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Elena Bobeica, Eliza Lis,
Christiane Nickel, Yiqiao Sun

Demographics and inflation

Task force on low inflation (LIFT)

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This paper presents research conducted within the Task Force on Low Inflation (LIFT). The task force is composed of economists from the European System of Central Banks (ESCB) - i.e. the 29 national central banks of the European Union (EU) and the European Central Bank. The objective of the expert team is to study issues raised by persistently low inflation from both empirical and theoretical modelling perspectives.

The research is carried out in three workstreams:

1) Drivers of Low Inflation;

2) Inflation Expectations;

3) Macroeconomic Effects of Low Inflation.

LIFT is chaired by Matteo Ciccarelli and Chiara Osbat (ECB). Workstream 1 is headed by Elena Bobeica and Marek Jarocinski (ECB) ; workstream 2 by Catherine Jardet (Banque de France) and Arnoud Stevens (National Bank of Belgium); workstream 3 by Caterina Mendicino (ECB), Sergio Santoro (Banca d'Italia) and Alessandro Notarpietro (Banca d'Italia).

The selection and refereeing process for this paper was carried out by the Chairs of the Task Force. Papers were selected based on their quality and on the relevance of the research subject to the aim of the Task Force. The authors of the selected papers were invited to revise their paper to take into consideration feedback received during the preparatory work and the referee's and Editors' comments.

The paper is released to make the research of LIFT generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the ones of the author(s) and do not necessarily reflect those of the ECB, the ESCB, or any of the ESCB National Central Banks.

Abstract

Most euro area countries have entered an unprecedented ageing process: life expectancy continues to rise and fertility rates have declined, while retirement age in the last twenty to thirty years hardly increased. This implies an ever smaller fraction of the working age population in total population, leading to changes in consumption and saving behaviours and having an important impact on the macroeconomy. In this paper we focus on the relationship between demographic change and inflation. We find that based on a cointegrated VAR model there is a positive long-run relationship between inflation and the growth rate of working-age population as a share in total population in the euro area countries as a whole, but also in the US and Germany. We also find that this relation is mitigated by the effect of monetary policy, which we account for by including the short-term interest rate in our analysis. One caveat of the analysis could be that the empirical relationship as found does not sufficiently take into account changes in policy settings following the high inflation experiences in the 1970s. Our findings support the view that demographic trends are among the forces that shape the economic environment in which monetary policy operates. This is particularly relevant for countries, like many in Europe, that face an ageing process.

JEL Classification: E31, J11, C22

Keywords: Demographic change, Inflation, Cointegration

Non-technical summary

Many advanced economies have been experiencing a prolonged period of low inflation since the global financial crisis, along with a modest recovery in GDP growth and falling real long-term interest rates. In the effort to understand the sources of the prolonged low-inflation environment, the adverse demographic trend has been invoked as a possible driver of low-frequency inflation. As the impact of ageing on the macroeconomy has been most prominently studied for Japan, this paper seeks to analyse the link between demographic change and inflation in the euro area.

Until recently, little attention has been paid to the link between demographic change and inflation. This can be due to the fact that the transmission channels from ageing populations to economic variables are manifold, working their ways through simultaneously and with offsetting effects. Moreover, the impact on nominal economic variables is very difficult to establish, mainly because one would have to go beyond the direct links between ageing and the real economy, which makes it notoriously hard to determine the net effects on inflation. In principle, demographic change would only affect low-frequency inflation if not counteracted by monetary policy. Still, the theoretical hypotheses on the existence of a potential link pertain to the theories of life-cycle consumption and savings, secular stagnation, financial wealth allocation and political economy. The related channels reach contradictory conclusions on the net impact of demographic change on inflation.

This paper takes an empirical approach and employs a cointegration analysis to study the relationship between demographic change and inflation dynamics for the sample period from 1975-2016. We find a positive long-run relationship between the euro area core inflation (HICP excluding energy and food) and the growth rate of the working-age population as a share of the total population. The growth rate of the working-age population relative to the total population captures broadly the ageing process reflected in a low fertility rate and an increasing life expectancy. The positive relationship holds also after attempting to control for monetary policy by including the short-term interest rate, albeit it becomes much weaker. The coefficient associated with demographics diminishes as would be expected as the common trend between demographics and inflation is largely counteracted by the strong correlation between inflation and the interest rate. One caveat of the analysis could be that the empirical

relationship as found does not sufficiently take into account changes in policy settings following the high inflation experiences in the 1970s. For robustness checks we investigate whether the empirical relationship found for the euro area also holds for the US and Germany. Applying the same methodology as for the euro area, we find the same result.

Our findings support the view that demographic trends are among the forces that shape the economic environment in which monetary policy operates. This is particularly relevant for countries, like many in Europe, that face an ageing process. Deflationary pressures coming from the effect of demographic change on the equilibrium real interest rate may imply that central banks could find themselves more often at the effective lower bound and thus need to resort to unconventional measures to counteract the decline in the equilibrium real interest rate. In the euro area, the ECB has taken unprecedented measures to prevent a too long period of low inflation and to secure a sustained convergence of inflation rates towards levels below, but close to, 2 percent over the medium term. Policymakers are encouraged to make use of demographic information in updating their forecasting strategies and designing policy tools.

1 Introduction

Many advanced economies have been experiencing an episode of low inflation after the global financial crisis, along with a modest recovery in GDP growth and falling real long-term interest rates. A growing body of literature has emerged to explain these developments centred, in particular, around the secular stagnation hypothesis and on the extent to which Europe mirrors Japan's experience of persistent low inflation. In the effort to understand the sources of the prolonged low-inflation environment, demographics have been invoked as one of the possible drivers. For Japan, most studies find that ageing affected inflation negatively, in particular given the limitations that monetary policy has been facing at the effective lower bound. Most euro area countries are currently undergoing a similar demographic transition: life expectancy continues to rise and fertility rates have declined, while retirement age in the last twenty to thirty years hardly increased. This paper seeks to explore the link between ageing and inflation in the euro area in a cointegration framework and finds a positive long-run relationship between the growth rate of the share of working age population in total population and inflation.

Until recently, with the exception of Japan, little attention has been paid to the link between population ageing and inflation. This can be due to the fact that the transmission channels from ageing populations to economic variables are manifold, working their ways through simultaneously and with offsetting effects. In addition, demographic change is a slow-moving process with no immediately observable effect but it is a powerful and unlikely to be overturned, especially in view of a likely irreversible demographic cliff stemming from the mass retirement of baby boomers. Moreover, the net impact of demographic changes in real time is technically difficult to assess.

Demographic change directly alters the size of the labour force, consumption and savings patterns and labour productivity, having an important impact on real economic variables (Aksoy et al., 2015; Shirakawa et al., 2012; Eggertsson and Mehrotra, 2014; Goodhart et al., 2015). The impact on nominal economic variables is, however, much more difficult to establish, mainly because one would have to go beyond the direct links between ageing and the real economy, which makes it notoriously hard to determine the net effects on inflation. In principle, demographic change would only affect low-frequency inflation if not counteracted by monetary policy. A few empirical studies have emerged more recently suggesting that a link between demography and inflation might exist, but they point to opposing signs of the impact on aggregate inflation, depending on the country and time coverage.

The most prominent hypotheses on the link between population ageing and inflation pertain to the theories on life-cycle consumption and savings, secular stagnation, impact on financial wealth and political economy. The related channels reach contradictory conclusions on the impact of demographics change on inflation.

The life-cycle theory suggests that individuals plan their consumption and savings behaviour over their life-cycle and smooth their consumption over lifetime. Aggregate demand and supply shift because certain age groups and their particular economic behaviour gain in relative importance to the rest of the population. Hence, changes in the demographic structure can exert potentially large effects on total savings. Given that households income is low when young, rising at working age and falling in old age, working-age people save more out of their income as compared to the young and the elderly (for the euro area, some evidence for a life-cycle type of behaviour is provided by LeBlanc et al. (2015)). When they are retired, they finance their consumption using the accumulated savings. In an economy as a whole, the savings rate tends to be lower when the young and old-age dependants come to have a higher share in total population. As a discrepancy between aggregate demand and supply arises, inflation is likely to increase to equate at steady state. At the same time, the shrinking labour supply puts upward pressure on wages, which further props up inflation through the cost channel on the supply side. The bottom line is that ageing is inflationary.

A prominent strand of literature discussing the impact of demographics on the rest of the macro economy refers to the secular stagnation hypothesis. Secular stagnation describes an economic condition of negligible economic growth and low potential growth, as savings are higher than long-term investments needed to promote future growth. A growing literature has emerged in the recent years around the secular stagnation debate as potential GDP and real interest rates continued to decline (Summers, 2014a,b; Eichengreen, 2015). One of the structural factors causing these developments has been found to be demographic change. The post-war baby boom stimulated aggregate capital accumulation, the growth rate of labour supply and savings. As the baby boom generation started to retire, the growth rate of the working age population slowed. That implied a current abundance of capital relative to labour having a negative impact on the marginal product of capital, hence the equilibrium real interest rate. A lower rate of return can depress investment growth, which in turn lowers GDP and employment growth. As a result, adverse macroeconomic shocks are more likely to require negative real rates to equate the investment-savings balance. And if the economy is already in a low-inflation and effective lower bound environment, this tends to undermine the effectiveness of monetary policy, which could imply a too tight monetary stance and hence low inflation for a prolonged time. Several studies found that ageing put downward pressure on real interest rates, as the supply of funds in the loanable funds market increases (see Carvalho et al. (2016); Batini et al. (2006); Krueger and Ludwig (2007). Going more in depth of the phenomenon, Katagiri (2012) argues that the impact of demographic change depends on the driving forces of the population ageing, whether it is fertility or longevity. They estimate that the ageing process has led to deflation of about 0.6 percentage points a year over the past 40 years – a huge cumulative impact. It is the unexpected longevity that has been deflationary in Japan. When the working-age population shrinks and life expectancy increases, the number of wage earners relative to the total number of consumers is expected to decrease. The longer retirement period incites households to save more to smooth out consumption in the future. This puts downward pressure on the equilibrium real interest rate.

Another explanation put forward for the observed link between inflation and demographics is related to the impact of ageing on financial wealth. Young people are debtors, accumulate assets over time and become sellers of assets when they are old. An important differentiation which has to be made is whether the assets sold by pensioners are denominated in domestic or in foreign currency. If the assets are sold abroad and funds are repatriated, which could be the case in many advanced economies which are net lenders for the rest of the world, this results in an appreciation of the domestic currency, which lowers costs of imports and exerts a deflationary pressure (see Anderson et al. (2014) for the case of Japan).

Related to financial wealth management, a political economy perspective could also explain why ageing contributes to containing inflation. That is, the swelling share of pensioners causes their political power to increase and express their preferences for low inflation that would otherwise erode their savings (see Katagiri (2012) or Bullard et al. (2012)). As young and working-age people have fewer assets and receive wages, they prefer high inflation, whereas older people that depend more on assets returns as a source of income will take more influence on redistributive policy to grant low inflation.

Given the theoretical ambiguity, some empirical investigations have stepped in to shed light, but their conclusions are contradictory. Most of the papers have focused on Japan as its transition from ageing society to aged society is the fastest in the world, but other advanced economies have also started to be in the limelight. Some empirical studies including Anderson et al. (2014), Yoon et al. (2014) and Gajewski (2015) find empirical evidence for ageing to be associated with deflationary pressures. In contrast, Juselius and Takats (2015) and Juselius and Takats (2016) find that ageing leads to more inflation. They argue that Japan may not be typical after all. They look at 22 advanced economies over the period 1955 to 2010 and find that a larger share of dependants – both young and old – is associated with higher inflation, whereas having more people of working age is linked to lower inflation. The explanation relies on the following: countries with more people consuming goods and services than producing them are liable to having excess demand and thus inflationary tendencies. Those with more producers than consumers will, by contrast, have excess supply and a deflationary bias. Similarly, Aksoy et al. (2015) estimate long-run effects of the changing age profile and find that dependent cohorts enhance the inflationary pressures in the long run.

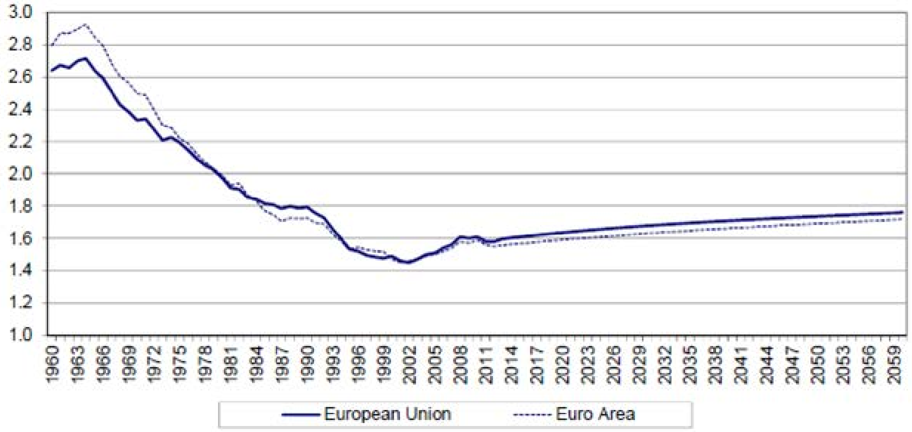
Our paper relates to the strand of work that attempt to link demographic trends and inflation empirically. We investigate the case of the euro area, also in comparison to the US and Germany. This allows us to treat each economy individually, as opposed to papers investigating relationships in a panel framework, pooling together countries with very different demographic situations. As already pointed out in the literature, but not formally addressed, demographics is a slow-moving process, unlikely to influence inflation at the business cycle frequency. For this reason, we focus on long-term relationships between the two variables by employing a co-integration framework. We find supporting evidence for a positive relation between inflation and the growth of working age population in total population. A diminishing growth rate of the working age population, which can occur due to a higher share of the elderly, comes hand in hand with fading inflationary pressures, if the monetary policy does not react. If ageing increasingly and more importantly conditions the economic environment in which monetary policy operates, it will be possibly required to adapt to the changing environment. Policy-makers are encouraged to make use of demographic information in updating their forecasting strategies and designing policy tools, as had been advocated in earlier literature by Lindh and Malmberg (2000) and Lindh (2004). In order to derive pertinent policy recommendations, forces that impact the population growth and age structure, such as ageing or migration, need to be taken into account.

In the rest of this paper, section 2 provides a brief overview of the demographic developments in the euro area. Section 3 investigates empirically the link between demographic change and inflation, while section 4 discusses the link in the US and Germany. Finally, section 5 concludes.

2 Euro area demographics: An overview

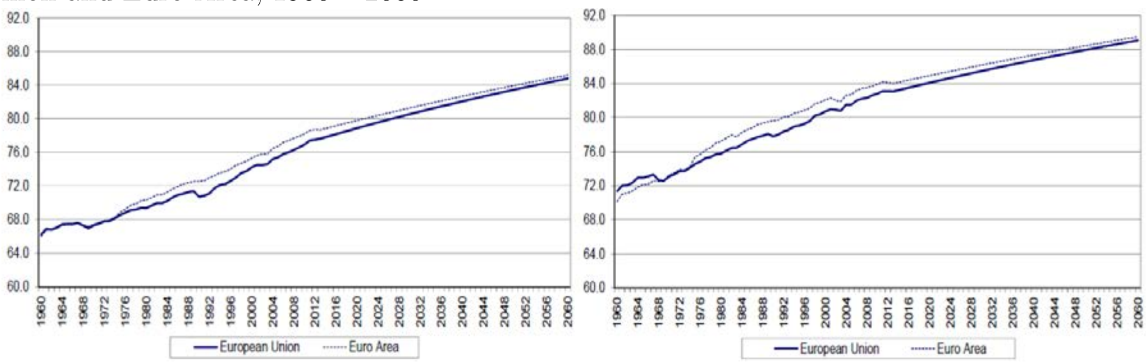
The European population has entered an unprecedented ageing process as outlined in the latest European Commission Ageing Report (May 2015). The projection data picture a transition from an ageing society to an aged society in Europe over the coming decades, induced by both falling fertility rate (Figure 1) and increasing longevity (Figure 2). The aforementioned European Commission Ageing Report projects that the ageing trend implies that the proportion of the active workforce (aged 20-64) supporting the retirees (aged 65 and above) will almost halve from an euro area average of about 3.1 to 1.7. The total dependency ratio that relates the proportion of non-working young people (aged 19 and below) and the retirees to the total working population is projected to rise from currently 52.6% to 76.9% by 2060.

Figure 1: Total fertility rate in number of children per woman, European Union and Euro Area, 1960 – 2060



Source: European Commission Ageing Report, May 2015

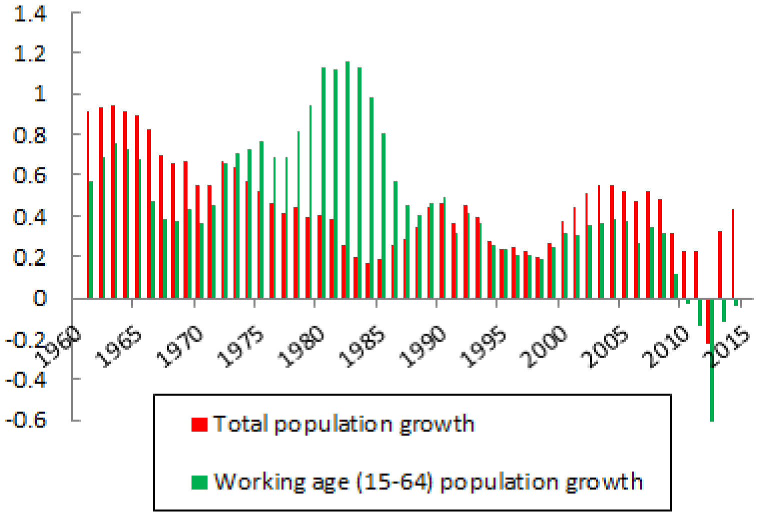
Figure 2: Life expectancy of men (left) and women (right) at birth in number of years, European Union and Euro Area, 1960 – 2060



Source: European Commission Ageing Report, May 2015

Although ageing is a global phenomenon, the UN population statistics highlight the European continent as the oldest continent with the highest old-age dependency ratio, coupled with a large drop in the share in the world population from 10.6% in 2010 to 6.9% in 2060. Figure 3 shows the slowdown in total population growth and a sharp decline in labour force supply. This worsening tendency will be maintained by both a stabilized fertility rate around 1.7 over the decades until 2060 and an elevating life expectancy at birth that is associated with a positive change of 6.5 years from 2013 to 2060 for males and 5.5 years for females (Figure 2). In the past years, the total population growth in euro area has been continuously declining, with a growth rate below 1%. In the 1980s the working population grew the fastest and has been recording negative growth rates since 2010 (Figure 4). Looking forward, the total population remains almost unchanged on the yearly basis and increases over half a century until 2060 by merely 1.6% in the euro area but with large heterogeneity across countries. For instance, Germany's population will decline by 17.2% but France's population will increase by 15.1%. Sweden and Belgium show the strongest population growth of 36.3% and 37.7% respectively until 2060. In contrast, Lithuania and Latvia will respectively lose 38.1% and 30.7% of its current population.

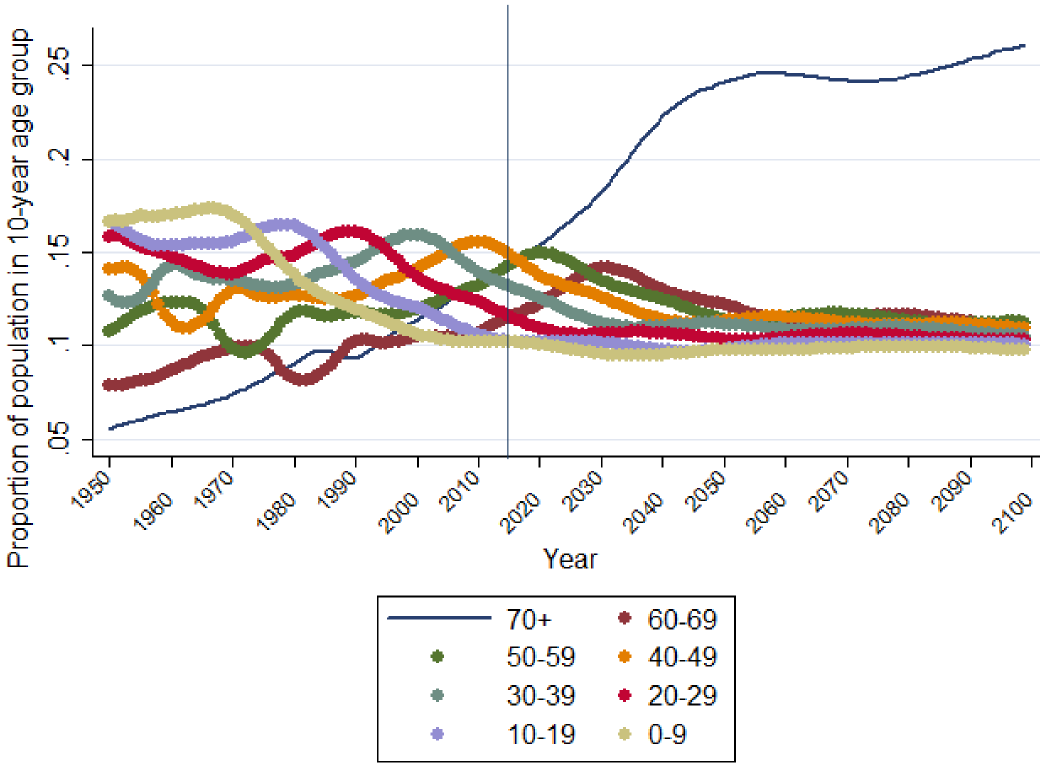
Figure 3: Total and working-age population growth, 1960-2015, euro area



Source: Eurostat and UN Population Statistics

Along with a stagnant population growth, the age structure however changes notably. Demographic forces often refer to population growth, labour supply and migration flows. But the age structure of the population expressed as proportions of the total population in each age group may also have an important impact on economic performance. In this paper we find that the share of working age population in total population is correlated with inflation. According to the life-cycle hypothesis, different age groups have different savings and consumption behaviours. As the demographic structure changes, aggregate demand may be induced to shift toward the goods most desired by the growing age group in its relative size. Supply-side effects may be reflected by different contributions to productivity gains as testified by the age profile of wages, contribute differently to innovation, generate different investment opportunities as firms target consumers' needs. As shown in Figure 4, all age groups below 50 years start declining in proportion to the total population from now on.

Figure 4: Past, present and future development of the demographic structure in the euro area, 1950 − 2100



Source: UN Population Statistics

We take demographic data from United Nations population database which contains detailed country-level statistics by gender and age as well as projections until 2100 under different scenarios. The population age structure is described by dividing the total population into $L = 17$ five-year age cohorts (denoted as N_{lit} for each country and quarter). N_{lit}, with $l = 1 \cdots L$, represents the number of people aged 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-49, 50-54, 55-59, 60-64, 65-69 and 70+ respectively. The share of cohort l in the total population of each country N_{it} is denoted as $n_{lit} = N_{lit}/N_{it}$. Broader age structure according to the life-cycle, the young, working and old population, can be easily calculated as follows: young (0-19 years old), $n_{it}^{young} = \sum_{l=1}^{4} n_{lit}$, working age (20-64 years old), $n_{it}^{working} = \sum_{l=5}^{12} n_{lit}$, and old population (65 years and older), $n_{it}^{old} = \sum_{l=14}^{17} n_{lit}$. Figure 4 depicts the evolution of euro area countries' demographic structure over time from 1950 until 2100. Projection data are provided by UN population statistics as of 2012.

Different dependency ratios relate different age groups with each other to provide a summary statistic, meaningful for economic interpretations implied by the population age structure. The total dependency ratio (TDR) that relates the proportion of non-working young people and the retirees to the total working population is projected to rise from currently 52.6% to 76.9% by 2060. Old-age dependency ratio (OADR) is the share of old population in working age population. Similarly, child dependency ratio (CDR) is the share of young population in working age population. The inverse of OADR is called potential support ratio (PSR). Figure 5 shows the development of the four variants of dependency ratios in euro area from 1950 to 2100. In addition to the ageing process reflected in the age structure, the dependency ratios saliently summarize the relative proportions of population with different economic attributes regarding consumption, savings and labour supply, and thus point to these dynamics as economic forces. The total dependency ratio highlights a turning point around 2015, indicating that we are entering an accelerated and yet prolonged transition phase from an ageing to an aged society under the baseline projection.

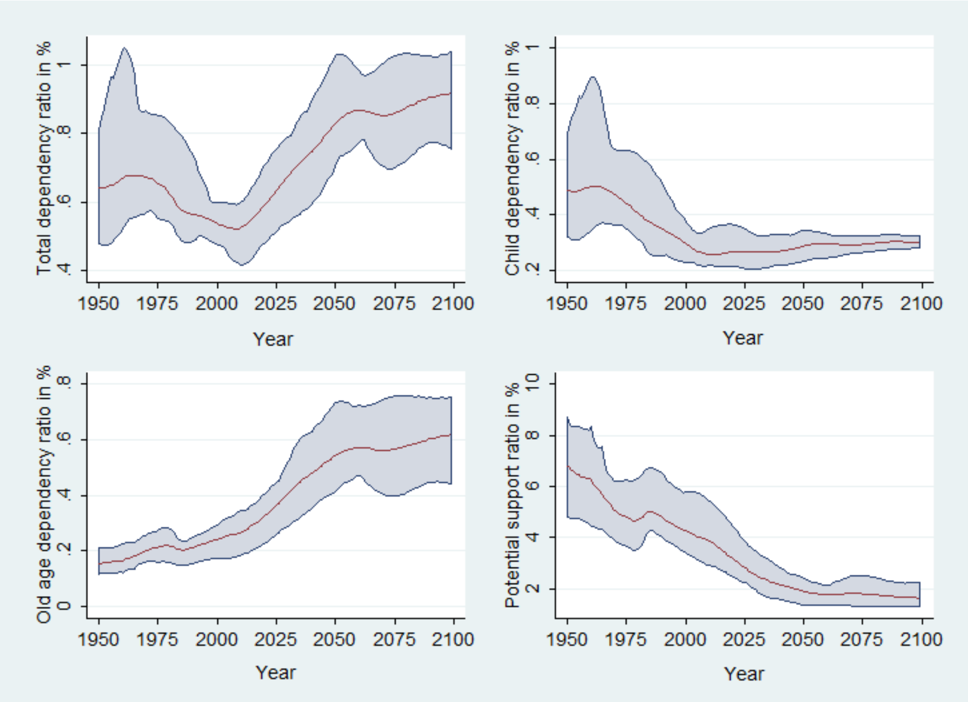
3 Empirical analysis: euro area's demographic change and inflation

We investigate the long-term relationship between demographic change and inflation. That is because any impact that demographics may have on inflation is unlikely to occur over the business cycle frequency, but rather at a generational frequency. Most standard general equilibrium models used for monetary policy guidance do not account for structural change determined by e.g., demographic changes, in the long-term inflation process.

To proxy the demographic trend we look at the growth rate of the working age population (20 to 64-year olds) as a share in total population[1]. This encompassing variable is a function of young people entering the labour force and old people leaving it; a decline in fertility rates leads to negative growth of labour force and increased life expectancy leads to a shrinking share

[1] We looked at both the growth rate of working age population and working age population divided by total population; the results are similar in the two cases. The reported results in this section refer to the latter.

Figure 5: Euro area dependency ratios, 1950 − 2100



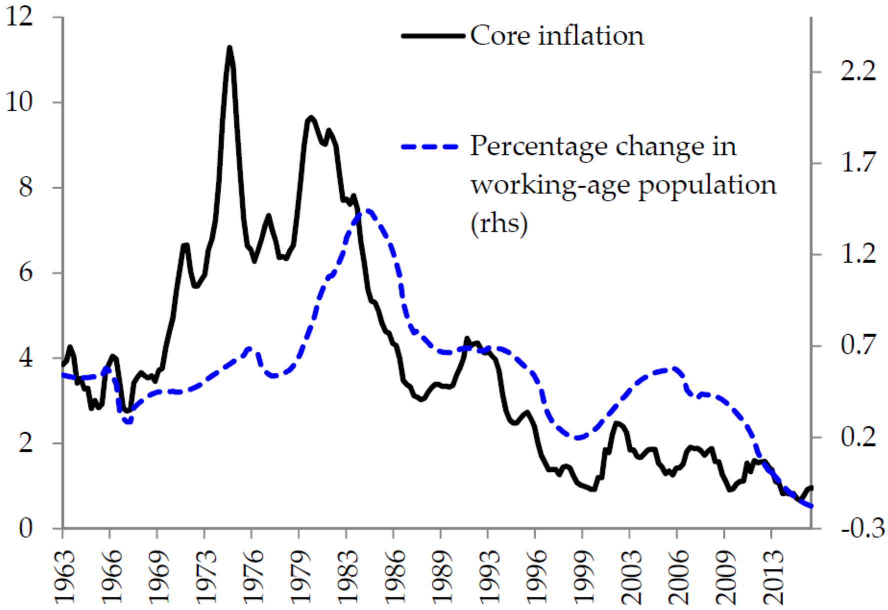
Source: Own calculations based on UN Population Statistics.

Notes: Total dependency ratio is the ratio of population aged 0–19 and 65+ to population 20–64; Child dependency ratio is the ratio of population aged 0–14 to population 15–64; Old-age dependency ratio is the ratio of population aged 65+ to population 19–64; Potential support ratio is the ratio of population aged 19–64 to population 65+; The lower (upper) blue contour traces the minimum (maximum) dependency rate across euro area countries in the respective year, whereas the red line shows the euro area mean.

of working age population in the total population. The working-age population can be seen as a production factor in relation to the growth prospects and demand conditions, also affecting the relative consumption and savings behaviour within the society. The impact on nominal variables depends on the reaction of monetary policy as well as other policy and behavioural responses. We focus on the HICP inflation excluding energy and food, as it is less affected by supply side shocks such as oil and food price related ones. For the euro area it seems that indeed, the growth of the working-age population and core inflation are positively correlated, notwithstanding the fact that the latter is much more volatile (see Figure 6).

To establish a long-run relationship between demographics and inflation, we employ the methodology of co-integration analysis. The Augmented Dickey-Fuller unit root tests presented in Table 1 fail to reject the null hypothesis that both series contain one unit-root. This is supported by the Phillips-Peron test in the case of demographics and in a less clear-cut manner in the case on inflation. In contrast to the typical non-stationarity property of demographics, it

Figure 6: Core inflation and working age population growth in the euro area



Source: Eurostat and UN Population Statistics

is rather a long-standing debate in empirical literature whether inflation rate is best treated as stationary or non-stationary. Those similar to Johansen (1992) who find that prices in the US are I(2), hence inflation is I(1) argue that inflation may be supposed to be stationary by nature but it is subject to a variety of transitory and persistent shocks rendering it non-stationary in empirical analysis. Relying on the unit roots performed beforehand, we proceed with the unit root assumption for the cointegration analysis.

Table 1: Unit root tests for demographics and inflation

The demographic variable				
H0	ADF t-Statistic	Prob	Phillips-Perron Adj. t-Stat	Prob
wa_population has a unit root	-1.80	*0.38*	-0.75	*0.83*
D(wa_population) has a unit root	-2.71	*0.07*	-2.71	*0.07*
The inflation rate				
H0	ADF t-Statistic	Prob	Phillips-Perron Adj. t-Stat	Prob
core_inflation has a unit root	-2.54	*0.11*	-2.70	*0.08*
D(core_inflation) has a unit root	-4.37	*0.00*	-5.87	*0.00*

We estimate a vector error correction model (VECM) as a representation of a reduced-form vector autoregressive model (VAR(p)):

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

where $D_t =$ are the deterministic terms and $t = 1, \ldots, T$. $Y_t =$ is the vector of endogenous variables, namely the inflation rate and the growth rate of working age population as a proportion of total population. To test for the number of cointegration relations, we focus on the long-run matrix $\Pi = \Pi_1 + \cdots + \Pi_p - I_n$ and study the $rank(\Pi)$:

1. $rank(\Pi) = 0$: $Y_t \sim I(1)$ and there is no cointegration

2. $0 < rank(\Pi) = r < n$: $Y_t \sim I(1)$ with r linearly independent co-integrating vectors and $n - r$ common stochastic trends (unit roots)

We perform a Johansen's trace test for a bivariate unrestricted system formulated by demographics and inflation (Model 1). Table 2 shows that the null of zero rank is strongly rejected but the rank equal to one cannot be rejected.

Table 2: 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.

The trace test leads us to conclude on one cointegrating relationship and one unit root when linearly combining the two time series. This allows us to further proceed to formulating a a bivariate co-integrated VAR(p) (CVAR). The matrix Π can be decomposed as follows:

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

where the rows of β form a basis for the r cointegrating vectors and the elements of α distribute the impact of the cointegrating vectors to the evolution of ΔY and are interpreted as speed of adjustment coefficients. In addition, we impose weak exogeneity of demographics such that only inflation adjusts to long-run equilibrium relationship but not the demographic variable, which, in this simple bivariate framework, is the common stochastic trend. This is equivalent to setting the alpha associated with the demographic variable to zero. The estimation results of the CVAR(2) are reported under Model 1 in Table 3. The estimated cointegrating relationship suggests that there is a structural break around 1983. Until roughly mid-80s the model fit is poor in capturing the inflation dynamics. Therefore, we consider a step dummy which takes the value of 1 until 1983. Various factors affected the inflation rate in that particular period, such as two severe energy shortages in the 70s', the second of which (occurring in 1979), tripled the cost of oil. Furthermore, the macroeconomic policies in the aftermath of the collapse of the global monetary system and before the introduction of the European Exchange Rate Mechanism were relatively ill equipped to fight inflation. The model fit improves significantly for the inflation rate with the deterministic dummy [2]. Including the step dummy requires that we repeat the rank test and use modified trace statistics by Johansen et al. (2000) [3] that account for the presence of structural breaks (see Table 2).

Re-estimation of the CVAR(2) including the step dummy as an additional deterministic term yields the results as tabulated under Model 2 in Table 3. The resulting cointegration relationship is without break and stationary around a constant as well as the model fit improves substantially. We report the conventional standard errors in parentheses. However, we check the likelihood ratio tests to infer about the significance of the restrictions showing that the null hypothesis of the β coefficient on the demographic variable being zero is rejected. Core inflation adjusts to this long-term equilibrium albeit very slowly, as suggested by the associated α coefficient. For the demographic variable we impose the restriction $\alpha_{demo} = 0$ as suggested by the test statistic for the weak exogeneity restriction.

We test the robustness of the link found between inflation and demographics by also including the short term interest rate to control for monetary policy effects in the model. The

[2] Graphical representations are available upon request.

[3] We use the Eviews program by Giles and Godwin (2012) downloaded from http://web.uvic.ca/ dgiles/downloads/johansen/index.html. The program generates the asymptotic p-values and the critical values that account for the presence of structural breaks

Table 3: 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.

long-term correlation between inflation and nominal interest rates has been thoroughly documented in empirical work and most studies find cointegration between the two, consistent with the implications of the Fisher hypothesis (see Crowder and Hoffman (1996), Westerlund (2008))[4]. We find the cointegration relationship between inflation and demographics also to hold after including the short-term interest rate (see Table 2). Moreover, the demographic variable is still significant in the long-run cointegrating vector and with a positive sign. In line with Juselius and Takats (2015) we find monetary policy does not fully offset the uncovered relationship between demographic change and inflation. However, we find that once monetary policy is accounted for, the coefficient associated with demographics diminishes. In terms of common trends accounting, in this larger system the one generated by demographic change (which is weakly exogenous in the VECM) is accompanied by a second common trend that loads on inflation and on the interest rate.

This reduced-form analysis cannot shed light on which channels underlie the transmission of demographic effects on inflation. Yet, this empirical finding would lend support to theories such as the one on secular stagnation, which suggests that a fall in the working age population

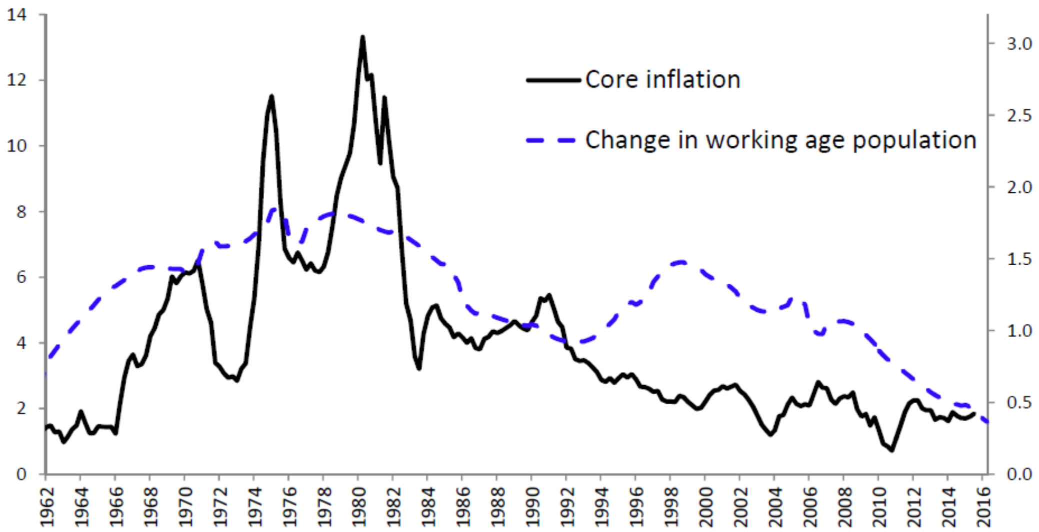
[4]Note that here the cointegration space on the core inflation was normalized to one for convenience, studies focusing on the Fisher effect would report normalize on the interest rate

leads to higher savings and lower investment that could only be equated by low or even negative equilibrium real interest rates. The risk of deflationary pressures coming from ageing arises if the decline in the equilibrium real interest rate is substantial. In such a case central banks could find themselves more often at the effective lower bound and the need to resort to unconventional measures to counteract the decline in the equilibrium real interest rate.

4 Comparison with the US and Germany

For robustness checks we investigate whether the empirical relationship found for the EA also holds for individual and large countries. In particular, we consider the US and Germany. As can be seen in Figures 7 and 8, broadly speaking, the US and Germany are also undergoing demographic transitions, even if to a different extent.

Figure 7: Core inflation and working age population growth in the US



Source: Haver and UN Population Statistics

Applying the same methodology as for the euro area, we find the same result. For the US as well as Germany, the cointegration rank test results as shown in Table 4 and Table 6 confirms that there is a co-integrating relationship combining demographic changes and monetary policy to determine inflation. The estimation results of the CVAR for the US and Germany are presented in Table 5 and Table 7, respectively. After controlling for the inclusion of the interest rate, the long-run positive relationship between demographic trends and core inflation

Table 4: 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.

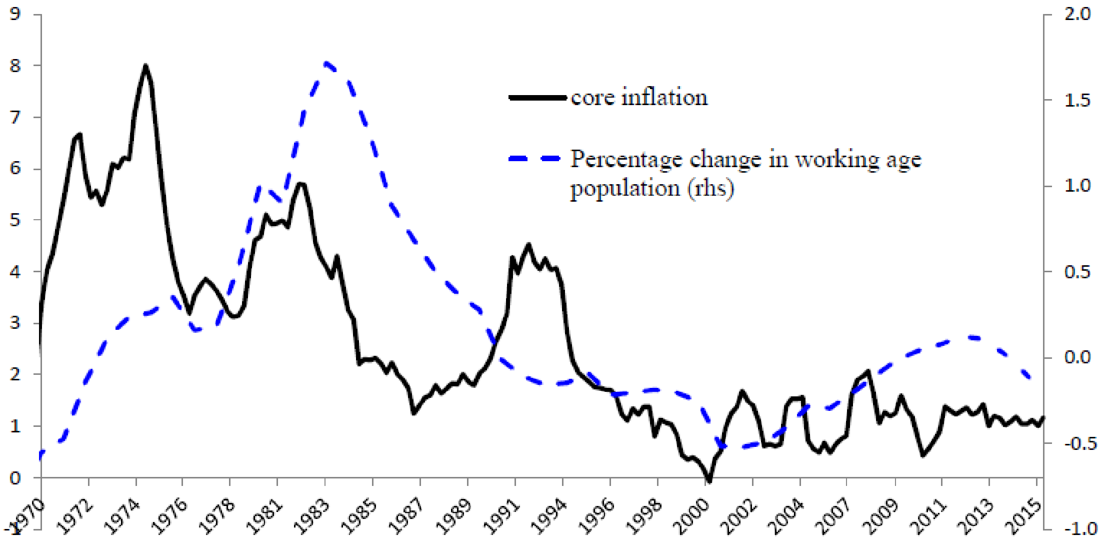
is still supported by the data. Both the weak exogeneity of demographic change and long-run impact coefficient estimate are confirmed by the data when examining the likelihood-ratio tests for restrictions. The robustness checks enhance the findings in the empirical literature that attributes a role to demographics as a possible structural driver of inflation at low-frequency, notably evidenced in advanced economies.

Table 5: 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]**

Figure 8: Core inflation and working age population growth in Germany



Source: Eurostat and UN Population Statistics

Table 6: 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.

Table 7: 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]

5 Conclusions

In this paper we present evidence in favour of a long-run positive relationship between the inflation rate stripped out of the energy and food components and demographic trends proxied by the growth rate of working-age relative to total population. The positive relationship holds also after attempting to control for monetary policy by using the short-term interest rate, albeit it becomes much weaker. The growth rate of the working age population has been on a downward trend and based on the projections of the United Nations, it is likely to stay subdued in the economies that we analysed.

Though this paper did not aim to shed light on the various mechanisms through which demographics impact inflation or to quantify relative effects, this reduced-form evidence supports theories which point to a net deflationary impact of demographic change. One example for such theory is the secular stagnation hypothesis, which suggests that demographic change could be one of the drivers of the downward slow-moving changes in the equilibrium interest rate. Deflationary pressures coming from the effect of demographic change on the equilibrium real interest rate may imply that central banks could find themselves more often at the effective lower bound and thus need to resort to unconventional measures to counteract the decline in the equilibrium real interest rate. One caveat of the analysis could be that the empirical relationship as found does not sufficiently take into account changes in policy settings following the high inflation experiences in the 1970s.

Our findings support the view that that demographic trends are among the forces that shape the economic environment in which monetary policy operates. This is particularly relevant for countries, like many in Europe, that face an ageing process. Although demographic change is a slow-moving process with no immediately observable effect over the usual policy-relevant horizon, it is a powerful process unlikely to be overturned. Demographic change directly alters the size of the labour force, with important impacts on consumption and saving decisions and via them on nominal economic variables.

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Elena Bobeica
European Central Bank, Frankfurt am Main, Germany; email: Elena.Bobeica@ecb.europa.eu

Eliza Lis
European Central Bank, Frankfurt am Main, Germany; email: Eliza.Lis@ecb.europa.eu

Christiane Nickel
European Central Bank, Frankfurt am Main, Germany; email: Christiane.Nickel@ecb.europa.eu

Yiqiao Sun
European Central Bank, Frankfurt am Main, Germany; email: Yiqiao.Sun@ecb.europa.eu

Postal address	60640 Frankfurt am Main, Germany
Telephone	+49 69 1344 0
Website	www.ecb.europa.eu

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