Demographics and inflation:
A cointegration analysis

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Outline

Introduction

1. Many central banks across advanced economies are challenged by the low inflation environment in their mandate as guardians of price stability
2. The demographic trend was brought forward as one of the possible structural drivers of low-frequency inflation and being deflationary, e.g., in Japan $\rightarrow$ Shirakawa et al. (2012), Fujiwara and Terashini (2007), Fujita and Fujiwara (2014) and Carvalho et al. (2016)
3. Substantial changes in the demographic structure over the last 4-5 decades: falling birth rates, increased life expectancy and shrinking labor force $\rightarrow$ higher dependency ratio (aging)

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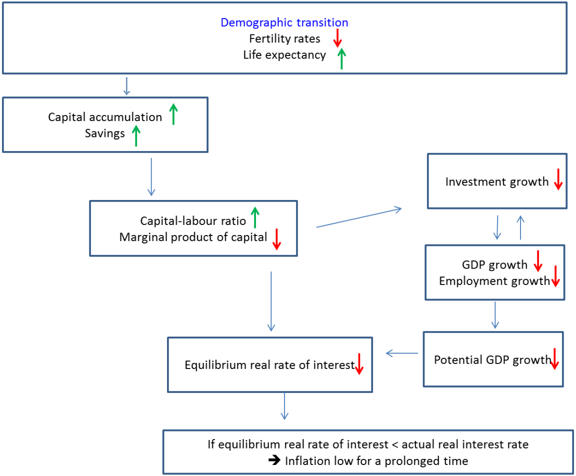
Literature review: How might ageing affect inflation?

1. Life-cycle hypothesis: Juselius and Taktas (2015, 2016)
2. Impact on financial wealth and political economy considerations: Taktas (2012), Brooks (2006), Bullard et al. (2012)
3. Relative prices and consumption preferences: Katagiri (2012)
4. Secular stagnation and monetary policy: Yoon et al. (2014)

Secular stagnation and inflation



Our contribution

We look at changes in the working-age population and the long-run equilibrium relationship between demographic trend and inflation, and provide cross-country evidence.

Why do we focus on the working-age population?

- The working-age population is a function of young people entering the labor force and old people leaving the labor force.
- A decline in fertility leads to negative growth of the labor force and increased life expectancy leads to shrinking share of working age population in total population.

How could this demographic variable affect inflation?

- Working-age population is a production factor
- Consumption behavior of people at working age relative to the old and young

Preview of the results

1. A positive long-run relationship between demographics and inflation
2. The positive link holds also after controlling for monetary policy
3. The link found to be present in the euro area, U.S. and Germany

Inflation and working age population - Euro area

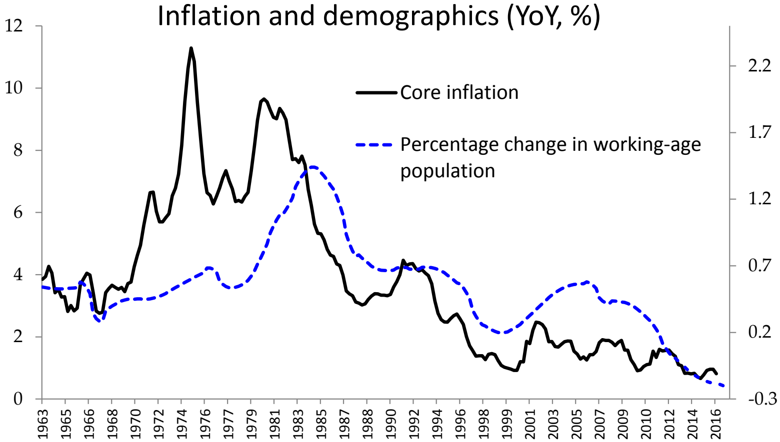


Figure 1: Source: ECB, UN Population Statistics (1963-2016)

Empirical results I - Euro Area

Step 1: Likelihood ratio-based trace test statistics:

$$\Delta Y_t = \Phi D_t + \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \quad (1)$$

Johansen's trace test for cointegration rank, Euro area

No. of cointegrating relationships	Model 1	Model 2	Model 3
0	40.83***	65.78 ***	79.22***
1	4.12	12.43	22.20
2			5.48

Notes: The estimation sample is: 1975(1) - 2016(2). *** denotes statistical significance at 1% level. For Model 2 and 3 we report the modified trace test (Johansen et al. (2000)), which is based on a Gamma distribution (instead of a normal distribution) as an asymptotic distribution to approximate the sampling distributions of the test statistics. We obtain the critical values from Giles and Godwin (2012). For Model 2 the simulated critical value at 5% significance is 12.26 for one cointegrating relationship with the step dummy running from 1975Q1-1983Q2 and total number of observations = 166. For Model 3 the simulated critical value at 5% significance is 30.70 with step dummy running from 1975Q1-1983Q2 and total number of observations = 166.

Empirical results II - Euro Area

Step 2: Cointegrated VAR(2) estimation: Factorization of Π:

$$\underset{n\times n}{\Pi} = \underset{n\times r}{\alpha} \times \underset{r\times n}{\beta'} \tag{2}$$

Long-run equilibrium relationship between demographics and inflation, euro area

	Model 1		Model 2		Model 3	
	β	α	β	α	β	α
core inflation	1	-0.06	1	-0.11	1	-0.13
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.02)
demographics	-4.22	(-0.00)	-3.40	0.00	-1.57	-0.00
	(0.69)	(0.00)	(0.35)	(0.00)	(-0.55)	(0.00)
interest rate					-0.20	-0.10
					(0.05)	(0.05)
constant	-2.50		-2.02		-1.2	
	(0.29)		(0.15)		(0.25)	
step dummy			-3.68		-3.49	
			(0.46)		(0.39)	

Notes: The estimation sample is: 1975(1) - 2016(2). The beta vector is shown such that all the coefficients are normalized to that of core inflation and all of the coefficients are on the same side of the "=" sign. Likelihood ratio test based on Chi-square distribution with df = 1 on the alpha restriction cannot be rejected and therefore supported by the data in all three models. To test the significance of the demographic variable, we perform the likelihood ratio test based on Chi-square distribution with df = 2 by setting $\beta_{demo} = 0$. For all three models we reject the restriction on β_{demo} at 1-5% significance level.

Inflation and working-age population - US

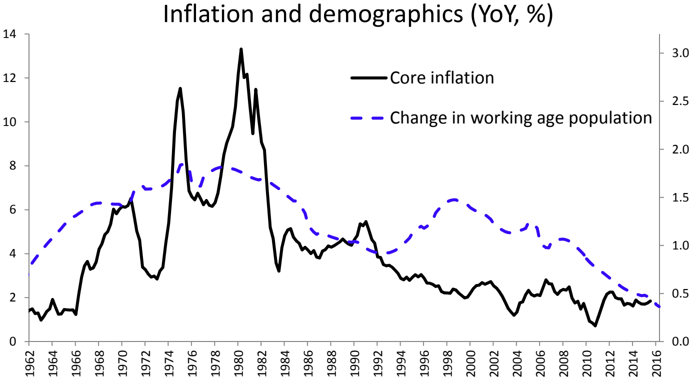


Figure 2: Source: ECB, UN Population Statistics (1963-2015)

Empirical results - US

Step 1: Likelihood ratio-based trace test statistics:

Johansen's trace test for cointegration rank, US

No. of cointegrating relationships	Model 3
0	34.19*
1	11.39
2	3.07

Notes: The estimation sample is: 1961(4) - 2016(2). The estimation does not involve structural breaks. Standard Johansen's trace test for cointegration rank is performed here. * indicates the significance level at 10%. The null of rank = 0 is rejected but the null of rank to be at most one failed to be rejected.

Empirical results - US

Step 2: Cointegrated VAR(2) estimation:

Long-run equilibrium relationship between demographics and inflation, US

	Model 3	
	β	α
core inflation	1	-0.10
	(0.00)	(0.02)
demographics	-3.43	-0.00
	(1.00)	(0.00)
interest rate	-0.30	-0.06
	(0.10)	(0.04)
constant	-1.56	
	(0.53)	

Notes: The estimation sample is: 1961(4) - 2016(2). The beta vector is shown such that all the coefficients are normalized to that of core inflation and all of the coefficients are on the same side of the "=" sign. Likelihood ratio test based on Chi-square distribution with $df = 1$ on the alpha restriction cannot be rejected and therefore supported by the data in all two model. Model 1: LR test of restrictions: $Chi^2(1) = 0.40294$ [$p = 0.5256$] and model 3: LR test of restrictions: $Chi^2(1) = 0.19973$ [$p = 0.6549$]. To test the significance of the demographic variable, we perform the likelihood ratio test based on Chi^2 distribution with df = 2 by setting $\beta_{demo} = 0$. For all models we reject the restriction on β_{demo} at 1 to 5% significance level: Model 1: LR test of restrictions: $Chi^2(2) = 7.8177$ [0.0201]* and model 3: LR test of restrictions: $Chi^2(2) = 12.224$ [0.0022]**

Conclusions

- Demography matters: evidence for a stationary relationship between inflation and working age population growth.
- If ageing increasingly and more importantly conditions the economic evironment in which monetary policy operates, monetary policy will be required to adapt to the changing environment.

THANK YOU FOR YOUR ATTENTION!

Beveridge-Nelson (BN) decomposition of cointegrated times series

The BN decompostition of Y_t into VECM parameters has the representation:

$$Y_t = \mu_t + C(1)\Sigma_{k=1}^{t} u_t + Y_0 + C^{*}\epsilon_t \tag{3}$$

where $C(1) = \beta_{\perp}(\alpha'_{\perp}\Gamma(1)\beta_{\perp})^{-1}\alpha'_{\perp}$ moving-average impact matrix. The common stochastic trends in Y_t are extracted using:

$$\beta_{\perp}(\alpha'_{\perp}\Gamma(1)\beta_{\perp})^{-1}\alpha'_{\perp}\Sigma_{k=1}^{t} u_t \tag{4}$$

where $\beta_{\perp}(\alpha'_{\perp}\Gamma(1)\beta_{\perp})^{-1}$ are the loadings on the common trend and the common trends are $\alpha'_{\perp}\Sigma_{k=1}^{t} u_t$.

Cointegration relations - Euro Area

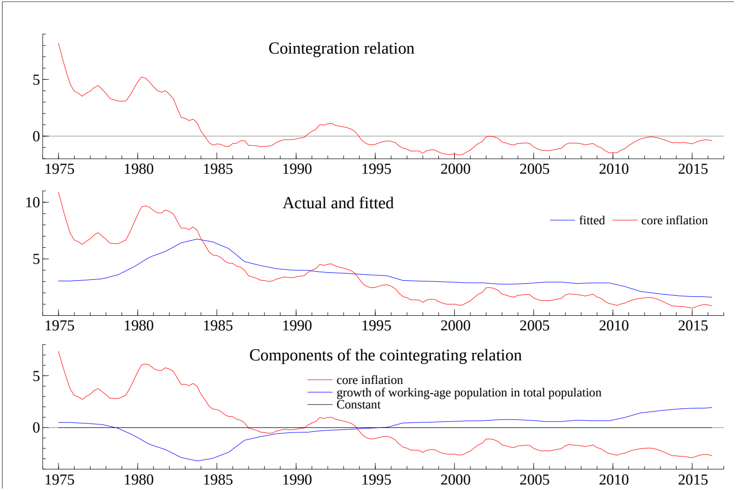


Figure 3: Long-run relationship between demographics and inflation

Cointegration relations - Euro Area

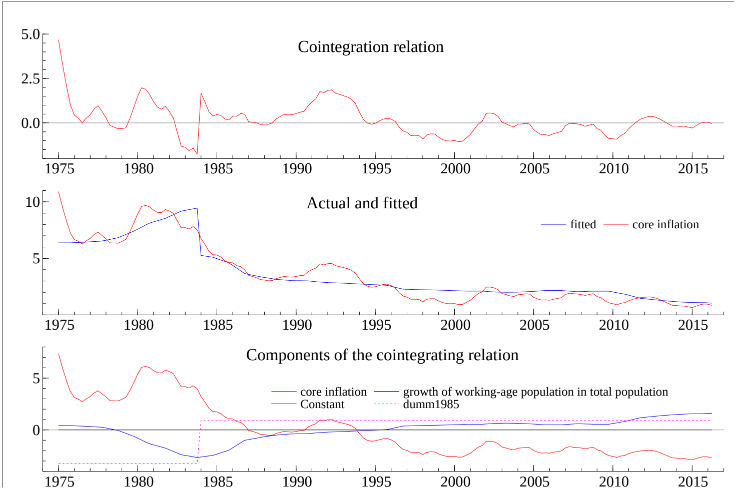


Figure 4: Long-run relationship between demographics and inflation

Cointegration relations - Euro Area

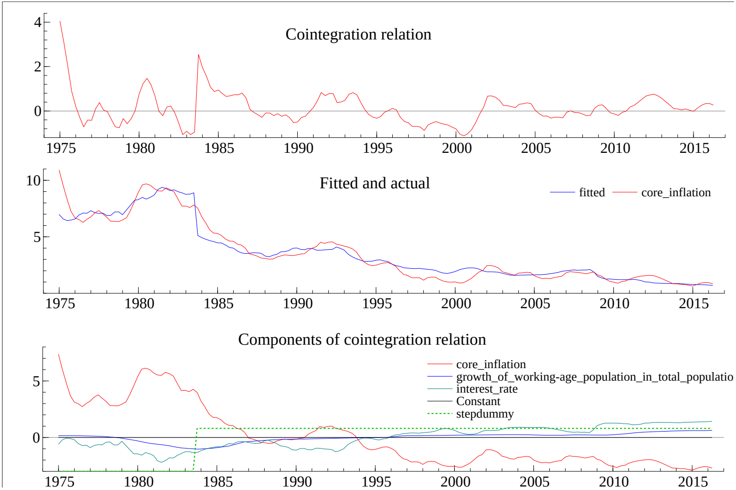


Figure 5: Long-run relationship between demographics and inflation

Empirical results - DE

Step 1: Likelihood ratio-based trace test statistics:

Johansen's trace test for cointegration rank, Germany

No. of cointegrating relationships	Model 3
0	60.09 **
1	16.75
2	4.56

Notes: The estimation sample is: 1970(4) - 2015(4) ** denotes statistical significance at 1% level according to the standard trace test. For Germany, we include a structural from 2010Q1 to control the ECB policy in the aftermath of the financial crisis and report the modified trace test (Johansen et al. (2000)), which is based on a Gamma distribution (instead of a normal distribution) as a asymptotic distribution to approximate the sampling distributions of the test statistics to provide the p-values. We obtain the critical values from Giles and Godwin (2012). The simulated critical value at 1% significance is 30.1619 for one cointegrating relationship with the step dummy running from 2010Q1-2015Q5 and total number of observations = 181.

Cointegration relations - DE

Step 2: Cointegrated VAR(2) estimation:

Long-run equilibrium relationship between demographics and inflation, Germany

	Model 3	
	β	α
core inflation	1	-0.23
	(0.00)	(0.04)
demographics	-0.16	0.00
	(0.18)	(0.00)
interest rate	-0.49	0.10
	(0.05)	(0.07)
constant	0.51	
	(0.25)	
step dummy	-1.41	
	(0.32)	

Notes: The estimation sample is: 1975(1) - 2015(4). The beta vector is shown such that all the coefficients are normalized to that of core inflation and all of the coefficients are on the same side of the "=" sign. Likelihood ratio test based on Chi-square distribution with df = 1 on the alpha restriction cannot be rejected and therefore supported by the data in all three models. LR test of restrictions: $Chi^2(1) = 0.32695$ [0.5675] To test the significance of the demographic variable, we perform the likelihood ratio test based on Chi-square distribution with df = 2 by setting $\beta_{demo} = 0$. We reject the restriction on β_{demo} at 10% significance level: LR test of restrictions:$Chi^2(2) = 5.1109$ [0.0777]