institute for Monetary and Economic Studies, the Bank of Japan, June 1

Shirakawa, M (2011b) "Globalization and Population Aging: Challenges Facing Japan", Speech to the Board of Councillors of Nippon Keidanren, December 22.

Taylor, J (2000) "Low Inflation, Pass-Through, and the Pricing Power of Firms" European Economic Review 44, 1389-1408

Williams, J (2006) "The Philips curve in an era of well-anchored inflation expectations" Federal Reserve Bank of San Francisco, mimeo

Yoon, J-W, J Kim and J Lee (2014) "Impact of Demographic Changes on Inflation and the Macroeconomy" IMF Working Paper 14/210 November.

Bank of Finland Research Discussion Papers 2016

ISSN 1456-6184, online

1/2016 Aino Silvo
The interaction of monetary and macroprudential policies in economic stabilisation
ISBN 978-952-323-088-0, online

2/2016 Rune Stenbacka – Tuomas Takalo
Switching costs and financial stability
ISBN 978-952-323-094-1, online

3/2016 Mikael Juselius – Mathias Drehmann
Leverage dynamics and the burden of debt
ISBN 978-952-323-098-9

4/2016 Mikael Juselius – Elod Takats
The age-structure–inflation puzzle
ISBN 978-952-323-099-6

http://www.suomenpankki.fi/en • email: Research@bof.fi
ISBN 978-952-323-099-6, ISSN 1456-6184, online